The Effect of the Virtual Laboratory on Students' Achievement and Attitude in Chemistry

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Abstract

In chemistry education laboratory activities increase students' interest in the subject matters covered in the class and help their learning. Due to lack of laboratories at schools or insufficient instruments in laboratories, hands on experiments are rarely performed in state schools in Turkey. However, such experiments can be virtually done as a result of recent developments in Information Technology. In this study, a virtual laboratory related to "Separation of Matter" unit for 9th grade students was prepared and its effects on students' achievements and attitudes were investigated. For this aim 16 virtual experiments prepared by using flash program and used in the experimental group. Result of this study showed that virtual laboratory applications made positive effects on students' achievements and attitudes when compared to traditional teaching methods.

Key Words: Virtual laboratory, Computer Animations, Chemistry, Achievement, Attitude

INTRODUCTION

As accepted throughout the world the idea of using student centred constructivist based instructional methods is widely accepted, since teacher centred, traditional instructional methods has given insufficient opportunities for student to construct their own learning. Eliciting students' individual capabilities, intelligence and creative thinking can only be achieved through student centered instructional methods (Alkan Deryakulu, & Simsek, 1995).

Although constructivism is a learning theory that describes the process of knowledge construction, it is the application of what are often referred to as 'constructivist practices'

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(Zemelman, Daniels, & Hyde, 1993) in the classroom and elsewhere that provides support for the active knowledge-construction process. Since, most of the contents of science lessons are abstract topics, to make students to understand such topics it is necessary to use constructivist based student centered instructional methods.

The concept of ''learning by doing'' (Bruner, 1990) is certainly not new; however, allowing the student to learn by doing within the classroom context is a departure from traditional methods. In this context, laboratories are important components of education to make students to gain experience. Especially when thinking that chemistry is totally an applied branch of science, the importance of laboratory applications in instruction is clearly understood. In the chemistry laboratory students become active in their learning by seeing, observing and doing. Such kinds of application cause not only a better but also a permanent learning (Temel, Oral & Avanoglu, 2000). Many researchers in science education admitted that laboratory studies increase students' interest and abilities for the science subjects (Bryant and Edmunt, 1987; Bekar, 1996; Algan, 1999; Bagci and Simsek, 1999).

Although laboratory application in students' learning has a very important place in science education, in use, it has some limits and problems, especially in developing countries. Some of the main problems faced in Turkey can be summarized as follows;

- In carrying out experiments and arranging with equipment, the laboratory activities are expensive
- For planning and application, it is much time consuming
- Checking students' performance during the activities can be difficult in over-crowded classes.
- Lack of laboratory or equipment, or insufficient lab conditions which limits the teacher to perform a simple lab activity.

As mentioned above, in the real world situation, sometimes due to the limitation of equipment, limited time allocated for the topic or insufficient laboratory conditions, force teachers to perform laboratory activities in crowded groups, or sometimes a demonstrational activity can be performed. This application is opposed to the basic constructivist philosophy at laboratory method which accepts that knowledge can be gained through personal experience and observation (Ozdener, 2005). When taking these limitations into consideration looking for appropriate alternatives is inevitable. Among these alternatives, the use of educational technologies, more specifically use of computer in supporting the laboratory methods can be a logical one (Kiyici and Yumusak, 2005).

Many researchers and educational practitioners believe that Virtual reality (VR) technology has provided new insights to support education. Duffy and Jonassen (1992) claimed that today's educational technology practices should indeed be couched in the constructivist paradigm. This plays out in terms of developing systems that are situated in the real world as much as possible and are as experiential as possible. Sung and Ou (2002) reported that VR's capability to facilitate constructivist-learning activities is one of its key advantages. Therefore, as an experiential learning tool, virtual reality is an enactive knowledge-creation environment.

Interactive learning environment by using animations and simulations for abstract topic, where students become active in their learning, provide opportunities for students to construct and understand difficult concepts more easily (Demirci, 2003). In this content, appropriate simulations and applications based on simulations generally increase learning speed by allowing students to express their real reactions easily (Karamustafaoglu, Aydin and Ozmen, 2005). Better designed simulations provide students opportunities to express their cognitive style and to choose from the computer screen. Such opportunities allow students to develop their own hypothesis about the topic and develop their own problem solving methods (Windschitl ve Andre, 1998). According to Isman et al (2002), complex information given to the students is simplified by technology and provides them opportunities learning by doing.

