University POLITEHNICA of Bucharest

Doctoral School of Automatic Control and Computers

PhD THESIS

Teaching and learning in 3D Multiuser Virtual Environments

“Predarea şi învăţarea în medii virtuale 3D multi utilizator”

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INTRODUCTION

Virtual Reality is an artificial world that is created with software and presented to the users in such a way that they accept it as a real world. They perceive the Virtual Reality through senses like the sight, sound and the sense of touch. The enormous development of technology in the field of computers and communications led to the emergence of new, innovative ways, to create different types of virtual environments, including teaching and learning environments. Many today educational software use simulations to render phenomena that cannot be reproduced in laboratories. The software applications based on Virtual Reality are considered the most adequate for simulations because they can improve the user perception by images, sound and immersion in the 3D environment.

The online three-dimensional (3D) virtual worlds enable users to interact and explore in 3D spaces. The MMO (Massively Multiplayer Online) virtual environments are shared simultaneously by many users and the interaction takes place in real time. Different means of communication are available within the 3D environment, like text, audio, video, chat tools and others, and each user is represented by an individual "avatar" which can react and interact with other avatars.

Modern hardware and software technologies have contributed to the development of new teaching and learning methods and tools, from computer assisted instruction and different forms of eLearning to 3D virtual laboratories and MMO educational games.

The online 3D virtual worlds have considerable impact on educational activities. Therefore, the 3D designers and teachers start to consider the interaction between design and usability of 3D virtual learning spaces as an essential tool for educational systems.

The use of computers in teaching and learning science, particularly chemistry, has some specific features. For example, they can be used to help students thinking at the particles level, to make dangerous chemical experiments in a virtual laboratory, to study the invisible parts of the human body in a 3D virtual space, etc.

1. Purpose and Motivation

The major challenge that confronts Chemistry teaching is how to teach and explain the main concepts using innovative methods and how to make the chemistry lesson more attractive for students. Instructors may improve the lectures by merging traditional boards and audio with visual tools, that makes chemistry more alive to the students, as our future students are mostly dependent on visual learning due to the image-centric visual world in which they are raised.

The 3D perception can also improve the understanding of a chemistry lesson (e.g. the 3D molecular forms of atoms). Also, a 3D virtual environment with different educational resources for teaching chemistry adds more advantages to a traditional way of teaching.

Self-education is one of the best tactics to consolidate knowledge. By using games as Virtual Learning Environments, the student can learn by himself. A 3D MMO game might provide an ideal learning platform for learning chemistry as it allows a personalization of the learning process, active communication, collaboration and socialization.

The main aim of this thesis was to investigate the effectiveness of using Virtual Reality in the process of teaching and learning of Chemistry in high schools. Also, to investigate the usefulness of other ways of using computers in teaching Chemistry, for example through computerized laboratories, and to compare the results of these modern methods with those of the traditional method, from two main points of view: knowledge acquisition and improvement of students' trend towards Chemistry.

To achieve these goals we decided to develop some Virtual Reality applications dedicated to studying Chemistry, some of them to help teachers and students, such as "Virtual classrooms" and "Virtual laboratories", others for self-learning as are the serious games. These applications were used in our experimental study on the effectiveness of using Virtual Reality and computerized laboratories in the process of teaching and learning of Chemistry in high schools.

For the development of the applications we decided to use two modern Rapid Application Development frameworks: EON Reality tools and OpenSim.

2. THESIS OUTLINE

In **chapter one** we specify what is the subject of the research from this thesis, its objectives and the research method.

Chapter two introduces different types of computer based methods and tools used today for teaching and learning: computer assisted instruction, computerized laboratories, simulations, eLearning, virtual environments, MMO (Massively Multiplayer Online) virtual environments and games.

Chapter three defines the concept of "Virtual laboratory" and the features of a virtual laboratory. As examples are shortly presented virtual labs from more universities in the world. Some studies about the effectiveness of using virtual lab are also discussed. The advantages and disadvantages using virtual lab versus traditional lab are outlined.

Chapter four describes shortly the features of the two application development frameworks used by the author of the thesis in the development of the 5 applications described in this thesis: EON Reality tools and Opensim.

Chapter five describes four applications developed by the thesis' author. All of them contain 3D virtual environments with multiuser facilities. Their objectives, content, implementation, usage and evaluation are outlined.

