A Web-Based Dual Mode Virtual Laboratory Supporting Cooperative Learning

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Abstract

This paper suggests the solution to build a Full Virtual Reality Learning Environment, and we have built both virtual and real laboratories on the web, in which students practice their experiments as in a conventional one. In our system, the experiment may be undertaken by a single student or by many students cooperating via networks. We have developed many teaching materials and tools to support experimental operations in a distance-learning environment. Our study suggests a virtual-reality laboratory which is an effective way for experimental operations to be carried out on the web. It is a good experience for us to integrate both virtual reality and cooperative learning for education.

Key Words: Virtual Reality, WWW, Cooperative Learning

1. Introduction

In recent years, the continuing development of information technology has ensured that diversified computer applications are increasingly widespread. Personal computers deal with data including not only text, but also graphics, image, voice, video, and animation, etc. Therefore, its potential as a teaching tool is enormous.

More than 80% of the information received by us comes from our sense of vision [8]. There is also further research supporting the view that vision serves as an important role in the learning process [1].

There have been many distance learning systems developed by researchers who pay careful attention to theories and completely implement their ideas. Most of the systems have not been used for a long time. By analyzing those disused ones, we find that one of the main reasons is that the researchers have only considered learning theories. They have forgotten that a successful distance learning system is based not only on careful design but also on attracting students' interest. A good distance learning system should, by doing this, come to the notice of students and motivate them to use the system enthusiastically. In this study, we build an Internet learning environment based on teaching theories and taking motivation into account to allow students to undertake virtual-reality experiments.

2. Related Work

In our research, there are two principal strategies being adopted. Firstly, our user interface of learning system is based on Virtual Reality technology. The VR technology is regarded as a useful new technology for the development of teaching materials and teaching aids. Secondly, cooperative learning is a learning strategy in distance learning system [7]. Many distance learning systems only allow users learning by themselves, so these learning activities lack interaction and communication. Cooperative learning provides learners with opportunities to express their own opinions and with interaction between group members to exchange what they have learned and thus to learn something new. It is quite different from traditional teaching approaches, in which learners remain passive and can not express their own ideas when it is necessary. The essence of cooperative learning is, therefore, that all group members should make joint effort to achieve the learning goal, and during the process of learning, they should communicate with and help each other.

2.1. Virtual Reality

In order to attract students' attention and motivate them, many researchers have proposed different theories based on students' characteristics, environment, and mentality. Much research has proven that a good way to motivate students is by the use of games [2]. For example, MUD (Multi User Dungeon) is an Internet online game that has been developed over many years and now has many people participating in it. In these Internet games, players interact with living players, instead of the inflexible programs, so they attract many players. The interaction and fascination of similar educational games should motivate users to spend more time learning.

Three-dimensional (3D) representation has been a hot topic in recent years due to improvements in hardware speed, rendering algorithms, animation research etc. Virtual 3D reality is coming closer and closer to realization. Much furniture is now designed by 3D technology. Another hot topic is network multimedia technology which is applied to virtual museums, sample houses and virtual shopping malls. Virtual reality is a popular concept that is brought about by the application of 3D geometry and graphics. The NICE project, which applied virtual reality technology to distance

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learning, was very successful [5]. Applying both virtual reality technology and interactive media in a game format, we built a learning environment in which learners are motivated by immersing themselves in a thoroughly fascinating experience.

2.2. Cooperative Learning

Before commencement of cooperative learning activities, students are divided into heterogeneous groups. And here heterogeneity includes students' learning capabilities, learning achievements, learning motives, behaviors, genders, races, social backgrounds etc. Heterogeneous grouping aims at provision of opportunities for students to know different learning objects, to hear different opinions, to share with each other and to achieve good learning results [3].

