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Effect of a Virtual Chemistry Laboratory on Students' Achievement

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ABSTRACT

It is well known that laboratory applications are of significant importance in chemistry education. However, laboratory applications have generally been neglected in recent educational environments for a variety of reasons. In order to address this gap, this study examined the effect of a virtual chemistry laboratory (VCL) on student achievement among 90 students from three different ninth-grade classrooms (an experimental group and two control groups). Study data were gathered with pre and post chemical-changes unit achievement (CCUA) Test, laboratory equipment test (LET), and unstructured observations. The collected data were analyzed using SPSS (version 16.0). Comparisons were made within and between groups. It was concluded that the developed virtual chemistry laboratory software is at least as effective as the real laboratory, both in terms of student achievement in the unit and students' ability to recognize laboratory equipment.

Keywords

Virtual laboratory, Chemistry laboratory, Students' achievement, Learning environment

Introduction

Chemistry is perceived by students as a challenging subject, since it is difficult to construct the abstract concepts frequently encountered in the subject area (Ayas & Demirbas, 1997; Nakleh, 1992). Although Turkish students study chemistry as a minor part of the primary-school science course, it is first encountered as a separate course during the ninth grade. More than 70% of these students took the course for the first and last time (Ministry of National Education 2007). Therefore, achievement in the chemistry course during this period profoundly influences students' branch preferences in their subsequent education.

Previous studies of ninth- grade chemistry topics found that students can understand the course unit on physical and chemical changes (Ayas & Demirbas, 1997), but have difficulty understanding events at the micro level and explaining chemical changes in relation to chemical bonds (Mirzalar Kabapinar & Adik, 2005). In addition, the literature shows that students have difficulty in constructing the topic of the chemical-changes unit in their minds; and that teachers do not support students adequately during this construction process (Palmer & Treagust, 1996; Ayas & Demirbas, 1997; Ayas, Karamustafaoglu, Sevim & Karamustafaoglu, 2002; Kabapinar & Adik, 2005; Ozmen, 2005; Atasoy, Genc, Kadayifci, & Akkus, 2007). The reason for this weakness is frequently attributed to the lack of laboratory practice (Yang & Heh, 2007). The reason for this weakness is frequently attributed to the lack of laboratory practice (Yang & Heh, 2007). Although laboratory work is an indispensable element of understanding chemistry courses, previous studies have reported that it cannot be properly embedded into traditional chemistry courses for various reasons, such as safety concerns, a lack of self-confidence, and an excessive amount of time and effort required to conduct accurate experiments (Elton, 1983; Bryant & Edmunt, 1987; Hofstein & Lunetta, 2004; Durmus & Bayraktar, 2010). Nonetheless, it is not impossible to overcome these obstacles via technology-based alternatives (Okon, Kaliszan, Lawenda, Stoklosa, Rajtar, Meyer, & Stroinski, 2006).

An alternative learning environment, called a virtual laboratory, can help to make this crucial educational application available to students (Kumar Pakala, Ragade, & Wong, 1998; Shin, Yoon, Park & Lee, 2000; Grob, 2002; SAVVIS, 2010; Jeschke, Richter, & Zorn, 2010). Virtual laboratories simulate a real laboratory environment and processes, and are defined as learning environments in which students convert their theoretical knowledge into practical knowledge by conducting experiments (Woodfield, 2005). Virtual laboratories provide students with meaningful virtual experiences and present important concepts, principles, and processes. By means of virtual laboratories, students have the opportunity of repeating any incorrect experiment or to deepen the intended experiences. Moreover, the interactive nature of such teaching methods offers a clear and enjoyable learning environment (Ardac & Akaygun, 2004 Jeschke, Richter, & Zorn, 2010). Table 1 shows a comparison of the reasons why chemistry teachers do not include laboratory applications in their teaching and the solutions offered by virtual laboratories.