In **chapter six** we describe our study on the efficiency of using Virtual Reality and computerized laboratories in teaching and learning. The study is based on an experiment made with three groups of students, a control group (which used the traditional method of teaching and learning) and two experimental groups: one of them used a computerized laboratory, the other our VR applications for teaching and learning. The student' grades and responses to questionnaires were statistically analyzed using "One way ANOVA" method by means of SPSS software. The analysis results are then discussed.

Chapter seven is dedicated to "Serious Games". First, the definition and scope of the serious games are introduced, and then the main features of Serious Games. Next, some studies about the use of Serious Games are discussed and advantages and disadvantages of Serious Games are synthesized. Further, the chapter describes the Serious Game developed by the author of this thesis: objectives, approach, the game's 3D environment, the mini-games included in the Serious Game. The last paragraph of the chapter presents some details about the design and implementation of the game.

Chapter eight summarizes the main contributions of the author and also some recommendations and suggestions regarding the use of VR and computerized laboratories in teaching and learning.

CHAPTER 1. THE RESEARCH FROM THIS THESIS

1.1. INTRODUCTION

The world is witnessing a scientific and technical progress today in the various fields of life. Education is one of the areas that have been influenced by this technical progress, which contributed to providing a variety of tools for the development of teaching and learning methods.

The courses of sciences are considered one of the most related or connected with technology subjects. Many of the educators proved the importance of integrating the ICT (Information and Communication Technology) in the field of teaching science [Alshaya, 2005]. One of the most prominent arguments is that the use of IT (Information Technology) in the field of teaching science will enable students to study the scientific phenomena. Many of these couldn't be studied in the school boundaries because they are very difficult and dangerous and there is no enough time to complete experiments. Or, many objects in the chemistry world, like electrons, are very small, very difficult to be seen in the suitable place and time. The final reason is that, when you work in a real lab, some chemical reactions may happen very quickly, so you can't follow and understand them [Alfar, 2011].

Simulation can be considered as one of the most important methods to be used in science laboratories [Alshaya, 2005]. It is an alternative way to teach certain phenomena that cannot be studied it a real environment. The simulation is possible by using computers and their multiple potentialities to clarify a certain thing or to develop a special skill. Many studies [Tüysüz, 2010] [Allison, 2000] assured the importance of using Virtual Reality laboratories and computerized laboratories in studying sciences. They showed the effectiveness of using computer simulation programs in the execution of laboratory experiments, the scholastic achievement, the understanding of abstract ideas and saving the information by the students. The computer provides the element of wish and excitement of the learner by using various means of teaching such as pictures, graphics and different sounds. This kind of teaching is considered as the most prevalent in using computers to conduct laboratory experiences and activities [Alfar, 2011].

The computerized laboratories use interactive software running on computers which have sensitive terminals (sensors) connected to them. Sensors are used for measuring variables in practical experiences. So, the computerized laboratory becomes a tool to collect data, analyse and then save them [Alshaya, 2005]. Among the studies that proved the effectiveness of using computerized laboratories in the development of understanding are: [Swyer, 2002], [Alshaya, 2005], [Taylor, 2005].

With the spread and the development of computer technologies and information systems, the interest of educators was growing to reconsider the content of the educational process and its objectives and means. Many of them proved this by using computers in teaching [Alhudhaifi, 2005], [Albencinalb, 2008]. Others [Alpaddy, 2009] recommended the need to develop teaching methods and use modern technological methods, especially the use of computers in the teaching of the sciences.

1.2. RESEARCH TOPIC

Researches and studies showed that the teaching methods which are used in the school in Jordan are still traditional. They depend primarily on the role of the teacher in the classroom.

Many studies [Alhudhaifi, 2005], [Swyer, 2002] proved that there is a weakness in the level of the school achievement in the chemistry at the secondary level. Through some studies it was found that the students couldn't understand a lot of chemistry subjects. This caused negative attitudes towards chemistry [Basawapatna, 2010], [Smetana, 2012]. I observed during my work in public education and teaching, which lasted for eight years, the presence of two kinds of difficulties: for students, to understand some of the chemical processes; for teachers, to clarify the scientific subject and this can lead to the misunderstanding of the subject by students. Occhuizzo [Occhuizzo, 1993] recommended the necessity to use the suitable teaching methods that help to correct conceptual errors which are resulting from misperceptions.