In regard to achievements and abilities, Webb [14][15] did a research on learners with different abilities based on different groupings of high, medium and low abilities. Research results show that there are more cases of mutual help in the mixing group and the group of medium ability than in the group of high ability and the group of low ability. Webber again divided the groups in another way. The result is that learners with high ability and learners with low ability benefits more than learners with medium ability. [10]

The success of cooperative learning lies much in the manner of grouping. For this reason, it is advisable to adopt heterogeneous grouping approach. Among the factors to be taken into consideration in this approach, students' achievements are of great importance, which are mainly judged from scores they obtained in the past. Students with different scores, which are not sufficient to reflect their knowledge structures, are actually mixed into one group. So we suspect that there should be a neglect or mistake in this grouping approach for the reason that same scores do not mean same knowledge structures and that heterogeneous grouping based on scores is insufficient to reflect actual diversity among students. This paper therefore proposes a new learning approach, i.e. progressive cooperative learning with the aid of conceptual graph aiming at improvement of learning efficiency and achievement in cooperative learning.

3. Real experimental equipments and virtual experimental equipments

For physics education, classroom lectures are not enough; learners must also experiment in the laboratory. Experimentation is the best way to help learners to study physics [6]. In our virtual physics laboratory, we have developed many experimental materials, such as free falling, thermodynamics, and electricity.

In a conventional laboratory, some experimental materials may be too expensive or too dangerous and the experimental environment may not be capable of adjustment, so learners may find difficulty in designing an experiment or using certain experimental materials. Therefore, learners only obtain their experimental data by calculation and theoretical models. We have now developed a set of experimental materials for solving these problems. Every experiment provides a Reality and Virtual mode, which allows learners to change mode.

3.1. Real experimental equipments

Here, we introduce the "free falling" which is one of our physical experiments. Figure 1 is free falling experimental equipment. On the metal frame, there are two pairs of light sensors, which are connected to a personal computer through a sound card.

Figure 1. Real experimental equipment- free falling

In our system, we have developed experimental equipments, which simulate a physics laboratory and a complete computer-based experimental assistant system. Such an assistant system allows users to collect outside information by sensors or computer interface cards. There are three steps for every real experiment: signal transmitting, recording and analyzing. Figure 2 shows a real experimental procedure.

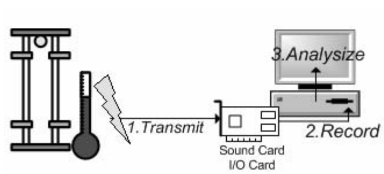

Figure 2. The scheme of real experiment procedure

Firstly, when a learner pushes the program button to start the free falling experiment, the personal computer sends a signal to shut down an electromagnet on the top of a metal frame. Then a magnetized metal ball starts falling. The ball passes through two pairs of light sensors and produces a series of signals. These signals are then transmitted to the sound card.

Secondly, these signals are recorded in the form as a frequency spectrum by the personal computer. Figure 3 is the frequency spectrum of a free falling experiment. Our sampling signals frequency is PCM44100Hz, 16 bits and stereo, so the time unit between two samplings is 1/44100 sec. The data we get from the frequency spectrum is very accurate.

Thirdly, two peaks of the frequency spectrum show the duration time that the metal ball takes to pass through two pairs of light sensors. So, we know s1 is the distance between light sensors and t1 is the value of the duration time. The learner can change the location of one of the light sensors and repeat each step mentioned above; he or she can obtain the value of t2 and s2. According to the gravity formula

$$g=\frac{2(s_2 t_1 - s_1 t_2)}{t_1 t_2 (t_2 - t_1)}$$

, the value of gravity g, is obtained.

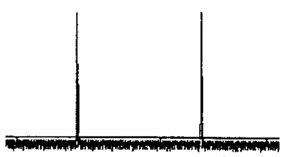

Figure 3. The frequency spectrum of a free falling experiment

3.2. Virtual experimental equipment

In our system, we adopt 3D techniques to improve the quality of the experimental scene and make it more realistic. The OpenGL library is used to handle three-dimensional graphical objects. The OpenGL library cooperates with Superscape VRT, which is a powerful tool for virtual reality by ActiveX techniques.

Learners must use Internet Explorer 3.0 or higher to browse our system to adopt ActiveX components to our system. To improve the interaction of our system, CGI, Java Applet, and JavaScript languages are also adopted to our system. VBScript language plays an important role in the system, which adopts much ActiveX technology. It is useful particularly for communication and connection between the ActiveX components and the Java Applet. Figure 4 shows the virtual experimental equipment used in the virtual free falling experiments that we have developed in accordance with real ones . Learners can operate these virtual experimental equipments by both keyboard and mouse. Our virtual experimental equipments provide a more readily expandable scheme. For example, learners can adjust the position of the sensors and add more sensors on to the metal frame, allowing for more creative thoughts.