Table 1. Problems encountered in chemistry courses and solutions offered by virtual laboratories

Reason for teachers' lack of use of the lab	Alternatives offered by virtual laboratories
Safety concerns	Experiments that involve risks in the real environment due to poisonous or unsavory gas releases can be safely performed in virtual laboratory environment / uncontrolled explosions (e.g., NI_3) have no real-world consequences, etc.
Lack of self-confidence	Virtual laboratories help students and teachers with little or no laboratory experience in terms of selecting laboratory equipment, setting up experimental apparatus, and completing the procedure. With the exception of starting the computer or accessing the website hosting the virtual environment software, virtual environments require no prior preparation of laboratory equipment, etc.
Lack of equipment	As virtual laboratory equipment is not at risk of being broken or lost, users can use virtual laboratories freely. Experiments that cannot be conducted in a real laboratory due to shortages of equipment and materials can be repeated in a virtual lab without any loss.
Time shortage	Time loss is reduced in virtual laboratories compared to time lost in real laboratories. The experimental procedure in virtual laboratories is similar to that of real laboratories. Understanding and following the experiments is easier in virtual media. After the experiment, it is not necessary to devote time to tidying the virtual laboratory. Students who become accustomed to the virtual laboratory environment can easily repeat the same experiments in the real laboratory environment.
Weaknesses of confirmation method	The interactive format of the virtual laboratory environment presents the problem case by arousing students' curiosity. They are made to put forward and test hypotheses, and are also given the opportunity to make generalizations. Since the subsequent experimental steps in the virtual laboratory are pre-planned, based on algorithms, there is no risk of the experiment producing improper results or no results at all. The students are able to research freely within a largely determined framework (Dalgarno, Bishop, Adlong, & Bedgood, 2009; Yu, Brown, & Billet, 2005).

As seen in Table 1, a virtual laboratory may sometimes be a preferable alternative, or simply a supportive learning environment, to real laboratories. A virtual laboratory provides students with opportunities such as enriching their learning experiences; conducting experiments as if they were in real laboratories; and improving their experiment-related skills such as manipulating materials and equipment, collecting data, completing experiment process in an interactive way (with boundless supplies), and preparing experiment reports (Subramanian & Marsic, 2001).

Researchers have determined that instructions carried out with virtual laboratories significantly increase student achievement levels. Virtual environments let students observe the process in more detail, compared to board and chalk activities of the traditional classroom or partially completed experiments of the real laboratory environment. In addition, virtual environments foster attention and motivation towards the course by supporting a discussion platform among partners, peers, and among students and teacher (Hounshell & Hill, 1989; Geban, Askar, & Ozkan, 1992; Kubala, 1998). Furthermore, some researchers even argue that performing experiments within a virtual environment is more effective than performing experiments in real laboratories (McCoy, 1991; Geban et al., 1992; Svec & Anderson, 1995; Kozma, Chin, Russell, & Marx, 2000; Browne, 2002).

Context of study

According to the literature, the laboratory approach is regarded as an indispensable element of chemistry education, and students subjected to constructivist learning theory-based laboratory instruction exhibit higher achievement scores, deeper attention, and more frequent participation in chemistry course (Duffy & Jonassen, 1991; Aydogdu, 2003; Puacharearn, 2004; Karagiorgi & Symeou, 2005; Celikler, Gunes, & Sendil, 2006; Atasoy, Genc, Kadayifci, & Akkus 2007 Koseoglu & Tumay, 2010) However, it is obvious that learning environments adopting and applying constructivist learning theory should be supported with activities facilitating cooperation and interaction (Ayas & Demirbas, 1997; Baki, 2008), which require more time.

Predict-Observe-Explain (POE) is known to have a positive effect on student learning, and is a recommended strategy to enrich constructivist learning environments (Liew & Treagust, 1998).