Therefore, use of VR in labs, in other word, use of virtual laboratory or simulation programs, overcomes some of the problems faced in traditional laboratory applications and make positive contributions in reaching the objectives of an educational system. It is not always possible to see the results of students' studies in a real laboratory application, especially in inadequate laboratory conditions. Use of simulation programs can overcome that mistakes occur as a result of such laboratory conditions or misuse of the laboratory.

Moreover they also overcome the possible dangers that can be seen in the real laboratory conditions (Yenitepe, 2001). For example a dangerous experiment for human health is prepared in computer as simulations, so that students can see the experiments design and perform the experiment in computer and observe the result. Other than performing dangerous, difficult or impossible experiments, simulations have advantages from the time, security, cost and motivation point of view (Rodrigues, 1997; Tekdal, 2002).

In the related literature several studies addresses the use of virtual laboratories in science especially in chemistry education. For example, Josephsen and Kristensen (2006) investigated in their studies which aimed to elucidate undergraduate chemistry students' response to the SimuLab computer-based learning environment, which simulates a 20 hours laboratory assignment. One of aims of their study was to increase the students' experience and knowledge of chemical reactions and the physical and chemical properties of common inorganic compounds. The results revealed that the students liked to work with this simulation program. They tended to enjoy working with it, they found it motivating, and they realised that it created a lot of experience, which they believed could be remembered more easily. Virtual Laboratory concept has been expanded to advanced opportunities for integrated teaching, research and promoting cross-disciplinary research **(**Rauwerda at all., 2006)

Winberg et al (2007) developed a computer-simulated pre-lab, which aimed to prepare students cognitively to real lab activity about acid-base titration. As a result of their study, they concluded that the experimental group of students showed a positive attitude towards learning.

According to Mintz (1993) one of the most promising computer applications in science instruction is the use of simulations for teaching material, which cannot be taught by conventional laboratory experimentation. But can a simulation be as effective as a conventional laboratory or replace it? More than two decades several studies have been performed about whether the computer simulation experiments or traditional laboratory experiments are effective on the students' achievement about science subjects. The answer would be that it depends on the concept or the situation.

For example, Kerr et al (2004) compared achievement among students instructed using hands-on Chemistry labs versus those instructed using virtual Chemistry labs (eLabs). They found out that there were no significant differences in achievement gain scores for the traditional versus the online students. They commented on that the findings obtained from their study demonstrated that students who completed the traditional, hands-on labs performed as well as students who completed the virtual labs. On the other hand, some other studies reported that computer simulation experiments are more effective (See Douglas 1990; Lewis 1993; Greenbowe 1994; Russell et al. 1997, Svec& Anderson, 1995; Redish et al., 1997).

In study was conducted to make a contribution in evaluation of researches in computer based instructional activities as parallel to rapid development in information technology, it is aimed to investigate the effects of virtual laboratory prepared by using computer animations in teaching "Separation of Matter" unit, a part of 9th grade chemistry curriculum on students' achievement and attitudes.

General chemistry knowledge is a core component of scientific literacy. In addition to being a long-established prerequisite for most of the traditional science, engineering, and medical fields, general chemistry knowledge is a foundation for many modern interdisciplinary pursuits such as forensics, environmental studies, and patent law. A basic chemical understanding also can assist everyday citizens with their personal choices as well as their participation in public policy decisions (Evans & Leinhardt, 2008). "Separation of Matter" is one of the important units in the chemistry.

METHODS

In this study a quasi-experimental research design partially taken from Campbell and Stanley's (1963), pre and post-test, experimental-control-group model was used. This study was carried out with 341 high school students (EG= 174, CG= 167) in the fall semester of 2006-2007 education year.

Data Collection Instruments

Two scales, Knowledge Scale (KS) and Chemistry Attitude Scale (CAS), were developed and used to collect data and to measure the differences in the students' knowledge levels and attitudes toward to chemistry before and after the study depending on the methods at instruction used.

