DOCUMENT RESUME

ED 454 820 IR 020 799

TITLE	ICCE/ICCAI 2000 Full & Short Papers (Creative Learning).
PUB DATE	2000-11-00
NOTE	50p.; In: Learning Societies in the New Millennium: Creativity, Caring & Commitments. International Conference on Computers in Education/International Conference on Computer-Assisted Instruction (Taipei, Taiwan, November 21-24, 2000); see IR 020 792. Some figures contain very small and illegible type.
PUB TYPE	Collected Works - General (020) -- Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	*Computer Uses in Education; Cooperative Learning; Creative Teaching; *Educational Technology; Elementary Secondary Education; Higher Education; Systems Development; World Wide Web
IDENTIFIERS	Collaborative Learning; *Learning Environments; Web Based Instruction

ABSTRACT

This document contains the following full and short papers on creative learning from ICCE/ICCAI 2000 (International Conference on Computers in Education/International Conference on Computer-Assisted Instruction): (1) "A Collaborative Learning Support System Based on Virtual Environment Server for Multiple Agents" (Takashi Ohno, Kenji Saito, Hajime Saitoh, and Takashi Maeda); (2) "A Java-Based Interactive Learning System of Junior High School Level Geometry" (Yu-Ru Chen, Tzy-Leng Allen Horng, and Don-Lin Yang); (3) "A Study of Collaborative Teaching for Creative Learning in an Engineering Class" (Jiunn-Chi Wu, Pei-Fen Chang, Shu-San Hsiau, and Tse-Liang Yeh); (4) "An Approach to Modeling an Educational Domain" (Gennadiy Atanov); (5) "An Interactive Game System To Stimulate Word Associations" (Naoko Nitsu, Takeyuki Kojima, Bipin Indurkhya, and Yoshiyuki Kotani); (6) "DIYexamer: A Web-Based Multi-Server Testing System with Dynamic Test Item Acquisition and Discriminability Assessment" (Ying-Dar Lin, Wen-Chun Sun, Chien Chou, and Huan-Yun Wei); (7) "The Artistic Interface--A Transition from Perception to Screen" (Peter D. Duffy); (8) Using Virtual Environments for Studying Water Phases and Phase Transitions" (Jorge F. Trindade and Carlos Fiolhais); and (9) "Agent-Oriented Support Environment in Web-Based Collaborative Learning" (Tomoko Kojiri and Toyohide Watanabe). (MES)

ICCE/ICCAI 2000 Full & Short Papers (Creative Learning)

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HOME

A Collaborative Learning Support System Based on Virtual Environment Server for Multiple Agents

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It is generally agreed that learning efficiency improves if the students find teaching/learning materials interesting. It is the same when we engage in collaborative learning with the use of computer networks. We take into consideration the collaborative learning environment that is suitable for each learner, the personality of the group and the knowledge levels of learners. We have been constructing a collaborative learning support system being developed on VESMA(Virtual Environment Server for Multiple Agents) system.

Keywords: **Collaborative Learning, Intelligent Agent, Virtual Environment**

1 Introduction

It is generally agreed that learning efficiency improves if the students find teaching/learning materials interesting. It is the same when we engage in collaborative learning with the use of computer networks. In other words, it is possible that the learner's interest and concern will be attracted if there is an intermediary who supports the learner with the idea of using the teaching/learning materials function as a learning object between the learner (user) and the learning object. And, it is very important to grasp the learner's mental state in collaboration with plural learners in a virtual environment like a computer networks. We take into consideration the collaborative learning environment that is suitable for each learner, the personality of the group and the knowledge levels of learners. We have been constructing such a learning support system as a part of our Virtual University project being built up on VESMA(Virtual Environment Server for Multiple Agents) system.

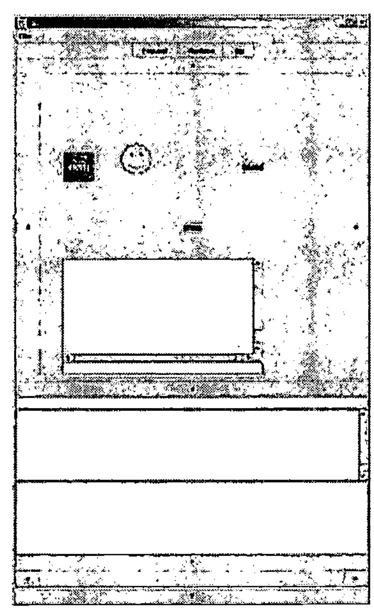

Fig. 1 Client of VESMA System

In the rest of the paper, we describe a general mechanism of VESMA system and its features in section 2. In section 3, we discuss on collaborative learning in such a virtual environment including some intelligent agents who support such learning. In section 4 and 5, we will discuss the supporting function of effective collaborative learning and the learning process in the collaborative learning support system. Concluding remarks and some future works are briefly described, in the last section,.

2 VESMA System

In this paper, we have been constructing a virtual environment using the VESMA system developed in the

Java language. This VESMA system provides the programming environment to simulate the virtual space which a lot of elements exchange the message and affect each other. This system has been used for an agent programming, the simulation of a physical/social phenomenon and a probabilistic network etc. by present.

2.1 Server-Client System The VESMA system is a system which consists of the server and the client, and contains user's avatar, the object and the agent that is in virtual environment in the server. The client displays an environment surrounding user(s), and interprets the inputs of the user, and let the avatar execute it. This system can be executable in all platforms, and translate an arbitrary object between server-client or server-server through a computer network, because this system uses the Java language.

The objects corresponding to the entrance can exist in a virtual space of the VESMA system, these objects are connected with another place of this server or other servers, and the user can move between the servers freely by accessing this entrance object.

2.2 Layered Structure A virtual space of the VESMA system can take the layered structure, as can be seen in the last paragraph of section 2.1. When a complex virtual space and a lot of rooms are made, it is very convenient to be able to make the layered structure for representing a spatial metaphor. For instance, layered structures such as the city, university, faculties, and laboratories can be represented.

2.3 Autonomous Object The object is static or passive in a usual educational virtual environment system, so it can answer to a user's request or reply to a messages, but it is difficult to realize an object which behaves actively. The object in VESMA system can behave with own thread by programming the object to send oneself the message. In other words, VESMA system supports making of an autonomous agent.

2.4 Simulation of Various Phenomenon The VESMA system is not only suitable as the educational virtual environment programming environment, but also suitable for the simulation of a physical phenomenon. Our collaborative learning support system on VESMA system can simulate a physical phenomenon as well. It is also possible that the user can experiment by operating the experiment tool in the virtual environment, and change the parameter and setting the experiment, and repeat the experiment trying and erring. These experiments are useful for voluntary environments.

Moreover, our system can simulate not only physical phenomenons but also social phenomenons or probabilistic process, and can display the results of the simulations by various graphical expressions such as a density graph or digraph.

3 Collaborative Learning in Virtual Environment

3.1 Virtual Environment and Learning Style

The virtual environment in this paper means a "communication environment in computer networks". Usually, a user can take only the service that he had already known the existence in the usual network. Though such information is useful, sometimes people get information that is of significant value by chance discovery. We think that positively building up and providing such an environment to increase the chance of this happening are important. The virtual environment in made by various information can be considered for the typical example. In this paper, we use VESMA system to realize the collaborative learning support system. Because of server-client architecture supported by VESMA system, our collaborative learning support system can be "distributed" in space and "synchronized or non-synchronized" in time. Generally, learning styles can be divided into the following three types : 1. *Individual learning*, 2. *group learning*, 3. ***Collaborative learning***.

(1)*Individual learning* : the problem solving whereby a learner does by himself. (2)*Group Learning* : the problem solving via task sharing. (3) *Collaborative learning* : the problem solving by use of result sharing. In other words, Each learner solves his own problem based on the information and data given to him by other learners. Thus Collaborative learning is group learning with more goal oriented communications. In the field of the education, it is considered that the latter learning style is especially effective because the quality of the answer improves on the whole by having learners with differing knowledge do an information exchange.

3.2 Collaborative Learning

The following are the strong points of collaborative learning in a virtual environment[2] : (1)There is no restriction of time and geographical space. (2)It can lead to solving problems by doing opinion exchange with other people. (3)It can obtain objective awareness of problems. On the other hand, it has several weak points : (1)Learners get behind if they don't participate voluntarily. (2)There is the possibility that learning may progress in different directions. (3)Differing abilities of learners (members) may be a problem for the progress of their learning. We think about the method of the learner support which a weak point 3 is changed to the strong point.

Good ideas in subject preparation, group formation support, communication support, and ideas such as an interface become necessary to get over these problems. We examine the interface using intelligent agents in consideration of such characteristics in this paper.

4 Supporting Collaborative Learning

4.1 Grasp of the learner's state

It is important to grasp learner's state in the learning system. When learning in a virtual environment on the computer network, it is especially important. Because, people's communications become indirect in a virtual environment.

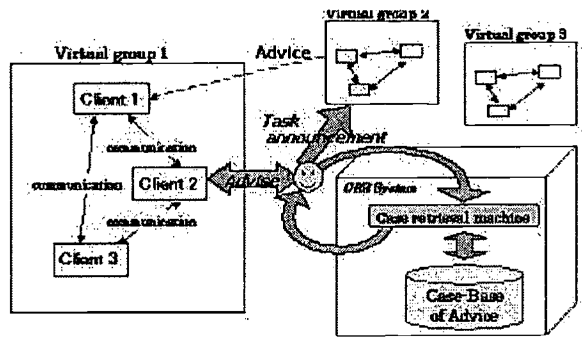

Fig. 3 <u>Architecture of Collaborative Learning Support System</u>

Generally, when students learn about certain topic, offering materials suitable to the learner's level of understanding is necessary. This research aims to check the learner's mental state, in broad sense, using agents to grasp it automatically. It is also important to promote collaborative learning smoothly by giving a kind of "role" to each learner in the group in consideration of the learner's personality. For example, the learner who is good at teaching others might become a leader, and give support to other learners in the group. The control that gives hints to make it refer to an exercise is necessary for cases when learners come to a deadlock in their learning.

4.2 Learner Modeling

Then, the following is necessary for the learner modeling from the viewpoint of collaborative learning,
The individual model : It has proper knowledge, the mistaken knowledge, the knowledge that it hasn't been studied, the interest or concerns, information such as a role, personal manipulation history.

$D_l = \{(T_1, U_1)......(T_n, U_n)\}$ D_l : learner model, T_i : learning topic, U_i : understanding of topic

4.3 Intelligent Agents

An agent works like a human beings, and supports teachers and learners. An agent communicates other agents or avatars, and behaves actively in various situation. Making a graphical representation of these agents, users can come in contact with an agent familiarity. In this paper, we will discuss the intelligent agents ('*learner modeling agent*', "*group agent*", "*advisor agent*", "*evaluation agent*") who support collaborative learning in virtual environment.

The *learner modeling agent* grasps the learner's degree of progress and the degree of his understanding. The *group agent* controls the information that a *learner modeling agent* has, and monitors the relationships of each learner in the group. An *advisor agent* carries out various supports directly for the learner. An *evaluation agent* judges whether or not the knowledge that a learner got by working at collaborative learning is useful. **Fig. 2** illustrates the architecture of collaborative learning in virtual environment including *advisor agent*. These agents do various support while the learner advances collaborative learning.

As different autonomous object, some characteristic mascots may be included in our Virtual University based on a feature described in 2.3.

5 The method of some supporting in Collaborative Learning

5.1 Collaborative Learning Support

As an example of collaborative learning support, *pattern1* • •When you come to a deadlock. *pattern2* • • When you mistake the solution. *pattern. 3* • •When you can not understand what to do next.

How to solve the problem of the pattern 2 : First is support by the learner in the group(using *Contract Net*). Next is support by the learner in other group(using *Contract Net*). Finally is Support by the *CBR* system. *Contract Net* achieves the allocation of the task by the negotiation between the processing nodes. In this paper, the selection of the advisor was attempted by contract net. We think it might be easier to understand "By getting advice from the learner who is close to one's understanding degree".

5.2 CBR and Calculation of Similarity Degree

CBR(Case-Based Reasoning) is a kind of reasoning which solve the new problem by a case similar to current problem. A case is expressed as

$$D_c = \{(T_1, U_1, W_1) \ldots\ldots (T_n, U_n, W_n)\}$$

follows.

D_c : case, T_i : learning topic, U_i : understanding of topic, W_i : importance degree of topic

The advisor agent selects a case that current condition and a case are the most similar.

$$Sim_{cl} = \sqrt{\sum_{i=1}^{n} W_i (U_{ct} - U_{lt})^2}$$

Sim :similarity degree, U_{ct} :understanding degree of topic of case base, U_{lt} : understanding degree of topic of learner model, W_t : importance degree of the topic

6 Concluding Remarks and Future Works

We have constructed a virtual environment on a VESMA system, and examined communication processes on it. And, we have examined the function of the intelligent agents in the collaborative learning support system and the validity and support for the learning process.

In this paper, we have discussed that learners can obtain better methods for voluntary learning by the appropriate support of the intelligent agents. And various intelligent agents provide environments for the group learning which enables learners to do active collaborative learning.

And we have realized practical collaborative learning support system in which the following advantages are provided using VESMA system. The learners communicate each other and share the teaching/learning materials in the virtual environment by not only a text-based interface but also a graphical interface. A user of VESMA system can move among two or more servers which is distributed in the Internet. We can make a small creature, or can make physical experiments because of the function of VESMA which realize autonomous objects. And VESMA system has the layered structure of virtual environment, so many places can be constructed in one server corresponding to user's spatial metaphor, and the learner can easily access a place he/she wish.

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A Java-based Interactive Learning System of Junior High School Level Geometry

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In this paper we propose a Java-based CAI system that provides a learning-by-doing environment with hands-on exercise and instant interaction capabilities on the World Wide Web. Our current topics of interest is the Euclidean geometry for junior high school students. To design the system, we adopt the theory of concept map to construct teaching and learning materials. We are currently testing the system and has observed that it does significantly help students in learning geometry.

Keywords: **CAI, concept map, Euclidean geometry, Java applet**

1 Introduction

As computer science and Internet technology make speedy progress at every moment, computer aided instruction (CAI) plays an important role in our life, especially in future education for global citizens at every corner of the world. Many researches focus on the web-CAI, but there are some drawbacks in these systems:

(1) Some of these systems simply use graphs or animations and text to describe the meanings of the teaching materials. Although this way of displaying is more lively than the traditional textbooks, the learners still need to stare at the screen uncomfortably to read the text thoroughly to understand its meanings. Besides, some subjects such as mathematics need to be learned by practicing with examples.
Plain text reading is just not enough.

(2) Most multimedia web-CAI systems requires high bandwidth, which is still a problem for the current internet infrastructure. Long waiting time for response will definitely degrade the effect of learning no matter how well designed the web-CAI system is.