However, studies showed that, in traditional learning environments, there are always inconsistencies between student predictions and observations (Champagne, Klopfer, & Anderson, 1980; White & Gunstone, 1992; Liew & Treagust, 1998; Kearney & Treagust, 2001. Such environments also make students reserved and cause them to refrain from expressing their opinions directly (Sheppard, 2006). In contrast, virtual learning environments enable learners to repeat the events several times without hesitation, to zoom in and out, and to watch in slow motion being questioned in any way (Kearney & Treagust, 2001.

The present study evaluated how student achievement levels are affected by the use of virtual chemistry laboratory (VCL) software. The software does the following:

- Models the positive influences on student achievement mentioned above.
- Eliminates adverse effects of virtual laboratories.
- Increases student participation.
- Visualizes macro, micro, and symbolical level presentations of the experiment.
- Provides a strategy that follows the procedural steps of the POE strategy.

Purpose

The principal aim of this study is to determine the effect of a virtual chemistry laboratory on student achievement in course units entitled "chemical changes" and "recognizing laboratory materials and equipment." The course units form part of the ninth-grade chemistry curriculum, and the virtual learning environment approach is based on constructivist learning theory, following the steps of POE strategy.

Material and method

The following steps were used to develop the virtual chemistry laboratory. First, topics and units in which students experience difficulties were determined by interviews with chemistry teachers (n = 20) instructing ninth-graders. These data were supported by the literature and led to the selection of the chemical changes unit, which constitutes 20% of the ninth-grade chemistry curriculum (Ministry of National Education, 2007).

We then conducted a pilot study in which the experiments within the chemical changes unit were performed by student teachers in the General Chemistry I course at the Karadeniz Technical University. The experimental processes were recorded, and the records were used to evaluate the reality of the experiments, which would be transferred to the virtual environment, and to determine what difficulties the student teachers encountered. We reviewed the virtual laboratory applications in the literature.

We prepared the content of the virtual chemistry laboratory software. Before the preparation, previous virtual laboratory applications and positive and constructive comments directed to these applications were reviewed. Following this review, it was determined that previous virtual laboratory applications used in the chemical changes unit contained only one or two dimensions. That is, some of the previous applications focused on visual dimensions but no instructional model was applied during development, whereas other applications prioritized molecular level representations but neglected student interaction. Still some others presented a very large laboratory environment but users were found to lose time, get tired, and, if they eventually managed to use these environments, took longer to arrive at solutions (Tatli, 2011).

We considered these findings during the development of the VCL used in the current study. We developed the virtual learning environment in the following stages:

- Determined the computer programs and applications to be used in the software (3D Max, Adobe Photoshop, Macromedia Flash 8, Adobe Audition, and CrazyTalk)
- Developed software content
- Modeled the laboratory interface, material and supply cupboards, experimental materials and equipment and avatars necessary for the virtual chemistry laboratory
- Created and recorded scripts for avatars and the software's scientific content
- Developed the virtual chemistry laboratory

- Collected expert opinions about the virtual laboratory
- Finalized the virtual chemistry laboratory before the pilot application
- Chose the school for the pilot application and provided administrative permissions
- Piloted the virtual chemistry laboratory

The pilot scheme let us see the shortcomings of our virtual chemistry laboratory that we piloted. By taking into consideration the results we got from the surveys we improved and finalized the virtual chemistry laboratory before the main application. Some screenshots of the software at that stage are given in Figure 1.

Figure 1. Screenshots from the virtual chemistry laboratory software

The piloted VCL software is more advanced than that of previous studies in terms of the following:
- Introducing experimental rules, laboratory equipment and materials to the user
- Providing the user with a learning environment based on constructivist learning theory and POE strategy
- User independency across a wide range of applications and parameters
- The recording of pre-information about the user for comparison with final results
- Presenting macro, micro and symbolical dimensions of the experiment simultaneously
- Providing the user with information about the relationship between the experiment and real life
- Presenting experiments in video format and directing some inquiries to the user, simultaneously presenting synchronized sound, music, visual and information (virtual TV component)

Sample

The sample group of this study consisted of one experienced chemistry teacher and 90 students from one high school. Table 2 presents the total duration saved for the chemical changes unit and the classroom/laboratory.