In Jordan, the experience in the field of computerized laboratories is new and modern. The governments made some trying with the use of computerized laboratories in some schools in a number of different regions. Because this experience is modern, it needs a lot of research to determine its efficiency compared with other methods. There is no experimental research in Jordan to study the effect of using virtual laboratories, and especially those based on Virtual Reality, on students' achievement, and if such laboratories have positive scientific trends on high school students, in the different subjects of science.

[Alshaya, 2005] noted that the computerized science laboratories can develop positive trends of students towards science. As indicated by studies of education and the technology of education to the potential contribution of computers, computerized laboratories have a role in raising the standard of students' achievement in science. [Alfar, 2011] observed the effectiveness of using the computers in the processes of learning and teaching.

Because the experiences of computerized laboratory and the virtual laboratories are new and expensive, the idea of this research comes to show the possibility of their contribution to the raising of the achievement level and development of positive attitudes towards science. Also, to compare the results of using these two methods with those obtained by the traditional way of teaching and learning.

The importance of research

The importance of this research appears as follows:

•Students: learning by using virtual laboratories and computerized laboratories may improve the level of the achievement in chemistry; in addition to this, it may help to make positive attitudes towards it (chemistry).

•Teachers: the research can help teachers to identify teaching methods based on simulation programs, Virtual Reality and computerized laboratory; this will increase the effectiveness of teaching and the culture of technology in the field of teaching.

•Educational development: the results of this research may help those that are trying to develop curriculum, to determine the effectiveness of using simulations, Virtual Reality and computerized laboratory in the teaching of chemistry. It can also help to generalize the experience of computerized science laboratories in all the schools.

1.3. RESEARCH OBJECTIVES

The research objectives can be summarised as follows:

1) To show the effect of teaching chemistry by using VRA (Virtual Reality Applications) and computerized laboratories on the achievement level in the knowledge of chemical concepts and phenomena, such as the reactions of acids and bases, for the tenth grade students, compared to the traditional way.

2) To show the effect of teaching chemistry by using VRA and computerized laboratory to develop positive trends of the students towards chemistry.

3) To investigate optimal designs of virtual 3D learning environments in terms of layout of the 3D space, density and distribution of information and optimal access to the information necessary to solve the learning tasks.

4) To create a series of Virtual Reality based programs for teaching and learning Chemistry and estimating their usefulness in the learning process.

5) To find patterns of exploiting the MMO (Massively Multiplayer Online game) features of a virtual environment in a learning process.

6) To conduct larger scale experiments to assess the efficiency of using MMO virtual spaces in chemistry learning.

1.4. RESEARCH METHOD

Our research is an empirical one, based on experiments conducted with different groups of students.

The first experiment was conducted with three groups of students.

Each group had a different style of learning:

- Control group: members of this group learned chemistry in the traditional manner, in the laboratory.
- First experimental group: members of this group learned chemistry in a computerized laboratory (a chemistry laboratory equipped with sensitive devices connected to computers).

- Second experimental group: members of this group learned chemistry using two Virtual Reality Applications (VRA), which were developed by us (described in chapter 5).

We analysed the results of my experiments using *one way ANOVA* (Analysis of variance) statistical method, by means of SPSS software, to calculate the *significant statistical differences* between the study groups, based on the variables *achievement* and *trend*, to answer the following empirical research questions:

1) What is the effect of using computerized laboratory and VRA on the student achievement?

2) What is the effect of using computerized laboratory and VRA on the attitudes of students towards chemistry?

3) What are the trends of the first experimental group of students towards the use of computerized laboratories in the teaching of chemistry?

4) What are the trends in the second experimental group of students towards using Virtual Reality in teaching chemistry?

Chapter 6 of this thesis describes the experiments conducted with the three groups of students and the results of the statistical analysis.

The second experiment was conducted with a group of students from the tenth grade, using the serious game developed by the author of this thesis. The aim of the experiment was to evaluate the students' experience with the game and the overall learning process compared to the traditional learning, based on our observations during the experiment and on students' responses to a questionnaire after the experiment. The game and the results of this experiment are described in chapter 7 of the thesis.