To demonstrate our ability of conquering the above problems, we have developed a web-CAI system in Chinese (http://www.math.fcu.edu.tw/~tlhorng/geometry) for teaching and learning junior-high-school Euclidean geometry (named just geometry in the following context). Students can have great fun in learning on our system owing to its highly interactive and experiment-oriented features. Besides, the system is designed all using small-size Java applets, and is therefore robust enough to tolerate the usual congestion on the internet.

The rest of the paper is organized as follows: Section 2 introduces our design theories such as the concept maptheory and dynamic geometry method; Section 3 shows the implementation and Section 4 summarizes the whole work and some future enhancement.

2 Theories behind our design

First we employ the concept map theory to plan the curriculum, and then apply dynamic geometry method to design the curriculum to be highly interactive, problem-oriented and, most importantly, interesting. In this way, the learners are encouraged to learn by playing with those Java applets, and to construct their knowledge system by concept map theory.

2.1 Concept map theory

In order for learners to make a meaningful learning, Ausubel present a meaningful learning theory [1]. The idea in this theory is that whenever to learn a new concept or a new knowledge it must base on the prior experience. Ausubel's theory considers that the relation between the new concept and learner's prior knowledge plays an important role in the meaningful learning. Whenever the new knowledge, learners' prior concept, and proposition framework are successfully joined, learning is created. In other words, learners can make a meaningful learning by utilizing learners' prior concept to link the new concept to organize the whole knowledge. Novak further presents a concept mapping method for the purpose of verifying Ausubel's theory [1]. Concept map is composed of propositions. Every proposition contains two concept nodes and a relation link between them. In a concept map, concepts are represented in a hierarchical way. A general or summarized concept is put in an upper hierarchy, and a specific or particular concept is put in a lower one. A graph describing the integration of concepts from the lower levels to higher ones and the relation linking among them is called concept map that can represent a knowledge structure effectively.

2.2 Dynamic geometry method

To teach or learn geometry effectively, we usually have the following two aspects in mind [2]: knowledge developing (the deductive method), and knowledge acquiring (the generalizing method).

Both are equally important. However, most of the current geometry curriculum in junior high school has been emphasizing on how to prove a geometric problem by the deductive way, and frequently ignoring how to the generalize a geometry concept by experiments and observation. Our web-CAI system present the curriculum in both ways and particularly emphasizes the latter one.

3 Implementation

In our web-CAI system, the whole curriculum is problem-oriented, and each geometric problem, besides its proof, is designed to be explored by experimentation which is implemented by Java applets. Java applet is selected owing to its full-featured library for designing internet applications and its platform-independent portability [3-5]. The code was written by JDK 1.1 and is entirely in Pure Java™.

3.1 Drawing the concept map

There are four steps to draw the concept map: 1. concept seeking, 2. concept categorization, 3. concept hierarchy, 4. concept relation.

Concept seeking: First list all important concepts to be taught. A concept is the foundation unit stored in the human brain, although everyone may store a same thing by concepts in his own different way. That is why everyone may response differently when seeing or hearing an identical event at the same time. This individual opinion of everybody is called the concept.

Concept categorization: After seeking for concepts, this step is to divide concepts into two parts: event and target. Taking circle as an example in our geometry curriculum, we can list twelve relevant important concepts as categorized in table 3.1

Concept hierarchy: After categorizing the concepts, we further place them into a hierarchy. As mentioned above, a more general concept will be put in a upper level, while a more specific one in a lower level. Figure 3.1 is the hierarchy chart of Table 3.1.

Concept relation: After putting all concepts in a hierarchy, we further denotes those relations among concepts to form a complete concept map. Following the above, the circle's concept map is shown in Figure 3.1.

Event	Target
line	relationship between a circle and a line
chord	relationship between a chord and the diameter
chord and center	relationships between a chord and its distance to center
central angle	relationship between a central angle and a chord
arc	relationship between a chord and a arc
circumferential angle	relationship between a arc and a circumferential angle
tangent	two tangents from an external point to a circle are equal in length
quadrilateral	the opposing angles of a quadrilateral inscribed in a circle is complementary
triangle	three bisectors are concurrent in a triangle
incenter	Distances of the incenter to the three sides of a triangle are equal
two circles	relationship between two circles
two circles and tangent	tow circle' s common tangent

Table 3.1. Concept categorization

3.2 Composing the plan for teaching materials

By the concept map, we can further propose the teaching materials and write down these ideas into a table called the plan of teaching materials. Following the above, Table 3.2 shows a small part of the plan: the relative locations of two circles and their common tangent.

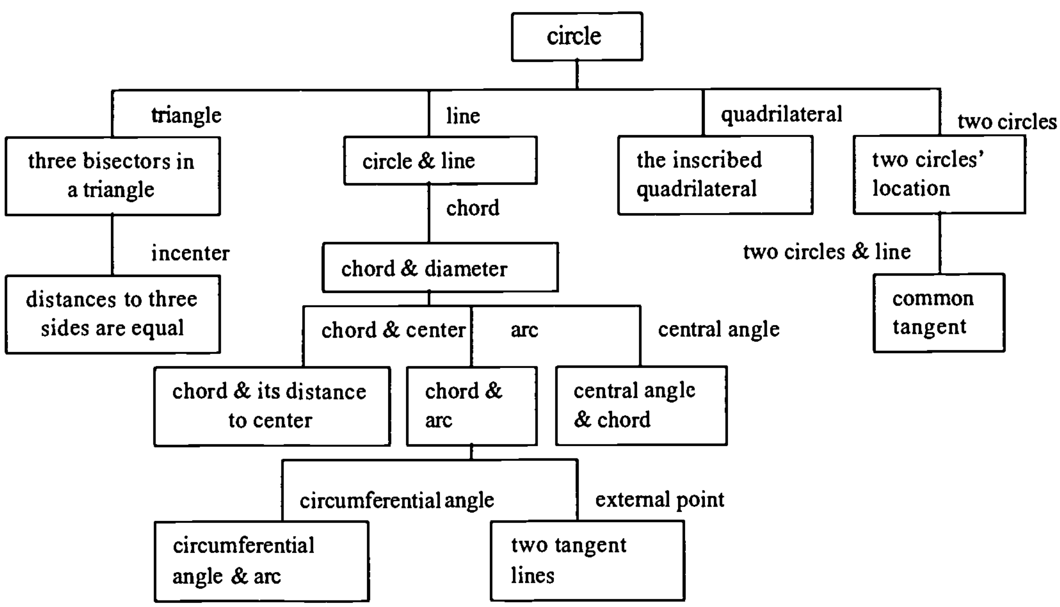

Figure 3.1 Circle' s concept map.

Page	Consist Concept
Circles' locations	There are six kinds of relations for two circles judging from their locations: separated internally, separated externally, tangential internally, tangential externally, intersecting and coincident.
Common tangent	Two circles on a plane can have the following common tangents according to their relative locations: When the two circles are separated externally, there are two external common tangents and two internal ones. When the two circles are tangential externally, there are two external common tangents but one internal one. When the two circles intersect at two points, there are two external common tangents and no internal one. When the two circles are tangential internally, there is only one external common tangents and no internal one. When the two circles are separated internally, there is neither an external common tangent nor an internal one.

Table 3.2 A part of the plan of teaching materials

3.3 Displaying the teaching materials by Java applet

Taking the common tangent of two circles as an example, we display this part of teaching materials by the

Java applet shown in Figure 3.2 (a)-(c). This Java applet is designed that the learner can play around by dragging any center (shown as red dots) of the two circles which will change the distance between these two centers. From the movement, the learner can observe various kinds of common tangents happening for the two circles. If we show it alternatively by some static graph or animation, the learner would have problem catching its meaning effectively.

3.4 The examination module

Besides those Java applets for displaying teaching materials, our web-CAI system also provides an examination module for on-line testing. Through this module, teachers can edit test problems and grade students' answers, and students can take tests and look up for their grades all on our web-CAI system. Four individual applets, in charge of problem editing, examination, grading, and grade looking-up, consist of this examination module. Figure 3.3 particularly shows the problem-editing part, in which teachers can edit a test problem and draw the illustration related to it. Also, all the test problems can be saved in a database server driven by JDBC• Java Database Connectivity. JDBC is a Java-standard SQL database access interface [6]. It provides access to varieties of databases. After teacher edit the examination questions, the students can take the exam on our web-CAI system. On that, students can write down the answers and draw some auxiliary lines on the illustration which may be required for proving a geometric theory or just to help them solve the problem. Teachers can then grade and comment the students' answers, and the students can look up for the grades and teacher's comment later all on our web-CAI system.

4 Conclusions and future work

We have developed a web-CAI system that provides an interactive learning and testing environment on Web. In this way, the learner can learn more effectively than other multimedia-CAI systems. Currently we have chosen Euclidean geometry in junior high school as an example, and plan to extend to other science subjects, the physics and chemistry in the future. Besides, we keep modifying the GUI in our system to be more friendly and interesting. We also plan to choose a junior high school to test our system and evaluate its performance.

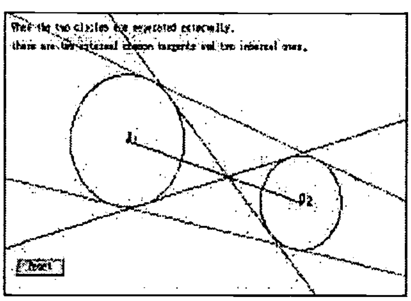

Figure 3.2 (a) A scene of the Java applet of two circles' common tangents. Red points are subject to dragging.

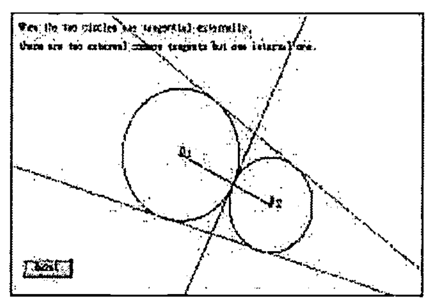

Figure 3.2 (b) Another scene following Figure 3.2 (a).Red points are subject to dragging.

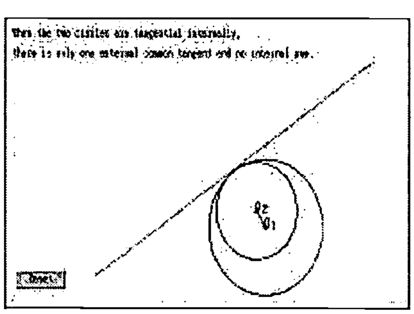

Figure 3.2 (c) Another scene following Figure 3.2 (b). Red points are subject to dragging.

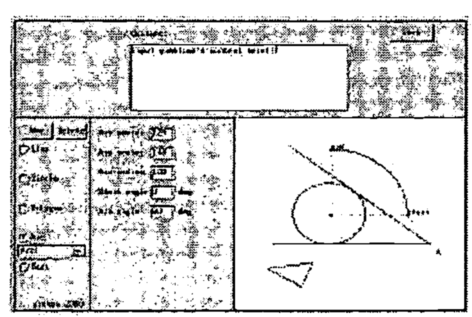

Figure 3.3 Test problem editing part of the examination module.

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A study of collaborative teaching for creative learning in an engineering class

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We synthesize a model for cultivating creativity that integrate the tasks of engineering design, and evolves four cognitive processes of creativity knowledge and skill via web courseware. This paper discusses three main themes of creative learning: 1) the effectiveness of collaborative teaching and course modules, 2) tools for fostering creative learning, and 3) interaction on the web-environment via creativity contest and design project. Several findings were observed based on qualitative evaluation of this class. First, the most rewarding course topics identified by the students is the creativity contest and design project because it provides ample opportunities to solve real-life open-ended problems, rather than to deal with dichotomous textbook problems. However, adapting dissimilar teaching style of our collaborative teaching generated anxiety to a number of students, which suggest the structure and sequence of the course development are need to be modified in order to fit students' level of capacity and readiness. Finally, we have demonstrated how problem solving and engineering design procedures can be closely integrated and taught, and what are the necessary knowledge and skills to enhance students' ability to become creative as well as effective problem solvers.

Keywords: **Collaborative teaching, Creative learning, Web-based learning**

1 Introduction

Creativity is inherent and a native intelligence. Many studies, show that the creative cognition can be trained and learned [1, 2]. Therefore, proper education and nourishing environment can foster creativity. *Creative problem solving* (CPS) is referring to use creativity or creative thinking for problem solving, which is a learning model being actively studied [3, 4]. It helps student use systematic method to solve a complex and realistic problem, possibly with multiple solutions. Students brainstorm to generate all possible solutions, categorize and evaluate solutions, develop implementation plan, and finally execute the plan [3]. CPS emphasizes the practice of creative thinking, implementation of creativity, and stresses on the creative leaning process. It can be regarded as a learning model for knowledge synthesis.

It is our responsibility and challenge as teachers to educate student who will be able to succeed in the high-tech environment. To educate students to cope with the rapidly changing world, they must not only to actively acquiring new knowledge, but also to have the skill of creative problem solving. In reflecting such responsibility and challenge, the course of "*Open-ended Creative Mechanical Engineering Design*" was offered in Department of Mechanical Engineering, National Central University for the last three years. The spirit of this course is asking students use their creativity to work as industrial engineers, form several mission-oriented teams, communicate and cooperate with other people, and deal with real industrial open-ended problems.

We wish to demonstrate how problem solving and engineering design procedures can be closely integrated and taught and what are the necessary knowledge and skills to enhance students' ability to become creative as well as effective problem solvers. Hence, we synthesize a model for cultivating creativity that integrate the tasks of engineering design, and evolves four cognitive processes of CPS knowledge and skill via web-based courseware. An integrated web-courseware [5] is constructed for above purposes. In the following sections, four main themes in our study will be introduced: 1) the collaborative teaching and course mo dules, 2) tools for fostering creative learning, and 3) interaction on the web-environment via contest and design project.

2 Collaborative teaching and course modules

2.1 Collaborative teaching

Based on the experiences for the past three years, we perceive the need for professionals from other disciplines to stress the importance of communication as well as teamwork skills for engineering students. More importantly, a scientific evaluation of the course and its effects on the students' learning of creativity must be done in cooperating pedagogical experts with engineering ones. The analysis of student outcomes can give information about the success of the innovative course in achieving our objectives.

But the question is: how can professors with engineering background to integrate their technical knowledge with an educational-oriented perspective? Engineering faculties may understand the cognitive and emotional conflict that students encounter, but couldn' t verify their teaching approaches in order to take into account students' different learning styles. Besides, an engineering course taught by faculty of non-engineering background face a challenge of given students the new perspectives without accommodating the technology orientation of engineering students.

With above forethought, we propose and implement the collaborative teaching from four professors of interdisciplinary backgrounds: thermal/fluid sciences, mechatronics, education, and network-based learning. Collaborative teaching is a novel teaching approach, it allow teacher deliver lecture in a more efficient way and share mutual teaching experience, improve teaching deficiency, and understand learning difficulty of students. In devising the design-oriented courseware, besides compose the materials for hands-on creativity project, we also strengthen educational idea of cognitive psychology, learning strategy and learning evaluation. Such collaborative teaching team up with the expertise of education and engineering is hoping to build a nourishing environment for rising student's learning motivation, encouraging student to develop mature, diversified cognition and thinking, and then be able to perform higher level of creative thinking.