Table 2. Laboratory/classroom of the control and experimental group students during instruction of the chemical changes unit

Group name	Preferred experiment environment	Class	Laboratory	Total
EG	VCL	4	5	11
CG-I	Real laboratory	9	2	11
CG-II	Real laboratory	8	3	11

To check the quality and functions of the developed materials, in-depth interviews were carried out with the participating teacher. Participating students were randomly assigned to one of three groups: experimental group (EG, n = 30), control-I group (CG-I, n = 30) and control-II group (CG-II, n = 30). The experimental group performed all the experiments in chemical changes unit using the virtual chemistry laboratory (VCL). The CG-I and CG-II groups were not manipulated, and the teacher taught the unit using their own conventional methods. Only the teacher of the CG-II was encouraged to do all the experiments of the unit in the real laboratory (when it was possible). However, the teacher was not given any additional suggestions and was only informed that one of the researchers would passively observe the session.

Data collection instruments

The data collection tools of the study were: the Chemical Changes Unit Achievement Test (CCUA), the laboratory equipment test (LET), semi-structured interviews, and unstructured observations.

Chemical changes unit achievement test (CCUA)

A validity–reliability study of the CCUA was done by Tatli (2011) to cover all the learning outcomes of the chemical changes unit. In the pilot study, the CCUA test, which initially had 30 items, was applied to 90 ninth-grade students who were formerly instructed in the chemical changes unit. As a result of item analysis, five items with a discrimination index lower than 0.30 were excluded. The item analysis showed that the discrimination index of each item in the test was 0.30 or greater, Spearman Brown reliability coefficient was 0.85, average item difficulty was 0.61, and Pearson product-moment correlation coefficient was 0.74. The pilot study showed that 30 minutes would be sufficient to apply the remaining 25 items.

Laboratory equipment test (LET)

A validity–reliability study of the LET was done by Tatli (2011). The items in the LET, devised by the researchers, were prepared in order to cover all laboratory materials and equipment used in primary school science and ninth-grade chemistry courses. The test was reduced to 28 items in accordance with the opinions of five academics from departments of instructional natural science and chemistry. In addition to these 28 items, a module was added, asking students to enter the names of laboratory materials and equipment into blank spaces beneath color pictures of the related material and equipment. It was decided that 15 minutes would be sufficient to complete the finalized form of the LET.

Procedure

The implementation took six weeks during the spring semester of the 2009–2010 academic year and was conducted at an Anatolian secondary school located in the city center of Trabzon. The control and experimental groups were chosen randomly. However, since within-group manipulation was impossible (i.e., students were registered to related classrooms), the study used a quasi-experimental method. Compared to an experimental method, the quasi-experimental method is used when it is impossible to choose a completely random sample. The data were collected using the CCUA and LET at the beginning and at the end of the study period as pre-test and post-test measures of student achievement. The implementation process and measurement tools applied are summarized in Table 3.

Table 3. Implementation process of the study and measurement tools applied during the process

Group name	Data collection tools		Process	Data collection tools	
	CCUA	LET		CCUA	LET
EG	X	X	*	X	X
CG-I	X	X	**	X	X
CG-II	X	X	***	X	X

* The teacher giving instruction to perform all the experiments of the chemical changes unit within the VCL environment. The experiences during the experiments were observed passively and recorded by one of the researchers, using the unstructured observation form.
** The teacher instructed with no manipulation. (The teacher used the real chemistry laboratory for experiments with his/her usual frequency). The teacher's consent was requested only for observing the lesson. The experiences during the experiments were observed passively and recorded by one of the researchers on the unstructured observation form.
*** The teacher instructed in the real laboratory environment. The experiences during the experiments were observed passively and recorded by one of the researchers on the unstructured observation form.