1.5. RESEARCH DELIMITATION

The experiments upon which is based the research described in this thesis are delimited in place, time and content:

First experiment

1) Place: public secondary school in Marfaq city from Jordan.
2) Time: research has been applied during the second semester of the scholastic year 2012-2013.
3) Content: interactions of acids and bases and periodic table, in the course of chemistry for the tenth grade students, the second semester (2013).

Second experiment

1) Place: 3D Lab (EG204) in University POLITEHNICA of Bucharest, with 20 students of tenth grade from IRAQ school in Bucharest.
2) Time: 6.05. 2014.
3) Content: information about chemical organic elements in the periodic table for tenth grade students.

CHAPTER 2. COMPUTERS IN TEACHING AND LEARNING SCIENCES

Educators confirm the importance of using computers in the educational fields, such as: educational planning, educational administration, design of curriculum, student evaluation. There are many classifications for the computer's role in teaching and education. The most prominent one is that of Taylor [Taylor, 2005].

According to Taylor's classification, there are three kinds of computer usage in the field of education and teaching:

- **Computer as a tutor**: the computer can be a tutor by means of software specialized on this subject. The student interacts with the software, taking information from software and responding to questions. Depending on the results of student evaluation by software, this decides on the next level of tutoring. With the use of Internet, there's a lot of information that can be absorbed. Computer is one of the important things nowadays because it is very useful to the students. However, computers, even though they can be a tutor, they cannot replace the role of the teacher. Teachers can adjust to the new curriculum; computers must be enhanced to adjust to the new curriculum. In the future, we shall see the computer in schools as a common tool for enhancement of the student's thinking, communication and collaboration skills.
- **Computer as a tutee**: the computer is used as a tutee when a student or a teacher develops software for tutoring. This can help the human tutor to better understand the teaching subject and also how the computer works, its advantages and limitations.
- **Computer as a tool:** computers are used as tools by means of different application programs, such as: word processors, calculator, text editor, spelling editor, etc.

2.1. COMPUTER ASSISTED INSTRUCTION

Teaching with the aid of computers is one of the most common uses of computers in many countries of the world, because it allows multiple methods of teaching and is appropriate for all the categories of students. The teaching with the aid of computers is connected with the development of the programmed instruction, which is designed to lead an active role in the educational process, so that the student can improve step by step to achieve certain aims [Temel, 2000].

Lehn [Lehn, 2007] defined computer assisted instruction as the use of computer to provide an educational material which requires the active participation of the learner and the response of the computer to what the learner had done.

Computer assisted instruction has rendered advantages cited by many researchers.
Islam [Islam, 2011] mentions that the teaching with the aid of the computer can provide an interactive environment between the learner and the computer programs. Alfar [Alfar, 2011] confirms the possibility to connect between the theoretical subjects and the practical applications using computers in the courses of science. The computer contributes to increasing the ability of students to solve problems and to their preparing for the future jobs, according to the techniques of the modern age. There are many basic kinds of teaching using the computer ([Fan, 2009] [Alfar, 2011] [Al - Harthy, 2010]), such as:

- instructional games;
- drill and practice;
- problem solving;
- Computerized simulation.

Modern technology has introduced methods and tools which contributed to the development of teaching and learning methods in the recent years. Such methods aim to improve learning by using higher order thinking skills and self-learning. Also, by making learning a cooperative action [Bing 2009].

Computers in teaching chemistry

The computers can be used in the implementation of chemical experiments and laboratory activities. The computer can help to achieve the objectives of the science curriculum. New methods have emerged from making laboratory experiments by using modern techniques of using a computer. These computer programs aim, by using the computer assisted instruction, to facilitate students' understanding of scientific concepts and to provide an opportunity for students to get knowledge by themselves.

This is the opposite of what happens in traditional laboratories that provide information with the result of students' indoctrination [Othman, 2014].

The computer can be used in the implementation of practical activities in laboratories of chemistry. They can be used effectively to help students to acquire the skills of scientific thinking, focusing on the mental skills such as analysis and evaluation, by designing special computer programs to make experiments by the students.
The main reasons for using computers in the implementation of experiments are:

- to reduce the risks facing the student if they made the experiments directly;
- to save time and reduce the financial cost;
- to give the student an opportunity to observe the situation practically, such as the installation of a nuclear reactor;
- to give the student a chance of learning individually

2.2. COMPUTERIZED LABORATORY

Computerized laboratories use computers to make practical experiments, data collection and analysis of these data by using special programs and sensitive terminals called sensors. For example, we can collect data on temperature every five minutes by using a special sensor then we can transfer these data to visualization software. The computerized laboratory is an advanced step in the field of integration of technology in science teaching. It can enable students to perform multiple types of real experiences by using experimental data collected with sensors connected to computers.