2.2 Course modules

The contents and modules (see Table 1) are designed to develop competence in mechanical engineering, creativity, and teamwork. Five major units are emphasized: 1) Introduction of creativity, 2) Basic principles of CPS process, 3) Hands-on learning activities to inspire creativity, 4) Engineering design process, 5) Creativity contest and design project. In the first one-third activities is centred on the development and inspiration of creativity and creativity education, and the next one-third of the units enable students to practice the creative mechanical engineering design. The last one-third of the activities finishes the implementation of creativity phase so as to show off student' s imagination with the creativity contest and design project.

We use creativity contest and design project as a tool to enhance creative learning of students. One creativity contest is hold in every semester in order to incubate students' learning interest. It is all up to students to decide the material, procedures, requirements, and rules for the creativity contest with teacher' s facilitation in order to develop the environment of freedom.

The design project could relate basic principles and concepts to real problems and to improve students' understanding, motivation and creativity [6]. Implementing a project is a way to encourage students to look deeply and laterally at individual topics and consider how they can be applied to real situation. They motivate students to confront both familiar and unfamiliar situations with confidence, providing a sense of achievement and satisfaction. Each team member is expected to be aware of the specific skills of others in order to achieve effective and collaborative working relationships. More importantly, each member needs to take other people' s views into account.

3 Tools for fostering creative learning

We construct three tools to assist the creative learning process: 1) the creative activity board, 2) the search engine, 3) the engineering courseware of domain knowledge.

The creative activity board, which is a web-BBS, is employed as the main interface for creative activity. Students are encouraged to actively utilize their own web-BBS for discussing their design projects with teachers and with classmates. They can announce important messages (e.g., resource acquiring) and post their current executing status of their project. More importantly, this board can be used to share their ideas and problem-solving approaches at any times with anyone who is interested in the topic. For convenient discussion of the creative ideas via network, particularly in the format hand-made sketches or the design charts, a FTP (download/upload) function is added in this board. Every user can participate the creative activity through web. The evolution and implementation of creativity can be recorded and exhibited. Properly application of this board can encourage students' morale for continually performing their design projects.

Students may encounter many problems when they execute the design project. The related information may be found in the courseware of domain knowledge or discussed in the creative activity board. Through the search engine, students can find useful knowledge and retrieve information from the integrated courseware more effectively by using appropriate keywords.

The creative activity cannot be successful without domain knowledge as its foundation [7]. When students are working on their team design projects, they need to integrate their domain knowledge based on the previous courses. There are four course modules materials are integrated: 1) Machine Design Course, 2) Electric Circuits and Electronics with Laboratory, 3) Innovative Application of Engineering Software, 4) Creative Mechanical Design. See [8] for detail description of content of these course modules.

4 Results: interaction on the web-environment

In the beginning whether students invest themselves in the class or not, depends on the development of the feedback from teachers. We use the web-BBS as the interaction interface with the students. After each team reported their project status, we will comment their idea and improvement of design prototype. Next, their status report will be upload in the creative activity board, and allow peers to review and comment. Encourage and endorsement from peers and teachers goes to those active teams. All interactions on the web are transparent and will inspire student if teachers can give feedback just-in-time, and guide each team to post their suggestion. In this way, both students and teachers will not be trapped in the classroom, and once the obstacle is encountered, it can be posted in the web and then exchange message. The more people to view these obstacles, the more possibility for the problem can be solved. Since not only teachers can help, peers can assist too. This is what we observed in this class when student performing their design projects. Positively and timely feedback from teacher and classmates enrich the value of the board.

We made surveys based on interviews, questionnaires, and articles of creative activity board. The most rewarding course content identified by the students is the creativity contest and design project because they provide ample opportunities to solve real-life open-ended problems, rather than to deal with dichotomous textbook problems. However, others are disturbed by the open-ended nature of the course materials. They claim that it is tiresome to cope with various teaching styles of four individual teachers. The evidence from our research also suggests that students' problem solving processes were affected by their understanding of the rationale of interdisciplinary course development. Therefore, teachers need to assist students to make their own links with the material they are engaging with in order to eliminate the negative impacts of the course content. For instance, increase the teaching topics involving mechanical hands-on activities might provide students more practice and appreciate the CPS process.

The issues of students' learning difficulties are complex and dependent on several factors, including course organization and development, the subject or topic being taught, teaching style, and students' expectations [9]. Although students see the new learning experience as an opportunity to broaden their scope, some others claim that the challenge of finding a design topic themselves was beyond their ability to manage. In order to set the stage for project design, our data showed that it is crucial that team members to accommodate each other and to devote their personal commitment. It is clear from our interview that failure to do so did influence the students' motivation to finish the project.

5 Conclusions

We have created a learning environment that facilitates students' development of problem solving abilities, enhances their confidence for cooperative creativity, and finally, provides students knowledge and skills for mechanical engineering design. The collaborative teaching is a novel experience to both of teacher and our student. Each member contributes their expertise and become the tutor to the other members. More importantly, the effort of compromising one another on the process serves as a role model for their students to work cooperatively.

The results of this study suggested significant concern for the students' anxiety created by the need to meet the special requirements of four individual teachers. It leads us to speculate whether the structure and sequence of the course development are appropriate to the students' level of capacities and readiness. Rather than viewing these problems as collection of obstacles and difficulties, we believe that we can make a difference in the learning of our students and chose to conceptualize those dilemmas and challenges in a constructive guide. Hence, we are currently adopting a new teaching approach by dividing the class into expert versus observer groups. The emphasis of the approach is to take responsibility as a learner and to develop the ability to ask questions about the projects done by other groups. We also conduct a peer-evaluation to encourage student to evaluate each other' s projects critically and objectively. We wish students to believe, as we did, that creative learning is within reach of anyone who is willing to exert himself and take responsibility.

Acknowledgement

This research work is supported by the Ministry of Education of the Republic of China in Taiwan under grant: Grand Project for Excellence, 89-H-FA07-1-4.

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Content Outline	Learning Activities
Orientation to creativity	1. Introduce the importance of creativity to learning
Cognitive process of creative problem solving	2. Illustrate four stages of CPS skills
Thinking styles and contexts for developing creativity	3. Demonstrate pros and cons of various thinking style
Creative personality and teamwork experience	4. Film-viewing to illustrate the characteristics of creative people 5. Interview team members and identify their personality

Principles and strategies of lateral thinking	6. Analogy 7. Simulation activities
Conventional engineering design process	8. Discuss basic rules for invention 9. Apply rules to improve the design of commercial product 10. Brainstorm potential ideas for creativity contest via web
Problem solving in electric circuits and electronics (E&E)	11. Problem solving a case to illustrate the E&E concepts relate to project design
The creativity contest (by individual)	12. Peer-evaluate and select the top three most creative rubberband-powered vehicles
Research for proposal (RFP) of creative design project (by group)	13. Develop a RFP based on all information gathered 14. Oral presentation to class

Table 1 The course modules of the *CEdesign* web-class.

An approach to modeling an educational domain

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The paper develops a topic of construction of the normative student model. The subject student model is a part of it representing a sum of demands to the curriculum of the subject, to students' knowledge and skills, and a semantic model of the domain. The subject student models pick out the educational domains from all the multitude of the domains, so the subject model is a model of an educational domain. Examples in physics are given.

Keywords: **student modeling, domain modeling, knowledge, skills, semantics**

1 Introduction

A fundamental concept of modern didactics and pedagogical psychology is the student (learner) model. It arose within computer technologies of education and was provoked by the necessity to formalize our representation about students. Of course such representations had been worked out long before any appearance of computers, and definite formalization of them began together with didactics. But it is computer technologies that gave a new impulse to development of these representations, transformed them into an object of deep investigations, transferred to a qualitatively new level [8,9].

In the widest sense, the student model is our knowledge about a student. There are two sides here: (1) knowledge about how the student is, and (2) knowledge about how we want to see him/her. The first knowledge is determined by the way of analyses of student' s behavior, and it is natural to call it a behavioral student model. It is changing together with the student' s change therefore it is also called dynamic, or current, one. Mechanism of construction of this model is the cognitive diagnostics [9].

Knowledge about how we want to see students, that is, demands to their final state is a normative student model. As a rule, this knowledge is various. It consists of demands to personal qualities of future specialists, their professional qualities and skills, their knowledge and skills in different subjects, characteristics of their physical and psychological state, and so on. The final aim of teaching is achievement of such a state when the behavioral student model concurs with the normative one.

2 The subject student model

A part of the normative student model determining domain knowledge is a subject student model [3]. In knowledge engineering, it is called expert knowledge, or domain model [5,6]. The subject student model picks out the educational domains from all the multitude of the domains, so the subject model is a model of an educational domain, or a model of a subject. Let us note that if the dynamic modeling is quite a developed branch of Artificial Intelligence, the domain modeling is developed to a lesser degree. It is clear, as specialists in Artificial Intelligence, as a rule, are not the ones in any other domain.

Under knowledge they understand the main conformities to natural laws helping us to solve particular problems (production, scientific, economic, and others) [5]. Facts, concepts, algorithms, intercommunications, rules, strategies of making decisions, and so on make up knowledge. The pithy sense of the concept «knowledge» is that knowledge reflects our imagination about domains and expresses a system of concepts, as well as relationships and dependencies between them.

According to the classification, there is a division of domain knowledge into declarative and procedural ones.

The first is statements about properties of the subjects of a domain and relationships between them. The declarative knowledge is often called a factual one, and this reflects its essence very well. The procedural knowledge describes the order and character of the transformation of the domain objects. Its another appellation is rules. In our opinion, it is not quite right, as the declarative knowledge, giving relationships between the objects, is also rules. Thus the procedural knowledge is not simply rules but rules of transformation.

The final aim of instruction is formation of way of acting. The way of acting is realized via skills in the practical activity [7]. The mechanism of this is operation with knowledge (both the declarative and procedural) being displayed in the behavior of a person. Therefore, in a wide sense, skills are attributed to knowledge, namely behavioral one [9]. The procedural knowledge is realized in skills. And sometimes, skills are called the procedural knowledge but, as we could see, the term "procedural knowledge" has been already occupied. Definition "operation knowledge" reflects the essence of the things clearly and in the most unambiguous manner. Thus, the subject student model has to contain skills that are to be formed in the process of instruction. Let us call a list of such skills the operational subject student model.

The declarative component of the domain knowledge makes up a semantic part of it, namely the semantic student model.

One of the distinctive properties of knowledge is that it has a certain structure. It is very important, especially for the instructional material, to define its structure. It is well known that to master a portion of the instructional knowledge is to determine its place in the structure of the instructional material. Therefore, one of the problems while constructing the subject student model must be determination of the subject knowledge structure. Studying the structure of the instructional material is a theme of an independent important and deep investigation. The subject student model must give more or less extended ideas about what the subject knowledge is. Such ideas are an essential part of any curriculum. A usual way here is a thematic approach when themes are enumerated. Let us call a list of themes liable to studying the thematic subject student model.

In teaching, it is very important methodologically to determine which role either knowledge plays and which functions it carries. In other words, it is necessary to fulfil a functional structuring of the instructional knowledge. It can be done with the help of a list of functional rubrics. The functional knowledge will be determined in such a way. Within it, there is knowledge performing both nontransforming functions (for example, facts, conclusions) and transforming ones (algorithms, methods, instructions). The functional knowledge makes up the functional subject student model.

In such a way, we suggest a four component subject student model consisting of thematic, functional, operational, and semantic parts. Such a subject student model in physics is carried out at the physics and didactics of physics department of the Donetsk State University [1-3].

3 The thematic subject student model

The thematic subject student model has been well known for a long time. In essence, it is a usual curriculum of the course, its program. It is built just according to the thematic principle, sections and themes liable to studying are enumerated in it. The model reflects the structure of the course. The program can be worked out in detail to different degree but it is always neither knowledge itself, nor its content but its names. In fact, this is a define characteristic of the subject knowledge, some knowledge about the subject knowledge. Knowledge about knowledge is called metaknowledge. Thus, the thematic subject student model is a metaknowledge.

It is a natural and convenient model for planning and organizing the instructional process. The more, it is an obligatory normative document. Preparation of any course begins with its creation (that is, creation of the course curriculum). Nevertheless, it is excessively general to use it for diagnostics.

As a rule, knowledge in many computer tutoring systems is structured according to the thematic student model.

4 The functional subject student model

The functional subject student model shows which role either knowledge plays; and it is also metaknowledge. It has a define structure in the horizontal direction, which may be given with the help of some rubrics. The role of knowledge and its functions depend on a particular subject. For example, we picked out the following rubrics for physics courses: *concepts, wordings, laws, properties, consequences, conclusions, reasons, formulas, equations, models, methods, and algorithms* [3]. The rubrics have a filling that, nevertheless, also does not reflect semantic of the subject and is metaknowledge.

It is the subject student model that allows working out in details what students must know. Let us give an example from the molecular physics. Students have to know: definitions of the concepts: *mole, thermodynamic system, pressure, temperature, density, concentration, ideal gas, equation of state*, and so on; wording and consequences of: *Pascal's law, Maxwell's and Bolzmann's distributions, Kirchhoff's law*, and so on; deductions of: *the mine equation of kinetic theory, equation of the adiabatic process, law of atmospheres*, and so on.

5 The operation subject student model

As it was noted, the operation subject student model is a list of skills liable to mastering by students. Let us note that skills in education make up a hierarchical system [2]. It consists of five groups of skills: fundamental, methodological, general, inter-subject, subject. Subject skills take the highest position in the hierarchy of skills.

We pick out three classes of the subject physical skills: general, particular, and experimental. The general skills are, on the first hand, methodological ones. Spectrum of the particular skills is far wider, for example, there are more than 200 them in the list in physics. According to the contents of the instructional material, the following skills are picked out: *to find, to determine, to fix, to build, to obtain, to calculate, to compute, to estimate, to distinguish, to pick out, to sort, to take into account, to represent, to traverse, to decompose, to compose, to generalize, to put in practice, to use, to formulate.*

There is a fragment of the list of the skills below:

3.1. General skills

To analyze physical processes and phenomena, to estimate orders of physics magnitudes and determine essential factors, to build physical models, to build mathematical models of particular physical processes and phenomena, to determine boundaries of applicability of the models, and so on.

3.2. Particular skills

3.2.2. Molecular Physics and Thermodynamics

To estimate quantity of particles and their mass in particular conditions, to determine parameters of state of gas, to determine number of degrees of freedom and molecular mass of a gas and mixture of gases, to determine possibility of the use of the model of an ideal gas, to make use functions of distribution to find average values of physics magnitudes, and so on.

Experimental skills are divided into three groups: *to measure physical magnitudes*; *to reproduce independently physical phenomena and processes; experimental particular skills.*

There is a hierarchical structure of the subject skills corresponding to the development of the subject in instruction. Besides that all of them also have a definite structure in the horizontal dimension because they are complicated, or composed, skills. In order to master them, a wide spectrum of skills both of the lower levels and subject is necessary. For example, skill *to solve physical problems* is composed of ten simpler skills: *to pick out the necessary information from the condition of a problem to solve it, to code the condition of the problem in a word form, to draw a picture to the problem, to choice a rational method of solving*, and so on.