Data analysis

The SPSS 16.0 statistical analysis program was used to analyze the data. In order to test whether CCUA and LET pre- and post-test scores of CG-I, CG-II, and EG groups were statistically different within group-paired samples *t*-test, to compare groups one-way ANOVA were carried out (Johnson & Christensen, 2004). Additionally, observation data and interviews were used to support the quantitative data.

Results

Student achievement at chemical-changes unit

Table 3 shows paired samples *t*-test results, used to check whether there was a significant relationship between pre- and post-CCUA scores of the control and experimental groups.

Table 3. Paired samples *t*-test results comparing pre- and post-CCUA scores of CG-I, CG-II and EG students

Group	CCUA	*N*	$\overline{X}$	*S*	*SD*	*t*	*p*
CG-I	Pre-test	30	42.666	12.015	29	2.895	0.007*
	Post-test	30	50.833	12.668			
CG-II	Pre-test	30	39.666	13.578	29	2.895	0.007*
	Post-test	30	55.333	11.121			
EG	Pre-test	30	39.66	13.578	29	6.388	0.000*
	Post-test	30	59.33	11.121			

The results show that there were significant differences between the pre- and post-test scores of each group, favoring the post-test (CG-I [$t_{(29)} = -2.895$, $p < .05$], CG-II [$t_{(29)} = -6{,}210$, $p < .05$], EG [$t_{(29)} = -6.388$, $p < .05$]). When overall pre- and post-CCUA results of the participant students were examined in more detail, it was observed that the average score of the CG-1 students increased from 39.66 to 55.33 and CG-II from 42.66 to 50.83, while the average score of EG students increased from 39.66 to 59.33. Student achievement at the end of the chemical-changes unit showed that the greatest increase was achieved in the EG group. This implies that the VCL software supported instruction at least as effectively as the real chemistry laboratory.

Table 4 presents the results of the one-way ANOVA, comparing CCUA pre- and post-test scores of the control and experimental group students.

Table 4. One-way ANOVA results comparing pre- and post-CCUA scores of CG-I, CG-II, and EG students

CCUA		Sum of squares	*SD*	Mean square	*F*	*p*	Sig. difference	Effect size
Pre-test	Between groups	180.000	2	90.000	0.659	0.520*	–	0.014
	Within groups	11880.000	87	136.552				
	Total	12060.000	89					
Post-test	Between groups	1085.000	2	542.500	4.500	0.014*	EG-CG-I	0.093
	Within groups	10487.500	87	120.546				
	Total	11572.500	89					

According to the results presented in Table 4, there was no significant difference between the groups at the beginning of the study [$F_{(2–87)}$ = .659, $p > .05$]. However, the post-test results showed a significant between-group difference [$F_{(2–87)}$ = 4,500, $p < .05$]. Scheffe's test was used to determine which groups caused the difference, indicating that the difference was between EG (= 59.33) and CG-I (= 50. 83), favoring EG. There were no other significant differences between the groups. This finding suggests that the VCL software was at least as effective as the real chemistry lab when assessed in terms of student achievement in the chemical-changes unit.

Student success in recognizing laboratory equipment

A paired samples *t*-test was used to check whether there was a significant relationship between pre- and post-LET scores of the control and experimental student groups (See Table 5).

Table 5. Paired samples *t*-test results comparing pre- and post-LET scores of CG-I, CG-II, and EG students

Group	LET	*N*	$\overline{X}$	*S*	*SD*	*t*	*p*
CG-I	Pre-test	30	24.80	9.65	29	−1.29	.20
	Post-test	30	22.19	7.58			
CG-II	Pre-test	30	28.53	7.66	29	2.71	.01*
	Post-test	30	35.43	12.54			
EG	Pre-test	30	29.45	9.839	29	13.21	0.00*
	Post-test	30	67.41	13.063		p	

The post-LET test scores of the CG-I students were lower than the pre-test scores, but this difference was not significant (Table 5) [$t_{(29)}$ = 1.299, $p > .05$]. However, the pre- and post-test scores of CG-II and EG were significantly different, favoring the post-tests.