Computerized laboratory is considered a technical progress in the field of science laboratory. The student can use the computer not only as a means of calculation or storing data but rather a laboratory tool for measurement and controlling and to clarify the theory in a meaningful and practical way during the time of practical experiments. Then, the computer can be used as a means to deduce laws from the reality of measurements during the experiments and so the computer is a tool of understanding and convincing by experimentation and conclusion.

The objectives of computerized laboratory

[Liao, 2009] has pointed multiple features of computerized laboratories, including:

1) The possibility of the computer to control the devices and sensors which are used in the scientific experiments.
2) The possibility of re - performing experiments easily, so the student will get self confidence and can display patterns of learning which are difficult or impossible to display in the laboratory, using simulation programs that allow the student to make mistakes without negative results.
3) Changing the role of the teacher from being a source of information to be a guide and prompt in the educational process, in an educational environment centered on learning and making him the basis and axis of the process of learning.
4) It allows adapting with the scientific level of the student and the rate of experiments will be according to the rate at which the student can move, according to his ability and potentials.
5) It provides the instant feedback, showing the results of the experiment quickly. The computerized laboratory increases the student's ability and confidence in dealing with the computer. This will enhance the integration of technology in the educational process; increase the student's ability to master the skills of dealing with the hardware and the tools in the laboratory, and the ability to analyze data by graphics and statistical tables for the results of experiments.
6) The time of experiment is very short in the computerized laboratory compared to the conventional science laboratory.

Some studies [Alshaya, 2005] [Alfar, 2011] [Bing 2009], have indicated that the computerized laboratory led to a decline in the time of preparing the experiment from 53% of the real laboratory time experiment to only 5% in the computerized laboratory. It also reduced the time to get the results of the experiment from 45% in the traditional laboratory to 1% in the computerized laboratory.

2.3. SIMULATIONS IN STUDYING SCIENCES

Simulations are used in education since the thirties of the last century, when the first plane simulator was presented [Gaba, 1997], [Garrison, 1985]. The simulations built for experiential learning and observation provide an opportunity to practice and learn within a controlled environment. The simulation is an excellent application example of the cognitive theory because the learner is more active in the position of learning; it requires prior knowledge, skills and orientation towards the target [Billings, 1998].

Simulation should be a preferred method of learning: it allows the learner to experience without fear of failure; many dangerous environments and events can be simulated and studied safely; its behavior can be adjusted according to the profile and the performance of the learner [Randal, 2002].

The simulation computer programs have a clear and important effect on facilitating both teaching and learning of chemistry, so that it can be used in multiple fields. The explanation may require using some devices and tools that may not be available in school.

In some cases, the question may require representation of the things that happen and they cannot be seen by the naked eye, due to their small size, such as atoms and molecules, or because of the distances of place and time such as the movement of continents or they may occur at high speed such as the chemical reactions, or may be slow to occur, such as the growth of plant, or they may be dangerous to the students such as the preparation of some toxic gases for example the chlorine gas [Alfar, 2011].

The simulation can also be used when laboratory experiments are expensive, or when the laboratory experiments cannot be performed in the school laboratory for example the experiment Rutherford [Swyer, 1998].

There are multiple sites on the Internet that present software of computer simulations.

2.3.1. Types of simulations

According to Cunningham [Cunningham, 1998] there are four types of simulations:

1) **Experimental simulation**. It relies on the traditional method in the practical experimentation to adjust and to process the variables, after that to test the hypotheses.
2) **Predictive simulation**. It is usually based on models of systems which try to expect the results more than data-checking. For example, the researchers used the economic models to simulate the national and global economies, and to test the changes of various economic trends. It is clear that the success of the simulation depends on the success of the simulation model in the replication of the system accurately.
3) **Evaluation simulation**. It is usually used in training. It aims to evaluate responses of the individuals or groups of individuals to the real problems that have been simulated. The evaluation simulation tries to control the basic elements of the concerned problems by making trials with the participants, adjusting their behavior and decisions.
4) **Education Simulation**. It is mainly for the teaching of the individual or group and it leads to the changes of the behavior and attitudes, which are associated with the individual or the group. Modeling methods can be used in this simulation including representation of typical roles [Yilmaz, 2006].