6 The semantic subject student model

Semantic knowledge in different subjects is contained in textbooks, other training literature. There are two parts in the content of any textbook: CON-1 and CON-2 [7]. CON-1 is knowledge making up the content of a domain directly, CON-2 is knowledge attending the CON-1 (for example, knowledge from other subjects, interpretations, explanations, examples from life). In fact, it is the CON-1 that is the semantic knowledge of a domain. Nevertheless, this knowledge is not picked out especially, it is distributed all around the textbook, interacts with another knowledge, and is not formalized.

Semantic knowledge represents the declarative component of the subject knowledge as the procedural knowledge is realized in skills (operational knowledge). Thus to construct a semantic student model on the basis of a textbook, it is necessary to pick out domain facts from it and group them in a definite order. According to their structure, facts may be of a great variety. As a rule, they are compound ones. Nevertheless, elementary facts may be picked out that, appearing in different relationships, form the compound facts. General questions of representation of facts in instruction are considered in works [4]. For example, expression "*Translational motion is the motion that all the point of a solid body have identical trajectory*" is a compound fact as it can be represented as a set of the following elementary facts: (1) *a solid body moves; (2) all the point of the body have identical trajectory; some motion is called the translational one.*

One can easily see that the elementary facts do not carry any semantic loading of the domain although they contain domain terms. Only on gathering together in a compound fact they acquire some doma in sense. Such compound facts are finished thoughts and they are represented by finished sentences, or expressions. Let us call them the *semantic* facts. As a matter of fact, the semantic facts are a unit of the domain knowledge, as smaller portions of it have no domain sense. The objects of the expression are concepts, phenomena, processes, laws, principles, theorems, conclusions, consequences, reasons, properties, rules, and so on.

It is the full set of the semantic facts that is the semantic subject student model. The order of their disposition is subordinated to the logic of the development of the course.

Such a semantic subject student model was firstly constructed in Gas Dynamics and than in Physics [1]. Those were very small brochures because there were no calculations, proofs, and explanation in them. Nevertheless, they contained all the statements of the courses. These brochures received the title *semantic synopsis*. As an example, there is a fragment from a physics semantic synopsis below:

3.1. The elementary work of a force is defined as the scalar product of the elementary displacement of the point of the force application.

3.2. The work of a force is defined as a line integral from the elementary work along the trajectory of the point of the force application.

3.3. The unit of the work is one joule that is equal to a work done by a force of one newton on a displacement of one meter.

In the opinion of instructors and students, the synopsis turned out an effective means while consolidating the instructional material, preparing to seminars. It helps to size up the structure of the instructional material, pick out and easily memorize the most essential its moments. It is very important that student remember them for a longer time.

The synopsis allows carrying out fast and regular control students' knowledge during a lecture. In this case, the expressions serve as a base for the open type test tasks being created by missing some keywords in the expressions. Students note a great value of the synopsis while preparing to the examinations when there is a danger do not pick out and master the main statements of the course.

Let us note that the semantic facts are distinctive rules as they define character of relationships between the elementary facts. In other words, they are rules according to which the elementary facts are connected between themselves. This circumstance stipulates possibility to represent the semantic knowledge by means of the production method. It is done with the help of rules of a kind "if A than B" where A and B are some facts. An example of such a representation of the above mentioned definition of the translation motion is given below:

If < *a solid body moves*> and
< *all the point of the body have identical trajectory*>
than <*such a motion is called the translational one*>.

Each of the expressions may be represented in such a way. Thus the production knowledge base of the subject will be constructed. Its constructing is considered in details in work [4]. As our practice shows, constructing production knowledge bases by students while learning is an effective kind of learning activity.

7 Conclusion

An approach to construction of the subject student model as a part of the normative one is described. The model consists of four components: thematic, functional, operation, and semantic. The thematic model gives ideas about the structure of the subject, the semantic one reflects its content, functional one determine what students have to know, and operation one does what students have to be able. The approach allows constructing more detailed current student models and reaching the main aim of teaching, namely forming the way of acting, more successfully.

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An Interactive Game System to Stimulate Word Associations

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We present here an interactive game system designed to stimulate user's knowledge associations between words. The system is based on a word-association television game called "Himitsu no Tsunagari". This game uses two different words and an association word. Each player is given a word, and must guess the other word and the association word to win the game. Our system allows person-to-person matches and person-to-computer matches. We believe that our system stimulates the users' creativity and their ability to form associations. Our system also acquires knowledge of word associations from game records. As more and more games are played, the system's knowledge of associations grows, and so does its ability to compete with the user.

Keywords: **Educational game, Interactive learning, Knowledge acquisition, Word association.**

1 Introduction

Many games have been designed to enhance various human abilities. Saeki [8] has pointed out that educational software needs to motivate learners in order to attract and retain their attention. If only its appearance is attractive, learners tire of the software soon. One approach developed in our lab to motivate children is the "Instruction Assisted Computer" (IAC) paradigm [4]. In this paradigm, the system is given a passive role and the children are put in the driver's seat. The result is that the familiar roles of teacher and pupil are reversed, and it is the children who end up 'teaching' the computer. To date we have successfully developed and studied several different systems using this paradigm [3][6][8].

Associations between words and concepts form a major dimension of human knowledge. Stimulating these associations can greatly influence concept formation and increase one's problem-solving skill [1][9]. Models based on association networks have been used for vocabulary acquisition [5] [7], and many association word-games have been developed [2].

In this paper, we describe a system to play an association game called 'Himitsu no tsunagari'. This game requires the player to think of several concepts at once and look for associations between them. We believe that this stimulates various associations inherent in the user's knowledge. Our system allows a user to play with another user (on the web, so that two users do not have to be in the same place), or with the computer. It also has a knowledge acquisition module, which analyzes the associations created in each game. These associations are added to the system's knowledge base, and result in a gradual improvement in the system's performance. In the rest of this paper we describe our system and the results of our initial experiments.

2 A Brief Introduction to Himitsu no Tsunagari

Himitsu no Tsunagari is a television game show in Japan. It is an association game using two different words (called 'keys') and another word that is associated with both keys (called a 'link'). There are two teams and a judge. Behind each team, a key is hidden (see Figure 1), so that each team can see the opponents' key, but not their own. Neither team can see the link. The goal of the game is to find their own key and the link. Each team takes turn guessing answers based on the visible key and the past guesses of the other team. The judge provides an evaluation of each guess ('correct', 'close', etc.). For example, in the second row in Table

1, Team B can infer that their key is something "yellow" from Team A's previous answer.

The associations between the keys and the link are not limited to those semantic or conceptual, but can be of any kind. For example, in Japanese "Niji" serves as a link between the keys "14 o' clock" and "rainbow" because both keys are homonyms of "Niji".

3 Design and Implementation of the system

Here we describe the interactive system for the Himitsu no Tsunagari game. We first describe the goals of our system. Then we explain the rules of the computer game, which are a little different from those of the TV game. Thirdly we present an outline of our system and discuss the relations among various modules. Fourthly, we describe the reasoning and knowledge acquisition modules in more detail. Finally, we describe the interface of our system.

Table 1. Flow of a game (Topic : keys - banana and strawberry, association - fruit)

Team	Visible key	Answer (Key)	Answer (Association)
A	Banana	Sunflower	Yellow
B	Strawberry	Lemon	Sour
A	Banana	Grapefruit	Fruit
B	Strawberry	Pineapple	Fruit
A	Banana	Raspberry	Fruit
B	Strawberry	Banana	Fruit

3.1 Design goals of the System

In order to allow many people to play and enjoy our system, we set the following design goals:

- The game can be played on the Web.
- The computer can be one of the players.
- The system has an easy-to-use interface.

3.2 The rules of the computer game

We clarified and added some rules to the TV game rules, as explained below.

- The game is played with two players and one judge
- At the beginning of a game, each player is given a key and the judge is given both keys and the link.
- The judge evaluates each guess as 'correct', 'near miss, 'incorrect', or 'strange'.•
- Each player is allowed 90 seconds for making a guess.
- The game is finished when the judge declares the guesses of the key and the link as correct.

3.3 Overview of the system

The structure of our system is shown in Figure 1. There are five modules in it: game server, user interface, knowledge acquisition, reasoning module (making guesses), and knowledge database. The game server is responsible for sending the keys and the link to the players and the judge, and for passing messages (guesses and evaluations) between the players and the judge. The words used in the game and their associations are saved in the knowledge

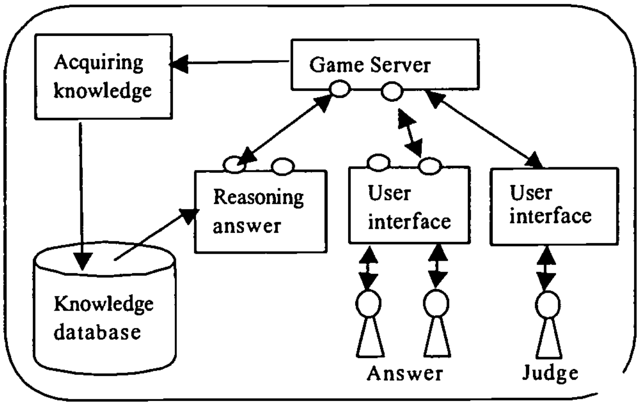


Figure 1. Structure of the system

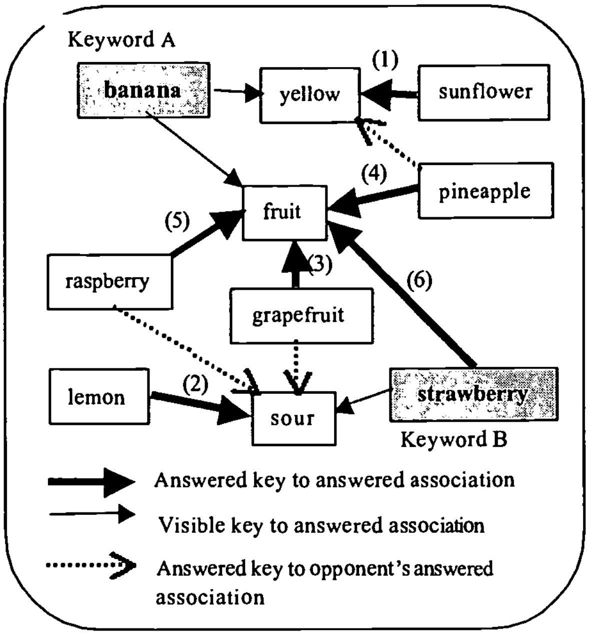


Figure 2. Association network from a game.

database. This knowledge is used to make guesses when the computer is one of the players.

3.4 Acquiring and Reusing Knowledge

We describe here our approach to acquiring knowledge about word associations from past games, and using this knowledge to make guesses in subsequent games.

3.4.1 Knowledge acquisition from past games

From the record of a game we can make an association network (Figure 2). It is difficult to say from the record which guesses of the opponent were useful for a player in making his or her own guesses. For example, when the opponent's guess seems quite unrelated to the visible key, a player may just disregard it. However, we assume that the link and the key in each player's guess are associated. We also assume that the link in each player's guess is associated with the key visible to that player. So we add <guessed-key, guessed-link> (→) and <visible-key, guessed-link> (→) to our set of associations in the knowledge base. We call each of these pairs an "association pair", and the network created by all the association pairs an "association net".

3.4.2 Reasoning Module: Guessing the key and the link

As mentioned above, we assume that the link guessed by a player is associated with the visible key and the guessed key. For this guess we make two assumptions: the guessed link is correct or incorrect, and the guessed link has something to do with the hidden key. For example, if the opponent guessed "the key is 'apple' and the link is 'red'", and it was judged incorrect, a player can infer that the opponent's visible key (and the player's hidden key) is associated with red and the correct link is not "red". From these two pieces of information we can search for plausible answers in the association net (Figure 3). Every time the opponent makes a guess, the computer searches the association net and adds a certain weight to each plausible association pair. When it is the computer's turn to make a guess, it selects the association pair with the highest weight.

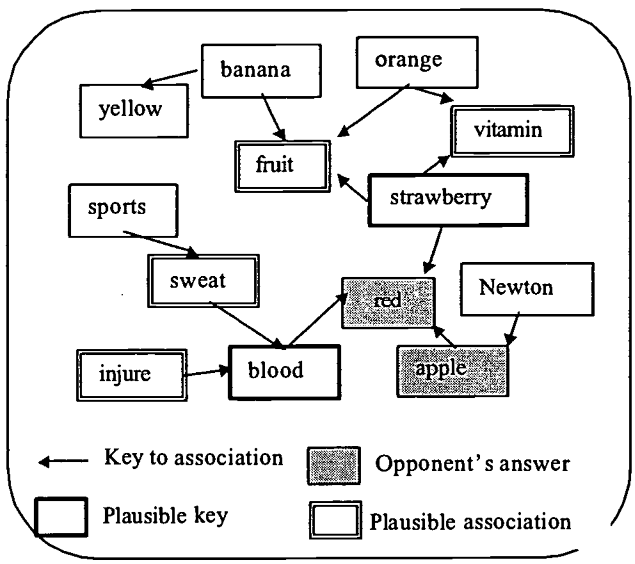


Figure 3. How to search for plausible answers

3.5 Interface

There are two displays, one for the judge and one for the players. They differ only in the input area. The player-interface displays the visible key and the history of the game (the player's guesses, the opponent's guesses, and the judge's evaluations), and has areas for entering the guessed link and key. The judge-interface is similar except for the input area. Instead, it has eight buttons (four each for the key and the link) at the bottom of the screen to evaluate the players' guesses. There is a time limit of 90 seconds, after which an answer is sent automatically.

4 Experiment

We tested our system with 10 undergraduate students in the Computer Science Department. In the beginning, we explained how to play the game with various topics and a sample game. Then subjects were matched to a computer to play the game using ten topics for two hours. Assistants judged the games. Subjects sometimes thought deeply and sometimes seemed to hit upon an idea quickly. We acquired about 1,400 answers. Here is a result of one game (see Table 2).

After playing the system, we let the subjects explain from which words they guessed the answers. We used their explanations to determine from how many words an answer was guessed • we call this the 'base-words number'. For example, "wiener" was guessed from "coffee" and "hotdog", so the base-words number is 2. The average base-words number was 1.4. This result shows that users try to consider more than one word in playing this game.