In this context, it can be said that the activities conducted by the CG-1 group had no effect on students' recognition of the laboratory equipment , while the activities performed by CG-II and EG students positively affected students' ability to recognize laboratory equipment.

The results of the one-way ANOVA, comparing LET pre and post-test scores of the control and experimental group students are presented in Table 6.

Table 6. One-Way ANOVA results comparing pre- and post-LET scores of CG-I, CG-II and EG students

LET		Sum of squares	*SD*	Mean square	*F*	*p*	Sig. difference	Effect size
Pre-test	Between groups	363.20	2	181.60	2.19	0.11		0.047
	Within groups	7213.76	87	82.91			–	
	Total	7576.97	89					
Post-test	Between groups	33799.523	2	16899.762	135.56	.000*	EG/CG-I	0.757
	Within groups	10845.908	87	124.666			EG/CG-II	
	Total	44645.431	89				CG-II/CG-I	

*: significant at 0.05

As seen in Table 6, there was no significant difference between the groups at the beginning of the study [$F_{(2\text{-}87)}$ = 2.19, $p > .05$]. However, at the end of the study, there were significant differences between the groups [$F_{(2\text{-}87)}$ = 135.56, $p < .05$]. The Scheffe's test indicated that there were significant differences between EG and CG-I; EG, and CG-II; CG-II and CG-I.

Discussion and conclusions

In previous studies investigating the effects of virtual laboratories on student achievement, virtual laboratory applications induce an expectation of higher student achievement (Yaman, Nerdel, & Bayrhuber, 2008). However, when the previous studies were reviewed, there was no stable relationship between student achievement and the use of virtual laboratories. Some previous studies reported that virtual laboratories positively influenced student achievement (Geban et al., 1992; Burke, Greenbowe, & Windschitl, 1998; Clark, 1998; Monaghan & Clement, 1999; Akpan & Andre, 2000; Jimoyiannis & Komis, 2000; Kennepohl, 2001; Dori & Barak, 2001; Huppert, Lomask & Lazarowitz, 2002; Blaylock & Newman, 2005; Yu et al., 2005; Hughes McLeod, Brown, Maeda & Choi, 2007; Bozkurt, 2008; Limniou, Papadopoulos, Giannakoudakis, Roberts, & Otto, 2007; Chen, 2010), while others reported no significant differences in learning outcomes between traditional environment and virtual environment (Bernard, Abrami, Lou, Borokhovski, Wade & Wozney, 2004; Cavanaugh, Gillan, Kromrey, Hess, & Blomeyer, 2004). Some other studies (Gorghiu, Gorghiu, Alexandrescu, & Borcea, 2009) reported that traditional laboratories were more effective, despite the fact that virtual laboratories provided a variety of benefits.

The results of the present study suggest that virtual laboratories are at least as effective as real laboratories in terms of acquainting students with experiment process (Yu et al., 2005; Dalgarno, Bishop, Adlong, & Bedgood, 2009), providing students with a safe experimental environment (Mercer-Chalmers, Goodfellow, & Price, 2004), allowing students to conduct experiments individually (Bozkurt, 2008), providing users with more options in shorter time with interaction (Regan & Sheppard, 2006; Ozdener & Erdogan, 2001), and simultaneously presenting micro, macro, and symbolic presentation levels to the user (Carlsen & Andre, 1992).

The research team proposes that this result is due to the greater number of experiments that were conducted by the experimental group students compared to the control group students. In addition, some advantages of the virtual laboratory listed below positively affect students' achievements in the experimental group. These advantages are as follows: the students in the EG focused on the process instead of the materials and equipment; the macro, micro, and symbolic dimensions of the experiments could be investigated in detail with virtual media; students could reach the solution by trying the different choices presented; the software was prepared along with the steps of POE; the software provided students with the opportunity to transfer domain specific knowledge into everyday life.