Knowledge Scale (KS)

KS was prepared to identify the readiness of the 9^{th} year students to the lesson before the instruction and their achievement level after the instruction. In the development stage, a 25-item draft scale was prepared. The questions were prepared as a two tier type. In other words, the first multiple-choice question was followed by another multiple choice explanation part to eliminate the possibility of guessing the correct answer and to identify whether the students really understand the topic asked in the question. To accept an answer as the correct one, both the answer choice and the explanation part must have been responded correctly.

Draft form of the test was applied to 156 students, and factor loads of them were calculated. As a result, 15 questions were selected as KS. The KR-20 reliability was found 0.86 for KS. In the KS, the minimum point a student would have got was 0 and the maximum was 15. As the point increase so does the achievement.

Chemistry Attitude Scale (CAS)

CAS is developed for measuring the interest and attitudes of students toward chemistry. It has 24 five point likert type items.

Draft form of the test which had 32 items was applied to 186 students, and factor loads of them were calculated. As a result, 24 items were selected as CAS. Cronbach α-reliability coefficient was found 0.92.

Application of the Scales (Methodology)

Before the instruction, the students were divided into two groups; control group (CG) and Experiment group (EG), randomly. First, the Knowledge Scales (KS) and Chemistry Attitude Scale (CAS) were performed as pre-tests to both groups.

In the next step, the unit "Separation of Matter", a part of year 9 chemistry curriculum, was taught to the control group (CG) by using chalk and talk method as commonly known name, the traditional method because, there is neither a science laboratory nor any equipment in the school. To the experimental group (EG) the same unit was taught by a constructivist based instructional approach which was enriched by computer animations at the computer laboratory. For this purpose 16 virtual experiments prepared, by using macromedia flash program (Figure-1). One of the experiments was given in Figure 1 as an example. The experiments were loaded to 20 computers and presented in the computer laboratory in the school as a virtual laboratory. The instruction period for both groups was 8 weeks.

At the end of the both instructional methods used for CG and EG, KS and CAS were applied to both groups as post tests.

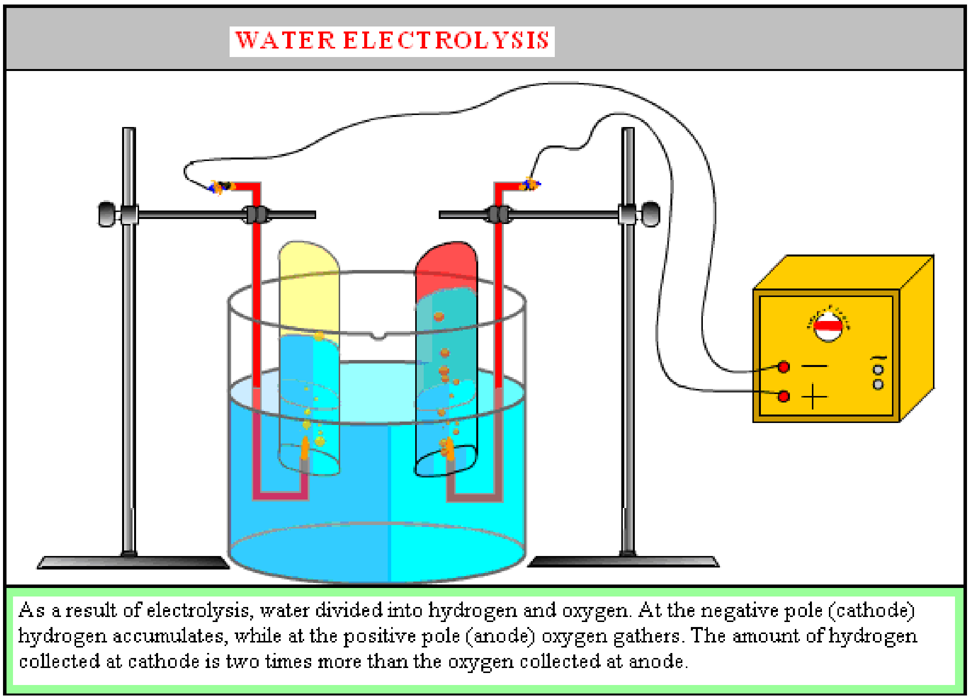

Figure 1. A sample computer animation used in this study.