Table 2. An example, "Wiener & Twins". Both concepts also called "sohseiji" in Japanese

Turn	visible key	Key	Association
Computer	Wiener	American	Coffee
Suject	Twins	Haliwood	Shuwalzneger
Computer	Wiener	Ketchup	Hotdog
Suject	Twins	No	No
Computer	Wiener	Salami	Sausage
Suject	Twins	Wiener	Sausage

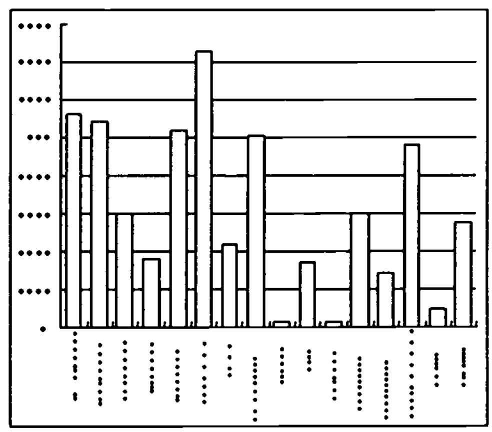
Some subjects tended not to answer within 90 seconds. Such subjects were found to have a higher base-words number than those who answered in time.

We categorized the associations into 16 groups (Graph 2), most of them from Togawa's classification. Superior, inferior, instance, synonym, same, emotion (<magic, muse>), character (<apple, red>), character2 (<Wright, airplane>), component (<sausage, pork>), inclusion (<apple, pineapple>), junction (<sun, flower>), place/time, phonic, verb, target (<knife, apple>), ellipsis (<wolf, liar>wolf boy lies a lot). Synonym was the most frequently guessed category. Ellipsis association represented 5% of the guesses. We think that playing with the system stimulates many kinds of associations.

We also gave a questionnaire after playing the game. In spite of its free answer form, most players answered that they enjoyed thinking and the moment of hitting upon an idea.

5 Conclusion

We described an interactive system using the Himitsu no Tsunagari game. In this game a user can play against either other users or a computer player. The computer uses the knowledge acquired from past games. It improved itself by acquiring knowledge from game records. Users tried to answer using associations to 1.4 words on average and in various categories. In addition, they said they enjoyed thinking about the answers in the experiment. We believe our system stimulates users' ability of associating words. Since many games were played, the computer acquired sufficient knowledge to compete well against users.



Graph 2 Categories of associations

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DIYexamer: A Web-based Multi-Server Testing System with Dynamic Test Item Acquisition and Discriminability Assessment

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With the rapid growth of both computer technology and the Internet, conventional models of testing are gradually being replaced by CAT (Computer Assisted Testing) systems. However, the major problem in most CAT systems is the difficulty in refreshing and supplying test items. This paper presents a novel network CAT system, DIYexamer (Do-It-Yourself Examer). It has three features that differentiate it from existing CAT systems: student DIY items, item-bank sharing, and automatic assessment of item discriminability. DIYexamer accepts test items contributed form teachers as well as students, and allows limited item sharing between item-banks possibly maintained by different organizations. An algorithm is applied dynamically to assess the discriminability of items in item-banks in order to filter out less qualified contributions, hereby assuring the quality of stored items while scaling up the size of item-banks.

Keywords: **computer assisted testing, test evaluation, test acquisition, discriminability, distant learning**

1 Intorduction

With the continuing development of computer technology and the Internet, educators now have new alternatives for creating, storing, accessing, distributing and sharing learning as well as testing materials. Should testing be performed on or learned from computers, and then a computer can best assess the work, Bugbee (1996)[1]. Hence, assessing the learning achievements and attitudes of students via computers or networks becomes a challenging task for many educators and researchers.

A. Computer-assisted Testing Categories

Computer-assisted Testing (CAT) or Computer-based Testing (CBT), the use of computers for testing purposes, has a history spanning more than twenty years. The documented advantages of computer administered testing include reductions of testing time, an increase in test security, provision of instant scoring, and an individualized adaptive testing environment [2][3][4][5]. As listed in Table 1, three categories of CAT are currently employed: standalone packages, test centers and networked systems.

TABLE 1: Categories of CAT

	Network support	Item generator	Random item selection	Item source	Item quality assessment	Item-bank sharing	Test result analysis
Standalone package	No	Built in item-bank	Yes	Fixed	No	No	Yes
Test center	Yes	Expert	Yes	Limited	Yes	No	Yes
Networked system	Yes	Built in item-bank	Yes	Fixed	No	No	Yes

1) Standalone package: This type of computer software package is typically stored on disks or CD-ROMs. Some packages have built-in item-banks, while others require teachers to input test items. These CAT packages generally do not have network capabilities.
2) Test center: The test centers or lab services require dedicated computer terminals for testing purposes. Students are required to complete the computer-based tests at the centers. Well-known applications of this type of service are Graduate Record Examinations (GRE) and Graduate Management Admission Test (GMAT), as provided by Educational Testing Services (ETS) [6].
3) Networked system: This enables students to perform an examination through an Internet connection. Concurrent testing of multiple users, automatic score calculation, and automatic test result analysis are supported by a networked system. The major advantages of networked systems are the convenience of examinations and test result calculation. However, the major flaws are the limitation of the amount of items and no item discriminability assessment.

B. Problem Statement

Regardless of which CAT system is employed, a critical issue in developing CAT is the construction of a test item-bank. Traditionally, asking teachers and content experts to submit items generates the item-bank. Three major drawbacks of the traditional method can be observed:
1) Limitation of item amount: Teachers and content experts tend to have similar views on the test subject. That is, in a given field vital subject matter might be confined. Therefore, although more teachers and content experts are invited to contribute test items, the total number of distinct items remains low.
2) Passive learning attitude: Students are conventionally excluded from the creation of tests. In a typical computer-assisted testing system, teachers generate tests, the system presents test sheets and students then complete the tests. That is, within the system of testing, they play a passive role, and are not afforded the opportunity to conduct "meta-learning" or "meta-analysis."
3) No guarantee on item quality: Permitting students to generate tests may be a possible solution to the aforementioned problems. However, this raises a new problem: quality assurance and ensuring that the tests are worth storing and used for further tests. Even when the whole item-bank is contributed by teachers and content experts, ways to dynamically assess and filter test items are needed.

The rest of this paper is organized as follows. The three distinct features of DIYexamer are introduced in section 2. Section 3 describes how the DIYexamer was implemented and its functionalities for administrators, teachers, and students. The discriminability calculation formula is then presented in section 4. Finally, the accuracy of discriminability discretion of DIYexamer and conventional methodology are compared through a real-life test in section 5.

2 The Diyexamer Solution

The DIYexamer[7] is a Web-based multi-server system that allows students to contribute test items, and provides an effective means of verifying the discriminability of these items. Three main ideas are as below:

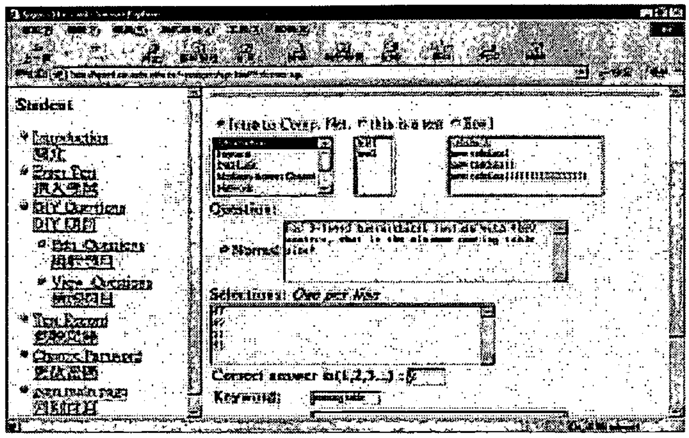
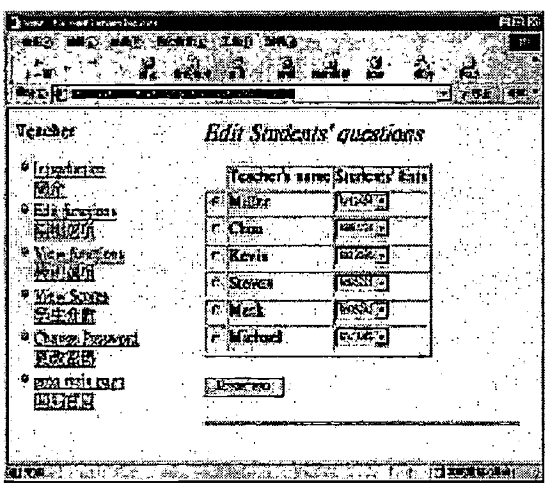


Fig 1: Students generate items into the item-bank

1) Item DIY by students: DIYexamer allows students to generate test items into the item-banks online as Fig 1. Teachers can query these items generated by students as Fig 2. In addition to rapidly increasing the total number of items in an item-bank, this feature also encourages students to develop *meta-learning*, i.e. *creative learning*. In order to submit tests, students must thoroughly study the learning materials, develop higher-level overviews of the materials, and practice cognitive and creative thinking.



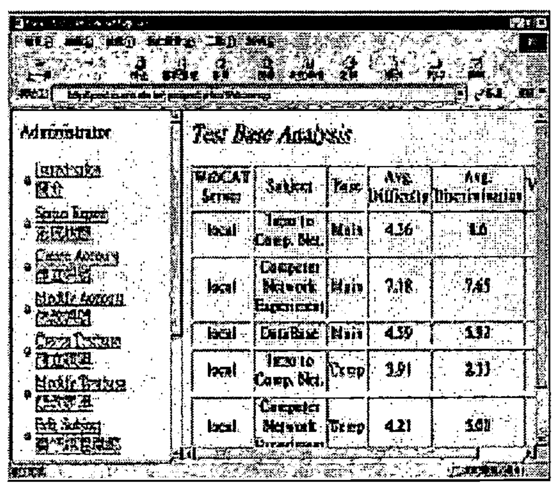


Fig 2: Student DIY items as queried by teachers

Fig 3: Average item discriminabilities of item-banks

2) Assessment of item discriminability: DIYexamer provides an item-discriminability assessment method to ensure the quality of the stored items. In addition to ensuring the internal consistency of existing test items, this method also continuously and dynamically screens additional new items in the item-bank. Fig 3 shows the average item discriminabilities of several item-banks.
3) Item-bank sharing: DIYexamer, a scalable multi-server system, connects many item-banks stored in different servers. Therefore, via the Internet, more items can be accessed and shared. The sharing is limited and controlled in a sense that a server issues a request, describing the criteria of a test item it requests, to another server. A server does not open up its item-bank for unlimited access.

Additional advantages have been identified and include the facts that since DIYexamer provides a real-time on-demand generation of test-sheet function, cheating is avoided. Also, DIYexamer provides an item cross-analysis function to which the degree of difficulty for each test as well as the entire test base can be accurately measured.

3 Diyexamer System Implementation

A. DIYexamer Network Architecture

DIYexamer is a WBT (WWW-Based Testing) system. An important feature is the sharing of item-bank via network connections. According to Fig 4, several DIYexamer servers form a *scalable test union*. Therefore, each server can access other servers and thus achieve item-bank sharing. A remote server can also join the test union to share additional test-bank resources, and leave the test union without affecting other servers.

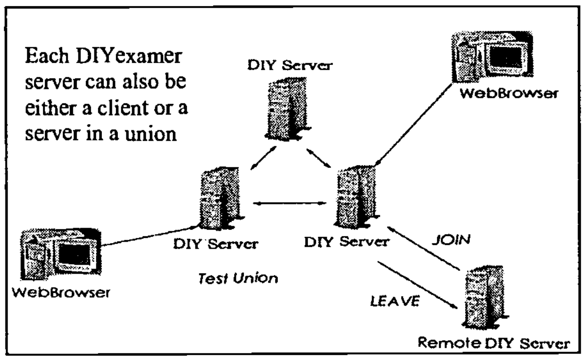


Fig 4: Network Structure of DIYexamer

B. Internal System Model

The internal architecture of DIYexamer (Fig 5) is divided into three layers. Interface layer is responsible for providing web interface for users. Test Profile Layer (TPL) selects items to form a test sheet, computes scores, and calculates the discriminability of selected test items. Test base Sharing Layer (TSL) accesses both local and remote databases via a network. Three functions of TSL are listed in Table 2:

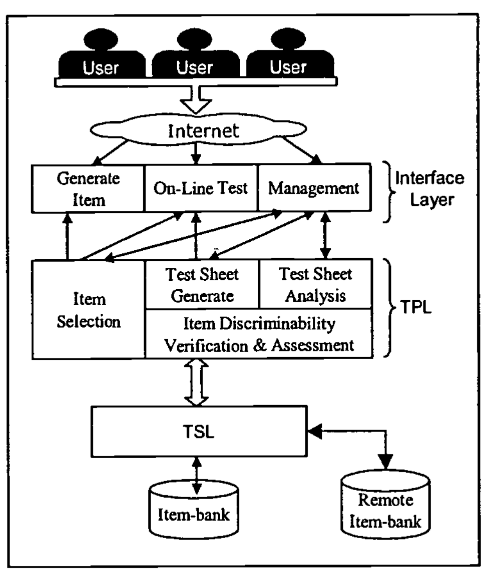


Fig 5: Structure of DIYexamer

TABLE 2: Functions of TSL

Function	Description
Add new items	New items and corresponding answers are categorized to specific chapters and stored in the local item-bank.
Access local item-bank	Accessing local while generating test sheets and calculating discriminability.
Connect to remote item-bank	Item-bank sharing through a connection to a remote item-bank.

Environments and development tools used to construct DIYexamer are listed in Table 3. Perl is used to write CGI programs to create user interface as homepage. Apache, an open source web server software, is responsible for front-end. The back-end, item-bank, is handled by Postgres.

TABLE 3: Environments and development tools

Fnnction	Tools
HTTP Server	Apache 1.3.3 [8]
Programming Tools	Perl 5.003 [9] 、CGI.pm-2.56 [10] 、Gd.pn-1.14[11]
DBMS	Postgresql 6.5.3 [12]
O.S.	Red Hat Linux release 6.1[13]

C. Functionalities for administrators, teachers and students

DIYexamer provides a web interface for users to remotely control and operate the system. Three types of users are supported: administrators, teachers, and students. Corresponding functionalities are listed in Table 4.

TABLE 4: Functionalities for different users

	Administrator	Teacher	Student
System and Database	• Examine system status • Join a test union • Leave a test union • Create personal accounts • Create group accounts • Modify accounts • Modify item-bank • Redact course division • Backup database	• React course division	
Item production		• Create tests sheet • Select test items • Edit test items • Read test items	• Edit test items • Read test items
Test	• Network Invigilate	• Input scores of homework	• On-line test
Analysis	• Analyze tests • Analyze test items	• Analyze tests • Analyze test items • Analyze subjects and divisions	• Analyze tests
Inquiry		• Inquire tests • Inquire test items generated by students • Inquire students scores	• Inquire personal scores

4 Discriminability Assessment Of Diyexamer

A. Method of Traditional Discriminability Assessment

A criterion against which the quality of test items is judged is the assessment of discriminability. An item is regarded as with high discriminability when competent students correctly answered it, while less competent students incorrectly answered it, and vice versa. When computing item discriminability, those students with relatively high and relatively low scores are taken as samples. Those students whose scores fall in middle range not considered. Next, item discriminability is computed according to the performance of these sampled students when answering each item.