Besides, certain experiments, for example, those dealing with radiation, chemicals or viruses are quite hazardous to carry out. Students can operate these virtual-type experimental equipments on the web to protect students from possible dangers and save money.

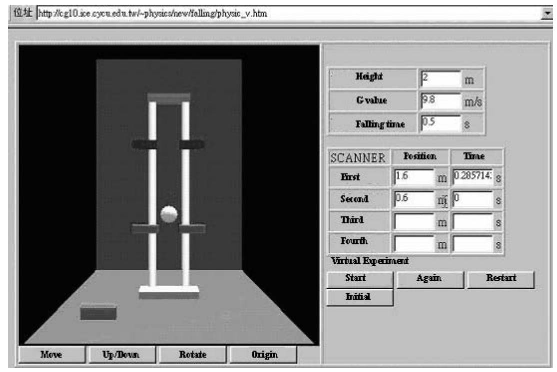

Figure 4. The virtual free falling experimental equipment

3.3. Integrating real and virtual equipments into virtual-reality experiments

Both real and virtual experimental modes play an important role in our system. Every learner can choose one or both of these two modes according to his or her demand. For example, if a learner wants to obtain theoretical data identical to those found in a textbook, he or she can choose the virtual experimental equipments needed. The results produced by those virtual experimental equipments are exactly correct and the procedures are correctly carried out. So the learner should obtain the same results as in the textbook. Besides, since those experimental equipments are virtual, learners can set up as many experimental situations as he wants. For example, if a learner wants to observe the free falling process on the moon, he or she can adjust the value of gravity on the gravity formula. Our system will show the falling process and results on the screen just like on the moon. These virtual experimental equipments overcome the limitations of real experimental equipments in the real world.

Unfortunately, the virtual experimental equipments involve some new problems. First of all, since the experimental results of adopting virtual experimental equipments are calculated by a set of formulas, we will get the same result in the same situation. But in the real world, there are many inaccuracies from resistance, measurement and so on; the exact same result from the same experiment is unusual. Second, virtual experimental equipments are designed by a computer program, so the operation of these materials is finite. You can't do something, which the experimental materials cannot support. For example, learners can not change the material (plastic or metal) of the falling ball.

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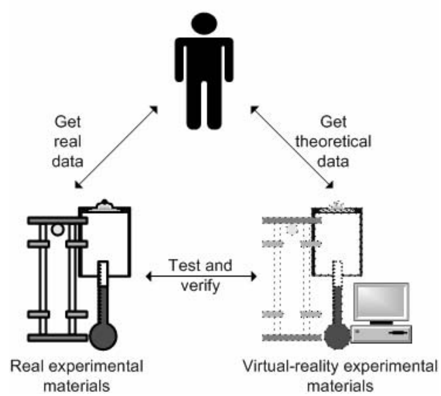

Figure 5. Integrated virtual-reality experimental equipments

We have integrated both virtual and real experimental equipments, and have developed a visual and virtual-reality laboratory called "VRSchool" [12]. The virtual-reality laboratory is shown in figure 5. If learners want to obtain realistic experimental results, they can adopt real experimental equipments, and the results will be shown on the screen via sensors, transmission lines and I/O cards. Learners can test and verify differences between a perfect situation (virtual environment) and a real situation (real environment). Also, they can adopt virtual experimental equipments if they cannot obtain real ones.

4. Grouping Strategy – Dynamic-Grouping

We had proposed a grouping strategy based on conceptual graph, and the strategy guarantees that all team members are heterogeneous within a team. [12][13]. Figure 6 shows the main idea of complementary grouping method. From figure 6, student 1 has successfully learnt concept A, while student 2 has not. When they were put in one group, student 1 can help student 2 to study concept A. This will enable student 2 to learn concept A under supervision. In our proposed strategy, we provide a serial of algorithms to calculate complementary score to group heterogeneous team members. The algorithms group students once in the learning process.