According to [Alfar, 2011] the simulations are of the following types:

1) **Physical Simulation**. It deals with the physical material to be used and to identify its nature, such as the equipments of the scientific laboratory that are used in chemical experiments, which in the real laboratory are dangerous.
2) **Procedural simulation**. The aim of this type of simulation is to learn a series of works or to learn steps which are designed to develop the skills. For example, the driving simulators for pilot training that allow trainees to exercise on the mechanism of aviation and not how it works.
3) **Situational simulation.** It deals with the trends and behavior of people in different positions more than with the performance; unlike the procedural simulations that teach a number of rules, the situational simulation allows students to explore the effect of methods for an event.

In the situational simulation the student is considered as a part of the simulation. He takes a primary role, while the other role can be carried out by the other students. They interact with the same program.

4) **Processing simulation**. In this type of simulation, the learner did not take any role, but he takes the role of external observer. He has to imagine, he notes, and he connects the relationships and results. So he can learn from the free discovery [Alfar, 2011].

2.3.2. Benefits and difficulties of using simulations in teaching and learning

Some educational researches confirmed that no educational method can achieve the wide range of educational objectives of learning. The simulation can help to achieve some educational aims and to reach to required conclusions. In the light of that, many of the studies and researches confirmed the importance of the use of simulation in the field of teaching because of its numerous advantages and benefits [Lunce, 2006].

For a long time, simulation has been used in the learning activities, facilitating accurate representations of real objects, turning learners into interactive participants [Choi, 2010] After the beneficial role of computer-based simulations proved in facilitating learning, it was a good chance to merge the computer-based simulations and virtual environments to create online virtual environments in which the students can access, interact and explore. The final product will be an opportunity for active learning [Song, 2002].

And [Lane, 2006] mentions that the simulation can help learners explore the information in an interactive and dynamic way. It also helps to make an atmosphere of desire and excitement for the educational position when studying a dry educational material. It also gives a chance to the learners to study the factual information that is difficult to obtain because of the far distance of time and place. It helps to understand the relationships between information elements and internal, invisible parts.

In addition to above mentioned, the simulation also helps learners to identify the functions and methods of their work, also it helps learners to predict the outcomes of the implementation of the experiments and educational projects, and it stimulates the creative thinking among learners to provide new educational ideas.

It can be concluded from the above mentioned that computer simulations have the properties of the best educational intermediate, especially in the field of teaching. It helps to provide scientific activities, which cannot be performed by the teacher himself. It also transfers the educational process of teaching to learning state. Although the direct experience in the teaching of science is very important and there is no equal other way, the learner may make through simulation some different laboratory experiments.

Although there are many benefits of using simulation in education, there are also some flaws that, according to [Wieman, 2007] and [Sharp, 2001] can be summarized as following:

- The simulation programs for education need a long time for planning and programming to become effective and efficient.
- They require a teacher with a high planning and programming knowledge.
- These programs also need a team of teachers, programmers, psychologists and experts of the curriculum and teaching methods.

Allison [Allison, 2000] mentioned a number of obstacles and problems that prevent a good use of simulation programs in teaching and training. The most important of them are:

1) There is not accurate identification of the objectives of education and training programs to be used in education and training.
2) There is not a specific plan to be employed in the positions of teaching and training.
3) There is not enough amount of the necessary information about how to use them in education and training.
4) There is a lack of financial resources for the needed laboratory equipment.
5) There is a lack of adequately trained teachers on the educational uses of simulation.
6) There are not enough beliefs for the most of decision-makers in the educational administrations on the importance of using simulation programs in the educational system.
7) There is not any kind of appropriateness of the educational simulation programs which are ready and available in foreign languages with the applied curriculum in all schools in the world.
8) There is not any kind of educational programs in the different languages.

2.4. e-LEARNING, VIRTUAL REALITY AND MULTI-USER ON-LINE (MMO) SYSTEMS FOR TEACHING AND LEARNING

During a Computer Based Training (CBT) seminar in Los Angeles, in October 1999 [AACRAO, 1999] an unfamiliar concept was used for the first time which was “Online learning”. This concept and “virtual learning” were used later to qualify and represent new methods to learn and teach using new technologies, through the Internet or by intranet, so as to make the process of learning more independent of time and place. Virtual Learning opens up new horizons for the learners that were not available before. It is a promising solution to achieve the students' future needs without overlooking the benefits of the traditional way of teaching.