In the traditional discriminability assessment method[14], those in the top 30% and the bottom 30% rank groups are chosen as samples. The top 30% scorers are defined as "high-rank group (H)", while the bottom 30% scorers are defined as "low-rank group (L)". The formula for calculating the discriminability of an item is as follows:

$$\text{Discriminability} = \frac{\begin{array}{c}\text{The number of students in H}\\ \text{that answered correctly}\end{array}}{\text{The number of students in H}} - \frac{\begin{array}{c}\text{The number of students in L}\\ \text{that answered correctly}\end{array}}{\text{The number of students in L}}$$

In the traditional method, two major drawbacks can be observed. The first one has something to do with whether the 30% is in terms of *count of students* or *range of scores*. The sampled students fall in the top 30% and the bottom 30% rank groups, i.e. in terms of *counts*. However, it is possible that these scores differ only slightly from the average score especially when scores are not wide-spread distributed, where many scorers should not be considered in computing the discriminability. Second, the effect on discriminability assessment by each student in either group is assumed to be the same. However, those students that received different scores have different degrees of tendency to correctly or incorrectly answer an item. For example, a sampled student who received 97 points should have higher referential value than a sampled student who received 80 points.

B. Method for DIYexamer's Discriminability Assessment

When selecting sample students, only those whose scores have large gap with the average score should be considered. Accordingly, those with the top 30%, in terms of range, scores are defined as "high-score group (H')", while those with the bottom 30% scores are defined as "low-score group (L')".

To show the different criteria and effects of choosing samples in the traditional method and DIYexamer method, Fig.6 depicts the score distribution in a test. In this example, the highest score is 92, the lowest score is 34, and the average score is 69. The "high rank score group" and the "low rank score group" are chosen according to these two methods. Take student X as an example, the score of X is 66, which differs only 3 points from the average score. The associated information of X should have little, if not none, referential value in computing item discriminability. However, X is chosen as a sample in the high rank group in the traditional method. This fallacy results from using rank group, in terms of count, as the criterion of choosing samples. In DIYexamer, X is not chosen since score group, in terms of range, rather than rank group is used. Only those with large gap with the average score are chosen as samples.

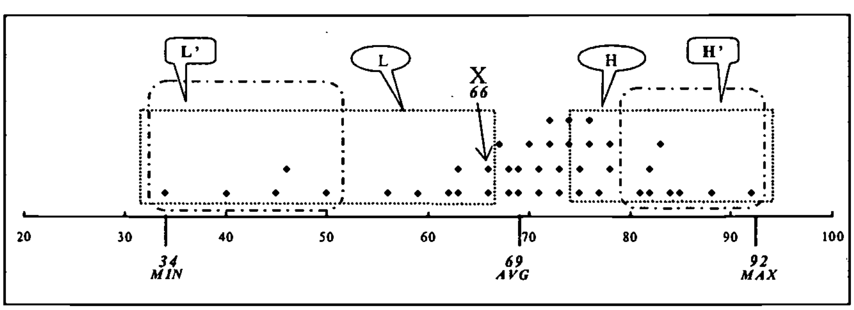


Fig 6: Comparison of samples taken in the traditional method and DIYexamer method

For different samples to have different impacts on discriminability, a referential value with respect to an item is generated for each student selected as a sample. We first define the item discriminability as the average of all associated referential values, as shown below:

$$\text{Discriminability} = \frac{\text{Sum of the referential values of sampled students}}{\text{Number of sampled students}}$$

Since the referential values depend on students' scores, the referential values are computed according to the ratio of correct and incorrect answers of the sampled students. The ratios of correct and incorrect answers are defined as follows:

$$\text{Ratio of correct answer} = \frac{\text{Number of items answered correctly}}{\text{Number of items on the test}}$$

$$\text{Ratio of incorrect answer} = \frac{\text{Number of items answered incorrectly}}{\text{Number of items on the test}}$$

TABLE 5: Principle to compute the referential value of a student with respect to an item

Student	Answer	Item discriminability	Referential value to compute discriminability
Competent (With high ratio of correct answer)	Correct	High	Ratio of correct answer
	Incorrect	Low	Ratio of incorrect answer
Less competent (With low ratio of correct answer)	Correct	Low	Ratio of correct answer
	Incorrect	High	Ratio of incorrect answer

According to Table 5, the referential value of a student correctly answered an item is the ratio of correct answer of the student. Alternately, the referential value of a student incorrectly answered an item is the ratio of incorrect answer of the student. This policy comes from the fact that an item should have increased discriminability if correctly answered by a competent student, while rendering decreased discriminability if correctly answered by a less competent student. In this way, a competent student contributes large referential value to a correctly answered item and small referential value to an incorrectly answered item, and vice versa.

C. Algorithm for DIYexamer's Discriminability Assessment

The test result of a student is used if the score falls in either the high or the low score group. A referential value is computed for each item the student answered. The discriminability of an item is the average of all of the associated referential values.

To calculate for each item, information must be recorded in the database. First, the highest and the lowest scores (i.e. Gmax and Gmin) of all students who answered the question item are recorded to calculate Gh and Gl. Gh and Gl are used as thresholds to determine whether a student is eligible to affect the rating of an item. Second, the number of students with referential values (i.e. n) and the sum of referential values (i.e. Accumulator) are recorded. The calculation formula and the corresponding definition of used parameters are listed below. Algorithm of DIYexamer's discriminability assessment summarized in Fig 7.

Accumulator: sum of referential values
n: number of students with referential value
T: number of correctly answered questions in this test
F: number of incorrectly answered questions in this test
Gmax: highest score of all students answered this question
Gmin: lowest score of all students answered this question
Gh: high threshold for ratio of correct answer
Gl: low threshold for ratio of incorrect answer
Ans: A Boolean variable indicates whether a student correctly or incorrectly answered the question

```
if((T/(T+F)>Gh) or (T/(T+F)<Gl))
{
 if (T/(T+F)>Gmax)
   Gmax = T/(T+F)
 else(T/(T+F)<Gmin)
   Gmin = T/(T+F)
 Gh = Gmax-(Gmax-Gmin)*30%;
 Gl = Gmin+(Gmax-Gmin)*30%;
 n = n+1;
 if (Ans==Correct)
   Accumulator = Accumulator + T/(T+F);
 else (Ans==Wrong)
   Accumulator = Accumulator + F/(T+F);
 Discrimination = Accumulator /n;
}
```

Fig 7: Discriminability assessment algorithm

5 Evaluation Of The Discriminability Assessment In Diyexamer

The fairness and performance of DIYexamer was evaluated. We conducted an experiment where 10 students took the test on-line using DIYexamer with 10 items. Table 6 summarizes the test results. Fig 8 shows the score distribution of the experiment. Discriminability for each item is computed using both the traditional method and the DIYexamer method. However, the discriminability originally falls between -1 to 1 using the traditional method, while falling between 0 to 1 using the DIYexamer method. To compare these two methods, both two ranges of discriminability are then normalized to 0 to 10, as shown in Fig 9.

According to Fig 9, the item discriminability differs in these two methods because the samples taken are different. The low-score group consists of student 1, 2, and 3 by the traditional method, while only 1 and 2 by the DIYexamer method. In this case, student 3 got 4 points, which differs from the average score (i.e. 5.2 points) by only 1.2 points. Since student 3 should have little, if not none, impact on the assessment of discriminability, student 3 is in fact not a proper sample.

Observe that, in Table 6, student 1 who is a less competent student and has incorrectly answered all items except item 1, and student 10 who is a very competent student and has incorrectly answered item 1. Thus, item 1 can be concluded as of low discriminability. Comparing the assessment results in these two methods, the computed item discriminability of item 1 is very low in the DIYexamer method but not as low in the traditional method.

Comparing item 3 and item 1 in Table 6, item 3 should have higher discriminability than item 1 because competent students tend to answer item 3 correctly and less competent students tend to answer item 3 incorrectly, which is not true for item 1. However, item 3 and item 1 have the same discriminability, i.e. 5, by the traditional method. In this case, the actual discriminability is more accurately reflected in the DIYexamer method than in the traditional method.

TABLE 6: Result of the test experiment

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Number of correct answers(score)
student1	1 (correct)	0 (incorrect)	0	0	0	0	0	0	0	0	1
student2	1	0	0	1	0	0	0	0	0	0	2
student3	0	1	1	0	1	0	0	1	0	0	4
student4	1	1	0	1	0	0	0	1	0	1	5
student5	0	1	0	1	0	0	1	1	0	1	5
student6	1	1	1	0	0	1	0	1	1	0	6
student7	0	1	1	1	1	0	0	1	1	0	6

student8	1	0	0	1	1	1	1	0	1	1	7
student9	1	0	0	0	1	1	1	1	1	1	7
student10	0	1	1	1	1	1	1	1	1	1	9

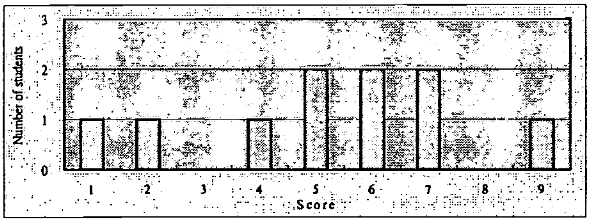


Fig 8: Score distribution of the test experiment

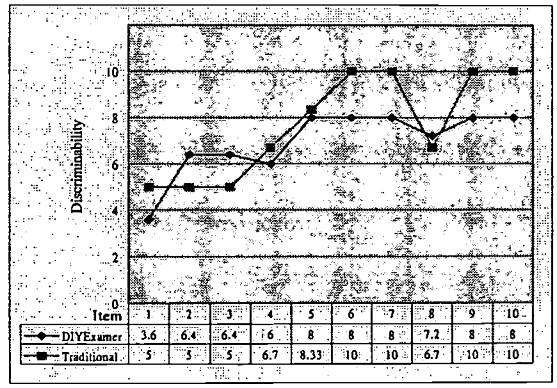


Fig 9: Comparison of item discriminability

6 Conclustion

This paper has presented a novel architecture for a networked CAT system, DIYexamer. It supports item DIY by students, item-bank sharing, and item discriminability assessment.

For discriminability assessment, new calculation formula were proposed. When compared with the traditional assessment scheme, the main difference is that the top and the bottom 30% of the *score* group, in terms of *range of scores* were selected rather than the *rank* group, in terms of *count of students*. Thus, item discriminability is more accurately reflected particularly when the tested students have close scores.

Item-bank sharing and item DIY by students has increased both the *amount* and the *variety* of questions in item-banks. Item DIY by students promotes *creative learning* within students, while automatic discriminability assessment assures better quality than traditional CAT systems.

A questionnaire was used to survey subjective attitudes of students about DIYexamer. As shown in Table 7, the outcome revealed that most students were interested in item DIY.

TABLE 7: DIYexamer questionnaire results: percentage and the number of students in parentheses of each question

Question	Strongly agree	Agree	No opinion	Disagree	Strongly disagree
Item DIY is interesting.	12.3 (7)	43.9 (25)	21.1 (12)	15.8 (9)	7.0 (4)
Item DIY is fanciful.	19.5 (10)	49.1 (28)	21.1 (12)	10.5 (6)	1.8 (1)
I am curious about the testing result of my DIY item.	26.3 (15)	59.6 (34)	10.5 (6)	3.5 (2)	0.0 (0)
I learned a lot when creating items.	12.3 (7)	47.4 (27)	22.8 (13)	17.5 (10)	0.0 (0)
I am curious about the teacher's opinion about my DIY item.	22.8 (13)	50.9 (29)	22.8 (13)	1.8 (1)	1.8 (1)
I am curious about other students' opinions about my DIY item.	15.8 (9)	56.1 (32)	21.1 (12)	7.0 (4)	0.0 (0)
I studied harder to prepare item DIY.	10.5 (6)	54.4 (31)	21.1 (12)	14.0 (8)	0.0 (0)
Judging the difficulties of my DIY items is easy.	40.4 (23)	38.6 (22)	14.0 (8)	7.0 (4)	0.0 (0)
Judging the fitness of my DIY items is difficult.	36.8 (21)	49.1 (28)	8.8 (5)	5.3 (3)	0.0 (0)
Item DIY by students comes from the laziness of teachers.	7.0 (4)	12.3 (7)	43.9 (25)	33.3 (19)	3.5 (2)
If possible, I hope such item DIY mode through the whole course can replace conventional testing.	1.8 (1)	10.5 (6)	35.1 (20)	38.6 (22)	14.0 (8)

Items generated by students are easier than by the teacher.	7.0 (4)	36.8 (21)	28.1 (16)	24.6 (14)	3.5 (2)
I knew more about the testing material after item DIY procedure.	8.8 (5)	50.9 (29)	22.8 (13)	15.8 (9)	1.8 (1)

The technique proposed herein is useful in general tuition not only to improve the quality of test items and fairness; but also to save time from generating questions and computing scores. We recommend that DIYexamer be popularized to schools.

ACKNOWLEDGEMENT

The authors would like to thank Tsung-shun Wu, Yi-Neng Lin, Chih-Hsuan Tseng, and Ding-Li Wang for the prototyping works of DIYexamer.

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The Artistic Interface - A Transition from Perception to Screen

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1 Introduction

At present a dichotomy of computer art instruction exists, where the computer as an art medium, presents the learner with almost limitless possibilities of image manipulation; yet instructional methodology and current art curriculum provide no coherent framework through which the learner can effectively access this information.

2 Research

Throughout the last five years the researcher has taught numerous art concepts and involved students in art tasks using the computer. The reality of the researcher's teaching situation is that the use of the computer within an art context is not debated, but accepted as a part of the everyday teaching process. After several years and testing different ways of approaching the teaching of computer programs several issues emerged which warranted further consideration:
1. Frustration exists due to the limited time that students had available to use the computer and the amount of information students were expected to utilize.
2. Many computer graphic programs are structured in similar ways (display a similar interface) and use similar symbols (icons) to represent functions within the program
3. Students seem unaware of these similarities and unable to transfer an understanding of one programs GUI (Graphic User Interface) to another computer graphic program.
4. Students appeared to have no mental map or problem solving strategies with regard to searching for answers to problems within a computer art environment.
These thoughts led to the intention within this research study which is to document the qualitatively different ways that students interact with the graphic user interface of computer graphic software in an art education context in order to create art.

It is hypothesized that students need to build some form of mental model regarding the software program they are interacting with in order to understand its application domain. That by examining the influence of different types of interface cues regarding navigation within a computer art context a greater understanding of students' conceptions regarding utilizing the computer as an artistic medium could be facilitated. Interface cues in this regard pertaining to the icons, layout and menus presented to the user. This is defined by the researcher as the Artistic Interface. This Artistic Interface is the interaction that occurs between the student's artistic intent and the graphic user interface of the computer.

The underlying art educational assumption here is that the clearer the mental model the student has, the more capable the student will be at understanding the program, at locating a specific function and achieving the desired artistic result. Within the context of this study it is postulated that students with a clearer mental model of the graphic user interface (GUI) will have a more effective art educational experience (a more effective Artistic Interface) when utilizing the computer as an artistic medium.