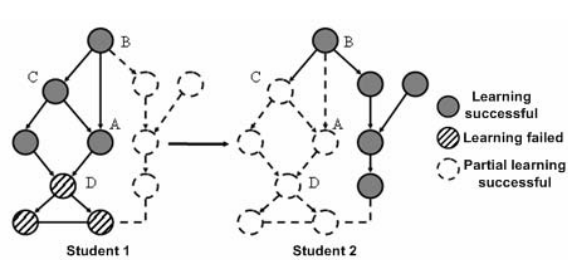

Figure 6. The complementary grouping method

However, students' knowledge structure are changing all the time in the learning process, so we need to monitor each team's learning situation and adjust team members. In this paper, we propose a dynamic grouping strategy which regroups some teams in each stage of the learning activities if necessary. This strategy is different from the previous one. The previous grouping strategy only groups students once, in the beginning, while the dynamic grouping strategy groups students progressively.

The group complementary score [13] represents the degree of heterogeneity. A higher group complementary score represents a higher degree of the complementary grouping method heterogeneity, and a lower group complementary score represents a lower degree of heterogeneity. According to Webb's research outcomes; a higher degree of heterogeneity is good for cooperative learning [14][15].

In our learning activities, we maintain the group complementary score for each team all the time. We will regroup the team whose group complementary score is too low.

Figure 7 represents the learning process we proposed. Before commencement of cooperative learning activities, students were grouped by their initial states. In the cooperative learning activities, team members learn together. Before each stage of finishing learning activities, our system monitors every team's state and picks the teams with worse performance. For improving effective learning, we regroup these teams with worse performance. These new groups continue the learning processes and our system also continues monitoring.

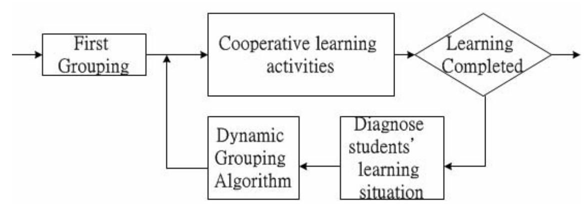

Figure 7. The process of our grouping strategy

To pick the teams with worst performance, we set a threshold value to separate the high complementary score group from the low ones. The higher the threshold value, the more teams will be regrouped. The instructor can adjust the threshold value according to all students' performance.

We regroup teams whose group complementary score is smaller than the threshold value. The regrouping algorithm also picks the same quantity of teams above the threshold value as the below ones. We analyze all these chosen teams and select the combination which has a larger group complementary score. These newly combined teams will learn effectively in the cooperative learning activities.

5. Learning Evaluation

Our main study occurred in November 2002. We selected "Electronic Circuits Laboratory" course from our virtual reality environment- "VRSchool". This course introduces electronic devices and instruments used in circuits, and provide students the opportunities to implement circuit theories. It makes students more familiar with basic theories and virtual circuits. One hundred and nineteen undergraduates participated in our study. The study period is five weeks.

In our evaluation, we adopt three grouping methods and compare their effect. Firstly, the S method is a very familiar method, and we often adopt this method to keep each group equally. The single grouping method only group students once at the beginning [13]. The third grouping method is Dynamic-Grouping we proposed. As the objective of the experiment is to compare the grouping method we proposed with the traditional grouping method, the experiment includes the following stages:

1. Every student has to answer the questions according to prompts from the system, and identify the learning concepts. In this stage, the students can study the teaching materials provided by the system, and must take SPRT test after they finish the learning. When the results of the test come out, the system will propose the advisory learning paths according to the learning results of the student. The student can then freely choose between his own learning flow and the suggestion of the system, until the whole concept learning is finished. And then an assessment is made to serve as the reference for grouping.

2. After the learning is finished, the experiment team will be grouped for the cooperative learning by the optimum grouping method: .In this stage, the students are divided into experimental groups, the A control groups and the B control groups. We pre-test the students and group them at random according to their pre-test results, to balance the ability and quality of the students in experimental groups and control groups. Experimental groups adopt the Dynamic Grouping method we proposed for the cooperative learning grouping. The A control groups adopt the S method according to the pre-test results for the cooperative learning grouping, and the B control groups adopt the single grouping method. There are thirty-nine students in experimental groups, forty in the A control groups and forty in the B control groups. All students are grouped by teams of three. Students can discuss with their team members, but not with other teams.