The researchers prefer to use the term “**e-learning**” rather than the term “**virtual learning**”, because this type of education is similar to the usual education, but it depends on electronic media. Therefore, it is “real” not “virtual”, as Dobbs and Philip [Dubois, 1997] say about the term, “virtual learning”. With the evolution of hardware and software technologies the term “virtual learning” changed its initial meaning, being associated now with “learning in a virtual environment” or more precisely “learning in a Virtual Reality environment”.

Since the early 1980s, the idiom “**virtual reality**” has been revealed and used [Gully, 2009]. Virtual worlds, as software applications, represent interactive three-dimensional virtual environments which include animated characters called avatars. Also, these environments host various types of activities and have communication features that connect people from different parts of the world.

Just like the real world, virtual reality is a dynamic entity, in interaction with the user in a three-dimensional space. A virtual user has the freedom to explore the world from his computer and to interact directly with it.

An important property of Virtual Reality environments is that of immersion, which provides "Realism", causing the feeling of "presence" in the virtual environment, that is, the user is "active" as part of the virtual environment that simulates a reality. This is of course a combination of simulations using advanced hardware and software, a whole network of subsystems that communicate with each other to play the interaction.

Virtual Reality environments allow users to interact with objects from the environment that they may not be otherwise able to interact with. Virtual Environments are considered to be perfect environments for testing phenomena that may be too costly or too critical in physical reality. The online three-dimensional (3D) virtual worlds enable users to interact and explore in 3D spaces. Such worlds are typically based upon interactive visualization of 3D synthetic models. Different means of communication are available within the 3D space, like text, audio, chat tools and others, and each user is represented by an individual "**avatar**" which can react and interact with other avatars.

There are different kinds of "Virtual Worlds". The most common characteristic is the **MMO (Massively Multiplayer Online)** meaning that the virtual environment is shared simultaneously by many users and the interaction takes place in real time. A MMO requires the existence of a huge virtual environment, governed by a set of rules, in which a very large number of users can socialize and interact in real time by using avatars. The largest and most common type of virtual world is the "**MMORPG**" which stands for **Massively Multiplayer Online Role Play Games**. An example of MMORPG is the "World of Warcraft" game [World of Warcraft]. Even if games were the first application of virtual worlds, there are now many other areas which benefit from using the virtual world concept [Dafoulas, 2012]. For example, the main aim of Second Life is socialization. Others, known as **Massively Multi Learner Online Learning Environments (MMOLE)** focus on learning and training [Drury, 2001].

In 2007, Gartner [Gartner, 2007] predicted that in the next five years the Internet will turn into a three-dimensional environment and that 80% of Internet users will be in virtual worlds by 2011. The number of users of virtual online worlds was about 1139 million users in the year 2012 and was expected to reach, in 2013, 1899 million users [Kaufmann, 2012] (see figure 2.1).

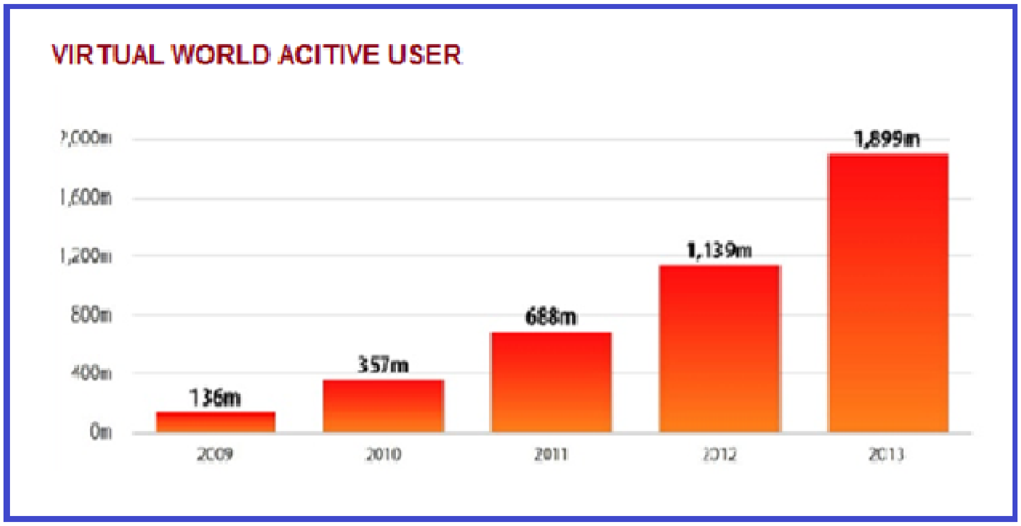

Figure 2. 1.Virtual world's users [Kaufmann, 2012].