In order to develop this 'mental model' a phenomenographical mode of inquiry will be used. Roth and Anderson (1988) stated that they consider learning to be a change in one's view of some phenomenon. Also Marton (1992) suggested that: "In order to develop teaching methods that help students arrive at new understandings of a given phenomenon, we must first discover the finite ways individuals may understand that phenomenon. Then, through experimentation, we may discover the most effective ways to bring students from a given conception to another, more advanced one, that is, from 'misunderstanding' to understanding." (p.253) Thus if students' conceptions of how they interact with the computer in an art educational context can be documented, then a learning framework could be developed which could enhance their understanding of the GUI of a particular program, and maybe other computer graphic programs.

3 Educational Considerations

Within a consideration of the influences of the GUI this study situates itself into the line of those devoted to the analysis of a possible correlation between the user's cognitive skills and his / her navigation abilities in an interactive, iconic, multimedia environment. This has been supported and further documented by Castelli, Colazzo, and Molinari, 1994; Elm and Woods, 1985; Osborne, 1990; Thuring, Hannemann, and Haake, 1995.

An effective analysis of students utilizing the computer in art education must begin with 'what is the student trying to do? Previous studies (Elm and Woods, 1985; Osborne, 1990) have demonstrated that getting lost is a consequence of the lack of a clear conception of the relationships within the system. In relation to this study this statement seems to imply that an effective use of the computer as an artistic medium depends upon the ability of the user to abstract from the system display discrete understandings relevant to the desired artistic result and that this may involve building a conceptual representation of a particular software programs GUI. It is further postulated within this study that if a learner can construct an effective mental map, or conceptual representation of a particular software programs GUI then this mental map maybe facilitate an easier and more effective understanding of another program due to the similarities in their GUI.

4 Conclusions

There is ongoing educational debate about the nature of the information society and the range of 'literacy's' needed to handle, understand, and communicate information in a variety of forms (Baker, Clay and Fox, 1996). The researcher has suggested that literacy in the information age requires not only the skills to operate the technology, but also the ability to identify and structure a line of inquiry in order to solve a particular problem. In this instance what is being analyzed is the range of 'literacy's' needed to form a line of inquiry into a computer art domain.

This research into the Artistic Interface is an attempt to document students' understanding of differing computer graphic arbitrary symbols (a software programs vocabulary) placed according to a systematic formula (a software programs grammar) to produce an understanding of various icons (pictograms used to represent a function of the computer). The researcher will seek to examine the qualitatively different ways that students understand the GUI in a particular computer graphic program and within a particular art educational context. This will involve a phenomenographical study that will lead to further understandings regarding students' perceptions of the Artistic Interface.

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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.

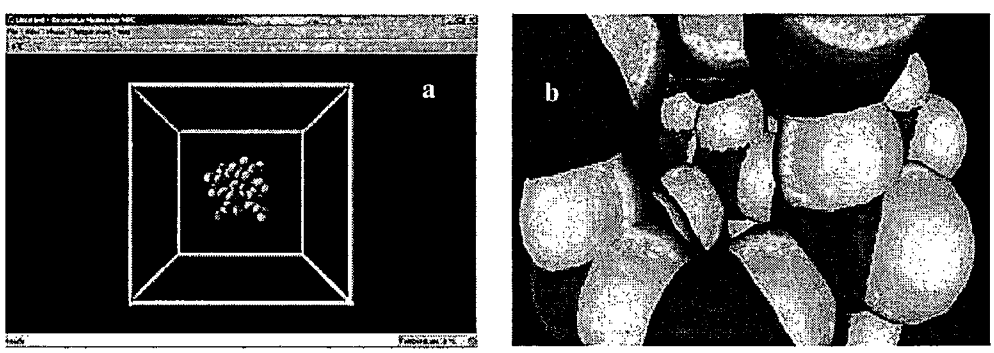

Figure 1: Two frames from the water solid phase (ice) of our molecular dynamics environment: a) balls model of a group of molecules; b) flying through the ice structure.

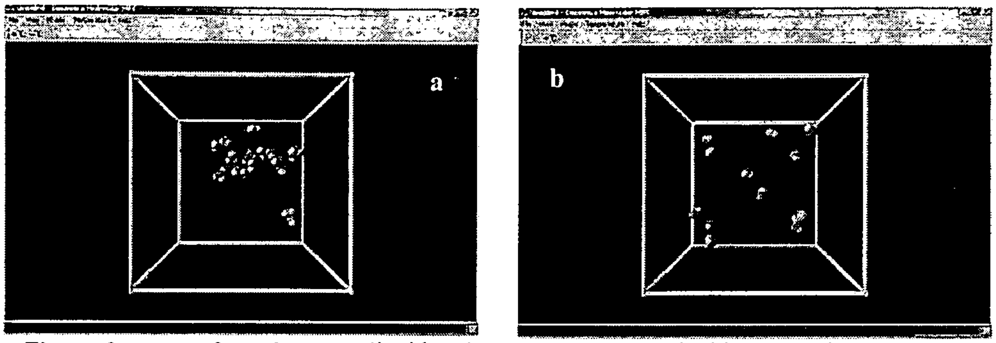

Figure 2: Frames from the water liquid and gas phases: a) the liquid phase, with the balls model of twelve molecules; b) The gas phase, showing the same molecules. These pictures, as well as those of Figure 1, were created with *PC Gamess*, *Molden*, *3D Studio Max*, being the dynamics implemented in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

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Agent-oriented Support Environment in Web-based Collaborative Learning

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Currently, the web-based learning support systems are one of interesting and hot topics in points of the utilization of Internet and the application of computers to education. In particular, the web-based collaboration is very applicable means to make unfamiliar students, who are unknown with each other, discuss together in the same virtual interaction space. However, there are some problems derived from the gap between the real world and virtual environment: coordination for discussions, cooperative reactions, comprehension of learning progress, etc. These problems may be dependent on the fact that the actions of students cannot be influenced from the behaviors of others directly.

In this paper, we address a coordination mechanism to promote cooperative actions/reactions for progressive discussions. Our idea is to apply an agent-oriented framework to this coordination mechanism and introduce two different types of agents. One is a coordinator and the other is a learner. The coordinator monitors the learning progress of group and promotes the discussion, if necessary, so as to reach their common goal successfully. The learners are assigned to individual students, and act as interaction mediators among students in place of the corresponding students. Of course, the coordinator is a passive entity and learners are active entities in our collaborative learning space.

Keywords: **Collaborative learning environment, coordinator, learning situation, learner, personal learning history**

1 Introduction

The fast and world-wide enlargement of Internet/Intranet has made it possible that every person can interact instantly without depending on their physical locations. Also, various applications, which are available on the web environment, have been developed with respect to the content-based resource sharing, in addition to the traditional message exchanges. The web-based collaborative learning is one of applications, based on such a hot topic, and has been applied as computer-support for virtual learning space. If their computers were connected mutually through the web-based learning environment, students can discuss their common solving process successively and exchange various solving methods/ideas cooperatively. However, there are some problems to encourage activated discussions among students and make it possible that individual students should understand the correct answer and solving process effectively:

1) students may not participate into the discussion interactively because of their hesitation, derived from the fact that they are unknown with each other;

2) students cannot grasp the behaviors of others directly or indirectly because only the direct actions and reactions are observable through the interactive interface.

These problems are radical drawbacks for collaborative learning.

In order to solve these drawbacks effectively, we propose an agent-oriented support environment for collaborative learning. Of course, the agent-oriented frameworks for the construction of collaborative learning mechanism/environment have been already investigated until today. Florea[1] proposed a multi-agent collaborative learning environment in the web world. In this environment, three kinds of agents were introduced: personal agent which gets the information according to the requests of each student, tutor agent which generates advices when personal agents asked for the help, and information agent which acquires more information from Internet. Agents are activated by students' requests so that this system environment does not benefit passive students. Ogata, et al.[2] proposed mediator agents in the collaborative learning environment which assist students to find suitable collaborators. The mediator agent for each student holds the corresponding students' profile which indicates the understanding and interesting degrees about knowledge. When a student has problems, his/her mediator agent asks other mediator agents for the learning situations of their corresponding students and specifies appropriate students who may be able to help solving the problems. This research copes with the above problem 1) indirectly because this functionality supports to arrange appropriate learning group, but does not manage the progress of collaborative learning. Nakamura, et al.[3] and Liming, et al.[4] introduced respectively pseudo students which correspond to individual human students. These pseudo students have the same knowledge as the corresponding students and participate in the discussion in their ways if the corresponding students do not join in the discussion positively or cannot understand the discussion stage. These research viewpoints focus on passive students such as problem 1), but do not solve the problem 2). So, in spite of these various agent-based investigations, the previous drawbacks are not always overtaken.

In this paper, we address a collaboration learning environment, organized systematically under two different types of agents: coordinator and learner. The coordinator takes roles to monitor the discussion situation among students, grasp the learning progress and guide the learning process if necessary. The learners are virtual students corresponded possibly to individual students in our web-based collaborative learning environment. The coordinator and learner are complementary entities in the learning environment: the coordinator is a passive entity; and the learner is an active entity as the autonomy for practically participated student. In our investigation, we expect the collaborative learning of high school students who study mathematical exercises together, especially computation for the roots of equations. First of all, we show an overall framework of our collaborative learning environment in the web-world in Section 2. The functionalities about two different types of agents are stated in Sections 3 and 4, and then our prototype system is shown in Section 5. Finally, we conclude our paper in Section 6.

2 Collaborative Learning Environment

In the web-based collaboration learning environment, the actions/reactions of participated students are inherently different from their behaviors to be performed in the real world. Students in the physically constrained learning space can speak with each other by means of face-to-face, feel/recognize activities, occurred from the discussions of students, directly by various sensitive receptors and find out some new events/facts indirectly. Although these are not always implemented adaptively in the web-based virtual learning space, it is necessary to organize a collaborative learning environment in which the logical activities for support of interaction, discussion and comprehension can be implemented successfully and effectively.

Figure 1 shows our collaborative learning environment conceptually, which is characterized by two different types of agents: coordinator and learner. The coordinator places on the center of our virtual classroom (as a network server), monitors the interaction among students and generates advices if necessary according to the learning situation. This interaction is supported on the conversation means through the public communication line. The learner is a pseudo student in our virtual classroom and is assigned to the corresponding student one by one. The learner takes roles of the personal management of interaction interface for the corresponding student, the handshaking control of public communication line, the management of its own private learning history, and so on. In addition, the learner can communicate with other learners directly through the private talking line in order to exchange their personal learning histories.

Since students are studying with limited learning tools in the virtual web-based learning space, they sometimes do not able to communicate naturally. Furthermore, various students participate in the learning group and the learning process is not always completed successfully: i.e. some students are not able to solve the problem, some students are not able to understand the derived answering process after all, and so on. The coordinator solves such drawbacks in the virtual web-based learning space by managing the learning situation globally: the coordinator takes a place of teacher in our classroom activity. For the purpose of resolving inappropriate learning situation stepwisely and guiding

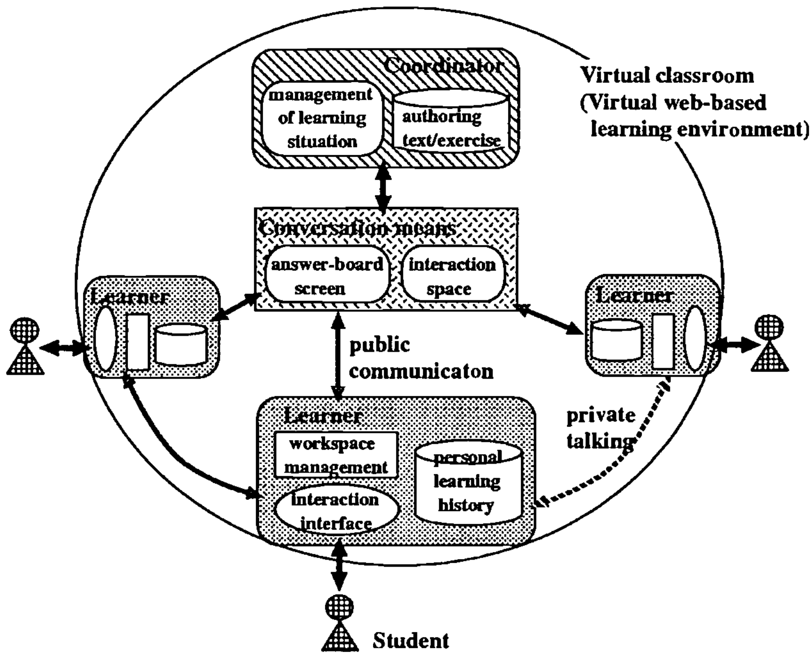

Figure 1: Collaborative learning environment

the learning group effectively, how to model and control learning situation is an important subject. If the coordinator grasps the learning situation appropriately, the advices which were generated from it may give appropriate hints in order for the learning group to proceed to the next phase of learning process. However, it is not always necessary to model the learning situation in detail precisely. This is, we think, because among the learning group students are able to help each other by discussion, so that the coordinator only has to detect the situation which the learning group cannot proceed the learning by itself.

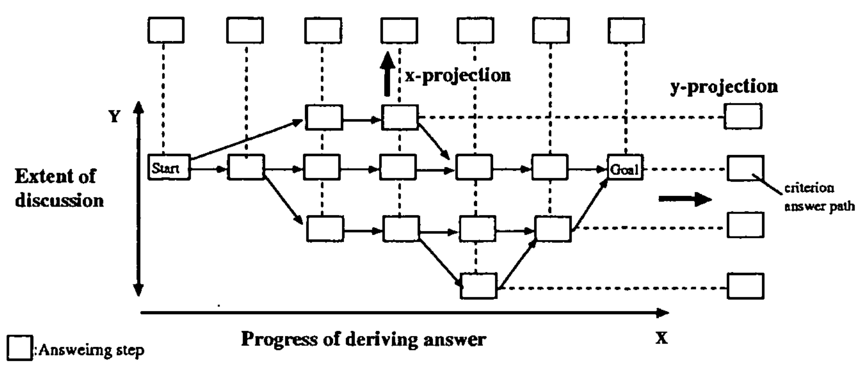

Figure 2: Answer space

The coordinator holds the right answer and the answering paths for an exercise as a knowledge to grasp the current learning situation. When the exercise has several answering paths for the goal, the answer space of exercise is expanded as 2-dimensional network structure, in Figure 2. In this figure, the learning progress along x-axis means the stepwise progress of deriving answer, whereas that along y-axis shows the extent of discussion. If the coordinator grasps the learning situation on the basis of the answering process of network structure as it were, it is very troublesome to manage the eventually changeable conversation stages successively. Therefore, our coordinator manages the learning situation with respect to the following two viewpoints separately: ratio of derived step for a whole answering process and extent of discussion. By monitoring the learning situation under these points of view, the coordinator is able to grasp the learning situation easier and generate advices timely. In particular, it is necessary and sufficient to manage the learning situation of group globally, but not individually do that of each student.