3. Cooperative learning activities: the system provides the related questions designed by Electronic Circuits Laboratory. The contents of the questions contain all different units, to process the cooperative learning activities through the group exploring methods. We take advantage of the characteristics of the Internet, abundant resources, fast updating, and easy availability, to implement the exploring learning online, and to provide a variety of teaching materials to improve the effect of learning.

4. Evaluation of cooperative learning and answer of the questionnaires: to probe into the learning results of the students and their points of views towards the teaching strategy.

This experiment divides the students into experimental groups and control groups. The relationship between their pre-test results and post-test results is shown in Table 1.

Table 1. Summary table of pre-test and post-test

		Pre-test		Post-test	
Group	Num of students	Average	SD	Average	SD
S method	39	61	16.92	69.16	18.3
Single Grouping	40	61.68	14	72.44	12.19
Dynamic Grouping	40	59.35	15.99	***72.6***	***11.8***

Because experimental groups and control groups are formed randomly after the pre-test with some adjustments at the same time, it can be known from the table that the two groups (the average score of the experimental groups is 59.35, standard derivation is 15.99; the average score of the A control groups is 61, standard derivation is 16.92; the average score of the B control groups is 61.68, standard derivation is 14) have no differences.

In Table 2, we adopt the ANOVA examination method to identify the post-test relationship between experimental groups and control groups (α=0.1). From this table, although we don't obtain significant difference between three groups in the post-test results, the average score of experimental groups (72.6) is higher than that of the A control groups (69.26) and the B control groups (72.44). So, we can say that, after finishing cooperative learning activities, the experimental groups have a little better performance than two control groups.

Table 2. Summary table of ANOVA of post-test

ANOVA

Source of variation	SS	Degree of freedom	Mean square	F
Between Groups	296.28	2	148.14	0.717215
In Group	23959.77	116	206.55	
Sum	24256.04639	118		

$F_{.90(2,116)}=2.35$

Table 3 shows the relationship between the pre-test and post-test results. To compare the scores of improvements of the students, the table shows the relationship between the three groups. The standard derivation (SD) of experimental groups is lower than the A control groups and the B control groups. And the SD of the B groups is also lower than that of the A control groups. From the variation of SD, the single grouping method has better effect than the S method. If we adopt our grouping method repeatedly according to each student's learning situation, we can further improve the effect of the grouping method. Therefore, we can conclude that our Dynamic-Grouping method is an effective cooperative learning grouping strategy.

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Table 3. The comparison between pre-test and post-test

	Pre-test	Post-test
S method(A control groups)	16.92	18.3
Single Grouping(B control groups)	14	12.19
Dynamic Grouping(Experiment groups)	15.99	11.8

6. Discussion and Conclusion

Although the evaluation result of our system doesn't obtain significant difference, the SD of Dynamic-Grouping category is decreased (SD=11.8). According to the analysis of the evaluation data, we can say that our grouping strategy is useful for cooperative learning on the web but there are other factors that influence the outcomes of cooperative learning. From reviewing the process of our evaluation, we find that team members have to spend most time for communicating in the process of cooperative learning. To communicate effectively, friendship and interpersonal relationships between team members must be concerned [4].

In this paper, we propose a method to embed virtual reality technologies into the web to set up a virtual laboratory on the Internet. By applying virtual reality technologies, our system simulates each stage of the experiment and provides effective operative procedures for users to control the experimental process. From the learners' point of view, our system provides a convenient way to study material relating to an experiment. Our system supports the function to allow the same experiment to be observed by multi-users for cooperative learning via network.

In order to extend our system, experimental devices have been amalgamated to improve the effectiveness of teaching. When learners operate real experimental materials, within our system, it measures the output of these devices and provides tools to analyze the measurements. In this case, students not only have real operative experience but also can note experimental outcomes and analyze quickly. Our system has reduced learning time and improved the learning effectiveness of learners on experimental courses. It seems to be an effective means of undertaking experimental operations on the web.

We also propose a Dynamic-Grouping algorithm to improve the effect of cooperative learning in virtual reality environment. The grouping strategy of cooperative learning raised by our research has got positive experimental results, but it is not so satisfactory in terms of group communication. We believe that we can take advantage of the students' relationship to improve interaction between the group members to effectively achieve cooperation between each other.

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