Data Analysis

The data collected in this study were analyzed by using SPSS/PC version 12.0 statistical program, two different t-tests were performed: Paired Samples t-test was conducted to determine whether there was a significant difference between pre-test and post-test results in each group, in-group analysis, as a result of the instructional methods used in the study. Independent Samples t-test was performed to identify whether knowledge levels and attitudes of all students in CGs and EGs were equal or at least similar before the study, and to find out whether a significant changes arise between groups as a result of the instructional methods used. Significance level was decided by taking p values into consideration $p>0.05$, meant there was not a meaningful difference, $p<0.05$ meant there was a meaningful difference.

FINDINGS

Results of Knowledge Scale (KS)

Knowledge Scale was used as a pre-test for determining the readiness levels of both CG and EG and whether there was a statistically meaningful difference between the readiness scores of CG and EG, and as a post-test to see whether the applied instructional methods made a statistically meaningful difference at the end of the course.

Pre-tests of all CG and EG, and post-tests of all CG and EG were compared separately to see whether methods used in this study affected students' achievement levels. The results of the analysis are presented in Table 1.

Table 1. Pre and post-tests results of KS.

	Group	N	X	SD	T	P
Pre-test	CG	167	1.48	1.14	-0,075	0.941
	EG	174	1.46	1.26		
Post-test	CG	167	5.40	2.02	12,666	0.001*
	EG	174	10.67	2.73		

As it is understood from the table that there was no significant difference between students' pre-test results (p=0.941). In other words, both control and experimental groups were selected from students with similar knowledge level before the study. On the other hand, as it is seen from the table that post-test results was significantly different depending on the instructional methods used (p=0.01).

The mean value of students who received the topic by traditional method in CG raised from 1.48 before the study to 5.40 after the study. However, the same value increased in EG from 1.46 to 10.62. These results implicate that students who were taught the topic through the virtual laboratory used in this study in EG were more successful than those students who received the topics through traditional chalk and talk method in CG.

Results of Chemistry Attitude Scale (CAS)

Chemistry Attitude Scale (CAS) was applied as a pre-test for determining the attitude levels of all students participated in this study toward chemistry, and as a post-test to identify whether the applied instructional methods made a statistically significant difference at the end of the course.

Pre-tests of all CG and EG, and post-tests of all CG and EG were compared separately to see whether instructional methods used in this study were affected students' attitudes toward to chemistry. The results of the analysis are presented in Table 2

Table 2. Pre and post tests results of CAS.

Group		N	X	SD	δ	t	P
Pre-test	CG	167	75,24	6,97	0,85	1,128	0,632
	EG	174	74,02	7,13	0,83		
Post-test	CG	167	75,65	4,16	0,51	-28,484	0,001*
	EG	174	103,63	7,43	0,86		

Table 2 shows that pre-test CAS scores of CG and EG are not significantly different from each other (p=0,632, p>0,05), on the other hand, the post-test scores are statistically significantly different ($p=0,01$, $p<0,05$). That means that depending upon the instructional methods used in this study attitudes of students towards chemistry have changed.

Before the study, pre-test CAS mean scores of both groups were similar as seen in Table 2, however, when we compare the post-test CAS mean scores it is seen that EG's mean scores are higher than those of CG's (EG= 103,64, CG=75,65). These results implicate that teaching the chemistry topics in virtual laboratory by using virtual experiments affected students' attitudes towards chemistry positively.

DISCUSSION

In this study, which was conducted to make a contribution in evaluation of researches in computer based instructional activities as parallel to rapid development in information technology, the effect of virtual laboratory prepared by developing interactive computer animations in Macromedia Flash programs about the topic of "Separation of Matter", which is a part of year 9 chemistry curriculum, on students' achievement levels and attitudes toward chemistry were investigated.

It was identified as a result of this study that the use of virtual lab increased students' achievement levels and made a positive impact on students' attitudes towards chemistry.