The learner acts as a network client in place of the corresponding human student in the virtual web-based learning space. This provides not only the interaction interface for virtual learning space attached to the corresponding student, but also the function of indirect interaction among students, so as to judge the understanding levels or personalities of them, which we call the focus function. According to the focus function, students select the opinions of particular students whom they evaluate as key students. In order to realize the focus function, the learner needs to have the knowledge about the corresponding student and exchange it with other learners. Therefore, the personal learning history is prepared for learner, which represents understanding level and personality of corresponding student. The learner constructs and maintains the personal learning history according to the current situation. Exchange of personal learning history is one-to-one interaction so that public communication is not necessary for the focus function. Therefore, we introduce mobile agents called mediators as children of the learner, that take responsibilities for the exchange of personal learning histories among learners. The mediator moves among learners by requesting/carrying the personal learning history on the private talking line.

3 Coordinator

The coordinator grasps the learning situation from two viewpoints: ratio of derived step for a whole answering process and extent of discussion. For the ratio of derived step, which corresponds to the x-axis of answer space in Figure 2, we have already proposed the resolution derivation scenario which represents the phases of deriving answer stepwisely [5, 6, 7]. The scenario is generated by means of projecting the answer space onto x-axis and consists of ordered states which correspond to individual phases of deriving answer. Grasping an approximate learning situation makes it possible that the coordinator generates advices timely and effectively because each state corresponds to the individual ratio of derived step. On our scenario structure, the current learning state is pointed by the indicator *current*, which points out the currently discussing stage. The coordinator infers the current state from student inputs and moves the indicator to the corresponding state. However, the utilization of only one current discussion indicator is not enough to manage the learning state of group sufficiently. In addition to *current*, indicators *upper* and *lower* are prepared for the representation of current understanding levels of learning group. *Upper* points out the state of understanding level which is estimated that best understanding student reached to and *lower* points out the state of worst understanding student did. The coordinator is able to grasp the learning situation on the basis of the relationship among these 3 indicators (Figure 3).

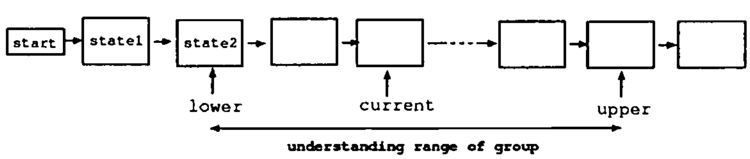

Figure 3: Resolution derivation scenario and indicators

On the other hand, the extent of discussion is estimated by the number of derived answering paths with different discussion viewpoints. The difference of discussion viewpoints among answering paths is defined as the ratio between common and uncommon answering steps. That is, if two answering paths contain large number of answering steps as common part, they are regarded as more similar paths; but if they have many different answering steps, they are judged as different paths. Common answering steps means that the answering methods which are used to derive those steps are the same. Once two answering paths were diverged, the following answering steps may be derived based on different answering methods so that they are regarded to be uncommon. From such viewpoint, the coordinator holds an answer tree which was transformed from whole answering paths as a tree structure. Figure 4 shows the construction of answer tree, derived from the answer space in Figure 2. The answering steps after the divergence are regarded as uncommon steps so that they are copied as different objects(Figure 4a). Then, the answer tree is transformed by means of collecting common answering steps for the purpose of grasping the difference among answering paths. The nodes in the tree are generated as a collection of answering steps that are common to particular answering paths and the path from root node to particular leaf node corresponds to each answering path. When the answer has been derived, the coordinator specifies derived/underived answering paths, calculates the differences between the derived answering path and other answering paths based on the answer tree, and estimates the extent of discussion.

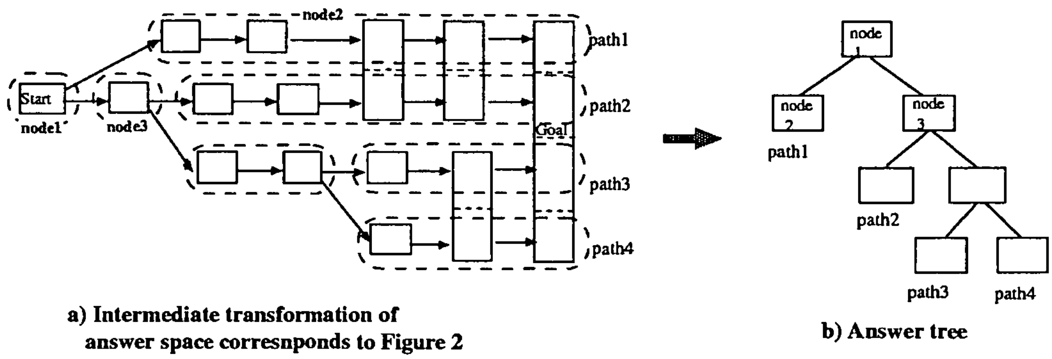

Figure 4: Construction of answer tree

By grasping the learning situation from these aspects, the coordinator is able to handle the changeable learning situation and generate appropriate advices at the right time.

4 Learner

The learner is situated on each student's computer and acts as a pseudo student in the virtual web-based learning environment. The learner provides the interface to the human student and controls the private talking among students such as focus function. Since the learner connects the private talking line according to only corresponding student's request, it behaves independently with the coordinator that manages the public communication.

A personal learning history is the model of corresponding student which is held by the learner. The personal learning history represents the understanding level and the characteristic of corresponding student. Some data of personal learning history are prepared by the human student beforehand and others are gathered by the learner occasionally through the learning. Currently, the picture and utterances of students are collected as a personal learning history. The feature of student does not change through the learning, so the picture is set by each student before the learning starts. Utterances indicate the understanding level of student and also attitude toward the learning; i.e. active or passive, understanding or not-understanding, and so on. They are gathered and added to the personal learning history by the learner when corresponding student send their opinions to the public communication line.

In order to exchange the personal learning history through private talking line, the learner generates mediators for each communication. The mediator is constructed as a mobile agent which processes its tasks while moving through the network autonomously[8]. Figure 5 shows the movement of mediator for acquiring the personal learning history of other students. When the corresponding student requests to get the personal learning history of particular students, the mediators are generated by the learner respectively. Once generated, the mediators move to the target learners through the network and ask for the personal learning history, attended inherently to the target learners. After the acquisition of personal learning history of target learner, the mediators move back to their original learner and disappear autonomously, since their roles are to acquire the personal learning history from target learners. Under such mechanism, students are able to know other students' characteristics even in our virtual web-based learning environment without any direct interaction.

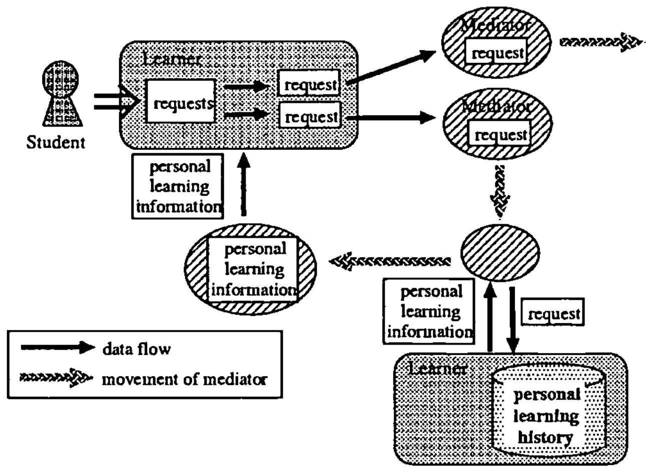

Figure 5: Mechanism for acquiring personal learning information

5 Implementation

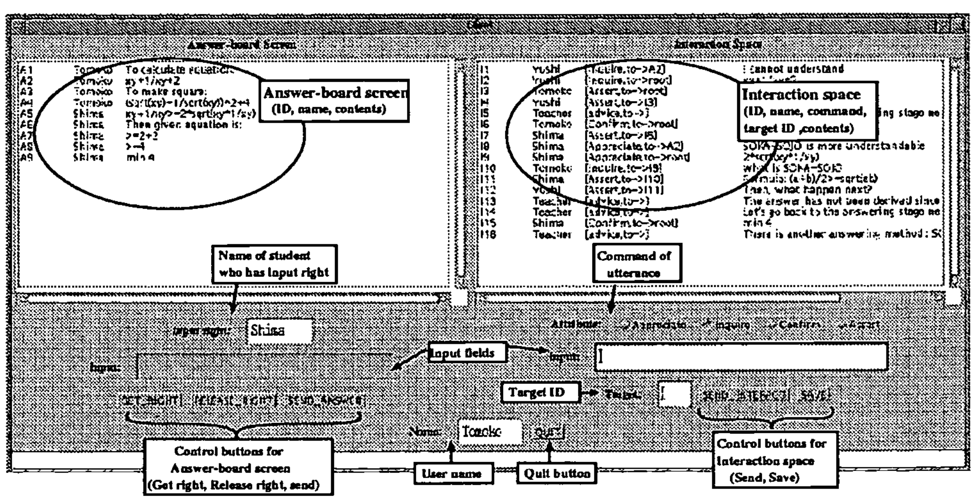

Figure 6: Interaction interface on student operation

We have implemented our prototype system on Internet using UDP protocol, since UDP protocol is suitable to control the frequent interaction of short messages. Figure 6 shows the interaction interface in our system. Two communication tools are prepared: answer-board screen and interaction space. The answer-board screen is a public communication tool which is used to arrange the group's answering process. Only one student is permitted to input on the answer-board screen at a time so that the input right is set. On the answer-board screen, ID, student' name, and contents of input is shown. The answer-board screen functions as a blackboard in our real world. On the other hand, the interaction space is prepared for free conversation so that all students are able to input freely. In order for the coordinator of our system to grasp the learning situation easily, commands that classify the opinions are introduced: Appreciate, Inquire, Confirm, and Assert. Students choose the commands when they input their opinions. In addition to the commands, students specify the target inputs which trigger off their opinions for the purpose of grasping the flow of conversation smoothly. Thus, in addition to the ID, student's name, and contents of input, command and ID of target input are also displayed on interaction space.

As for the coordinator, we prepared several advices which indicate the states of learning situation when the learning is proceeded inappropriately. Currently, the coordinator generates advices when it detects the following learning situation:

- learning situation has not been changed for a long time,
- some students cannot understand currently discussing stage, and
- students have not derived all viewpoints of solving the exercise.

The coordinator's objective is to activate the discussion, so the advices are generated on the interaction space as the same style as all other students' utterances. Figure 7 shows an example of advices generated by the coordinator. As for the advice, the speaker name is set as "Teacher", the command of advice is "advice", and the ID of target input is nothing because the advice is generated for the learning group but not for individual students.

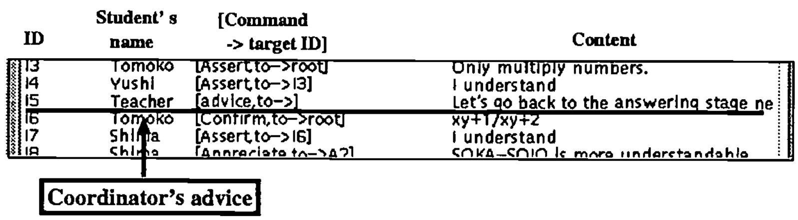

Figure 7: Advice example of coordinator on interaction space

The learners was implemented using AgentSpace[9] as a middle-ware to control the behavior of mediator. Figure 8(a) is an interface for generating requests. On the upper window, the causality of utterances on interaction space is arranged based on corresponding student's utterances. The arrangement of utterances on the upper window helps to decide the focusing students for generating requests. Once a student decides focusing students, he/she inputs IP addresses of focusing students, because mediators need IP addresses where they will work on beforehand in our current version. Then, he/she specifies the file name of focusing student's personal learning history. If a student wants to know only the particular utterances of focusing students, he/she sets the ID's of corresponding utterances shown on the upper window. Figure 8(b) is the result windows of requests for personal learning history. When requests have been completed successfully, the result windows are generated and the personal learning histories of focusing students are shown individually. Currently, the picture of focusing student is shown on the upper window and his/her utterances are shown on the lower window.

6 Conclusion

In this paper, we proposed a collaborative learning environment which contains two different agents: the coordinator and the learner. The coordinator monitors the public communication among learning group and generates advices so as to lead them to their learning goal. For this purpose, the coordinator grasps the learning situation globally from two viewpoints: the ratio of derived step for a whole answering process and the extent of discussion. Although the management structure of learning situation is simple, the coordinator may be able to find the most cases that students are not able to cope with inappropriate learning situation by themselves. On the other hand, the learner controls the private talking such as focus function. The learner holds the personal learning history of corresponding student as his/her characteristics and acquires other students' personal learning histories by generating the mobile agents called mediators. Currently, these agents function independently. However, for our future work, the interactions among coordinator and learners are necessary for the coordinator to generate more effective advices. In addition, the evaluation for the interaction interface of our prototype system and the preparation of more factors for personal learning history based on the result of the evaluation are also our future works.

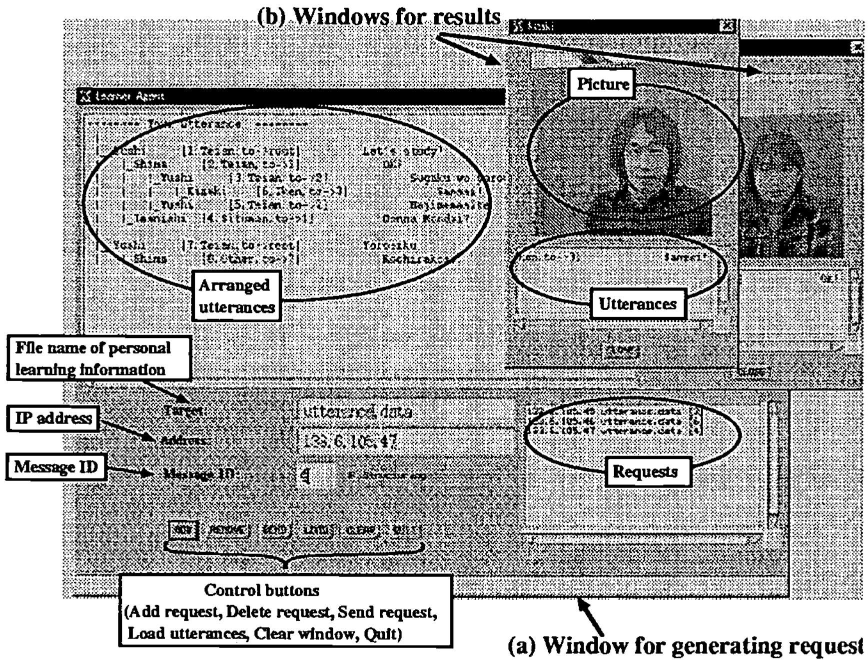

Figure 8: Interface for handling requests

Acknowledgments

The authors are very grateful to Prof.T.Fukumura of Chukyo University, and Prof.Y.Inagaki and Prof.J.Toriwaki of Nagoya University for their perspective remarks, and also wish to thank our research members for their many discussions and cooperations.

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