This conclusion is also supported by the theory that, by maximizing interactivity, virtual laboratory applications render students active thinkers instead of passive observers and thereby construct effective and meaningful learning processes (Trindade, Fiolhai, & Almedia, 2002). It was expected that the adoption of POE to the system increased student-student and student-teacher interactions, reasoning frequency and attentive participation of the students, and made the learning more persistent (Margel, Eylon, & Scherz, 2004; Thomas, Ashton, Austin, Beevers, Edwards, & Milligan, 2004; Karaer, 2007; Tekin, 2008; Chairam, Somsook, & Coll, 2009). The high frequency of abstract concepts that are presented in chemistry (Nakhleh, 1992; Ayas & Demirbas, 1997) is one of the most important factors adversely affecting student achievement (Gabel, 2003; Pekdag, 2010). However, previous studies have stated that virtual laboratories facilitate the formation of conceptual models by providing activities that improve cognitive skills (Kennepohl, 2001; Trindade et al., 2002; Ardac & Akaygun, 2004; Falvo, 2008; Pekdag, 2010). Since chemistry is closely related to daily life (Secken, Morgil, Erokten, Erdem, & Caglayangol, 1999), the use of an "associate with real life" tab within the software is expected to contribute to student achievement.

The pre-LET test scores showed that the achievement levels of the control and experimental groups were quite low and similar to each other. This situation can be attributed to the examination-oriented instruction applied throughout the primary school and, accordingly, the lack of laboratory applications in the study context (Saka, 2002). In Turkey, two highly competitive nationwide exams that place students in upper schooling are held at the end of grades 8 and 12. Since sufficient class hours are not reserved for laboratory applications at primary school level, and because students are not at the heart of the laboratory applications, they cannot recognize laboratory equipment properly (Guzel, 2000). The review of previous studies showed that primary school science courses in Turkey are supported by little or no laboratory applications. Furthermore, most of the laboratory hours involve only the teachers demonstrating the experiments (Guzel, 2000; Ulucinar, Cansaran, & Karaca, 2004; Ozmen, Demircioglu, & Coll, 2009). Even worse, a study carried out at the university level determined that students cannot properly recognize laboratory materials and equipment (Costu, Ayas, Calik, Ünal, & Karatas, 2005).

When post-LET scores were examined, there was a significant difference in the student achievement scores of the groups. The achievement level of CG-1 students dropped 10%, of CG-II students increased 24%, and the scores of EG students increased by 128%. Concerning the effect size, it can be said that 75% of the total variance was the result of the students' recognition of the laboratory material and equipment. These results indicate that VCL software is important for laboratory activities, and that virtual chemistry laboratories are at least as effective as real laboratories. Previous studies comparing virtual laboratories with real ones also support the finding that virtual laboratories are superior in terms of experiment materials and equipment and they lead to higher student performance, and that virtual laboratories are at least as effective as real laboratories (Gabberd, Hix, & Swan, 1999; Ozdener & Erdogan, 2001; Dalgarno et al., 2009; Ozdener, 2005; Gorghiu et al., 2009).

Some experiments can usually only be performed using a demonstration method, for reasons such as a lack of laboratories, insufficient material and crowded classrooms. For these experiments, it is clear that virtual laboratories can provide a valuable alternative to traditional laboratory applications (Ozdener, 2005). Students should be exposed to more laboratory applications and activities so that they can recognize laboratory materials and equipment. Knowing that students who do not have proper pre-knowledge and experience could not be successful while they were doing experiments (Temiz & Kanli, 2005), one can see that a virtual laboratory environment provides students with the opportunity to develop.

At the end of the study, the virtual laboratory software was shown to be at least as effective as real chemistry laboratories. It was determined that students in the control group could complete the experiments with reasonable results; they felt self-confident; they could associate the experiment with daily life; and they had the opportunity to examine macroscopic, molecular and symbolical levels of each experiment. It is anticipated that virtual chemistry laboratories will be adopted as supplementary and supportive elements in future. This will provide not only an effective learning environment but will also minimize school expenditures and the time spent on such activities to a large extent.

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