Our results are supported by many researches in the field, for example, in their studies, Russell et al. (1997) and Sanger and Greenbowe (1997) noted as a result of their studies that the proportion of correct statements increased and the proportion of misconceptions decreased after instruction using animations. It was reported in the related literature that computers with additional effect of animation, simulation and sound made positive contributions in increasing the quality of instruction (Walker & Hess, 1984; Heermann, 1988). Tsovaltzi et al. (2010) found that Virtual Laboratory promotes chemistry learning,

Kennepohl (2001) examined the benefits of computer simulations in a first-year general chemistry course. He found that the combination of simulations and laboratory offers advantages in time so that the laboratory portion can be reduced in length and students using the simulations have a slightly better knowledge of the practical aspects directly related to laboratory work.

It was also known that use of computer animations is effective in increasing students' motivations and their will to participate laboratory activities (Collette & Chiappetta, 1989). Similarly Sahin and Yildirim (1999) reported that computers are used in learning environment as a supporter tool for teacher by making instructional process powerful and increasing students' motivation, providing opportunities to students for self-learning and arranging their time needed depending upon their learning speed. Moreover, higher order interactive computer programs with various interesting units are increased students' motivation (Ustun and Ubuz, 2004). Similar results were declared by Josephsen and Kristensen (2006). They prepared a virtual lab called SimuLab and investigated the students' reactions and learning gain from the work with the program. Results clearly indicated that the students acknowledged the learning potential of the simulation program, and their improved learning of the performed task supported it.

CONCLUSIONS

Use of computer in science instruction is suitable, especially when the content of science is taken into consideration. Among the reasons of this suitability, allowing instructors to use lesson software enriched with visual presentations to make difficult and abstract scientific concepts and principles concrete and understandable by following appropriate instructional approaches. Rodrigues (1997) reported that there are many researches carried out on investigation of the use of simulations in science education. On increasing students' interest to the topic taught during the lesson, it was reported in the related literature that computer software are more effective than other methods used fort he same purpose (Geban, Askar, Ozkan, 1992; Hounshell, Hill, 1989). Similarly the use of computer animations is reported to increase students' interest towards lessons (Andoloro et all, 1997; Rodrigues, 1997).

Results of this study implicates that simulations prepared and used throughout the study had an instructional characteristics with positive contribution to education and improved students' motivation towards lesson. It was experienced throughout the study period that the developed material is pleasant, entertaining and makes topics understandable for students, and it is also foreseen that this method will be effective when used in other suitable topics. The positive ideas given by students to the material used in this study, can be originated from live colors of the material, colorful screen shows and animations drawing students' attentions and having a user friendly and inter-active nature of the software.

Results of this study also supported several research results reported in the related literature in which it was claimed that virtual laboratories enriched with simulations has many advantages on increasing students' achievement (Joseph et all, 1999; Ozdener and Erdogan, 2001). Thus, it can be reached a conclusion that the material developed and used in this study increased the students' achievement level and motivation by creating an entertaining learning environment.

Although the results of this study supported that the use of virtual lab increased students' achievement levels and made a positive impact on students' attitudes towards chemistry. We do not claim that simulation based laboratories are more effective than the real lab activities. Instead, we claim that when we are forced not to perform real lab activities, due to reasons such as danger of chemical reactions, time concerns, lack of laboratory or equipment, or insufficient lab conditions which limit us to perform a simple lab activity, a virtual chemistry lab can be an alternative.

Therefore, instructional materials develop by using computers can be a solution for schools which has no science laboratory but has a computer cluster or laboratory (Sake and Yilmaz, 2005). It is obvious that instead of making demonstrational experiment in schools where there is lack of laboratory or equipment or where there are over-crowded classes, simulations can be an alternative. Another advantage of using virtual laboratory is that the cost for preparing a science laboratory which is just used for science lessons is higher than for needed to prepare a computer laboratory which can be used for many different lessons.

However, active will of students to participate learning activities plays an important role to lead the learning being effective. Although a visual instruction developed by computerized technology would make a positive contribution to students' achievement in most of the scientific topics and concepts, it is also better to kept in mind that using simulations alone does not solve any problem. To gain a better result from the education, simulations must be supported with appropriate instructional methods and software related to the topics and concepts to be taught in the class. Moreover, a detailed lesson plan in which where simulations will be used, when and what students will do, the parameters related to the topics and concepts that students can change in the system must be defined. It is believed that only after these preparations, an ever-lasting learning can be achieved with simulations based activities in science education (Sahin, 2006).

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