Are researchers and teachers turning their attention towards interactive virtual environments such as virtual worlds and video games to modernize their teaching methods? One of the most popular virtual worlds on the Internet is "**Second Life**" [Getchell, 2009]. There are many examples of universities, such as Harvard and Stanford [Vega, 2009], which use Second Life for educating and training purposes [Secondlife]. Second Life can also be used for distance education [Zhang, 2010].

A 3D MMO game based on virtual reality technology might supply an ideal platform for learning sciences as it allows active communication, collaboration and personalization of the learning process [Edward, 1997]. Such an environment provides facilities for interactive learning and allows students to access it anytime and from their favorite place. The student has to solve tasks for reaching a specific goal, moving from one level of difficulty to another. In this environment, students can manifest their own personalities and abilities, can work in groups to reach specific goals and win competitions [Crumpton, 1997]. World of Warcraft for example, is used by some economic colleges to train students in economic concepts such as buying, selling or bartering [Karam, 2001].

Metaverses are immersive 3D environments where people can interact through characters called avatars, controlled by real people using different interactive devices and techniques [Schunk, 1998]. An avatar can be chosen and customized by its owner in a desired manner, to model its own personality. The metaverses are different from the virtual reality worlds of 3D MMO games, because there are no specific competition goals to achieve, so users can define their own goals. Second Life [Second Life] is among the most famous Metaverse environments; it was used for building business applications, but also in schools, universities, hospitals and government [Vickers, 2007].

The application of the virtual reality in teaching and learning

The influence of virtual reality in education is increasing gradually, likewise augmented reality. A lot of 3D virtual environments and materials of educational benefit are created, some are additions to other multimedia, and some can be considered environments of their own, including all theoretical and analytical parts taken together.

In the **virtual classroom** the individuals share experiences with each other by various means of communication, such as instant messaging or voice conversations. Every student participates through an Avatar, which represents his real personality and executes his activities in the virtual environment. Each student chooses a nickname (which could be real or not) to represent him in the virtual world. Usually, in the virtual world of education most of the users choose the real name because the student will be sharing the course with the teacher and a group of his colleagues. It is better for a student to use his real name because the role of the teacher is to monitor student performance and to put estimate scores of the activity on this virtual educational environment, therefore the real name is necessary in this case.

Virtual Reality can provide tools to increase student participation. Also, VR can be invested in various student activities, like the execution of virtual tours instead of reading about these places. VR allow overcoming the limits of space and time in the educational process, the student having instant access to information without being in a certain place and time [Aldrich, 2004].

With VR environments students can have easy access to the teacher with more flexible timetables.

Simulation for education can benefit from many advantages offered by VR:

- Virtual reality technology enables learner to explore many real things that cannot be explored in the real life. For example, students can explore the 3D structure of an atom.

- Today Virtual Reality environments utilize real-time 3D graphics that allow simulating complex or dangerous experiments, providing users with realistic but safe experiences.
- At the level of visual perception, students are more responsive to 3D environments, as a medium that mimics our life, compared to any representations in two dimensions.

A virtual space can be a perfect environment for creating an interactive multi-user classroom, in which learners are able to compare different forms of teaching methods and they have the ability to choose the one they prefer.

There are a lot of advantages for learners in virtual environments because of the discussions between them. Thus, the **collaborative virtual learning environments** provide more benefits of which the learner can take advantage through the interactive virtual environment, by thinking and sharing experiences.

CHAPTER 3. VIRTUAL LABORATORY IN CHEMISTRY

The great developments in communications and Information Technology strongly influenced the educational field, like many other fields of life. Thus, the spread of computer networks and the Internet, the modern multimedia and Virtual Reality technologies have led to the development of new forms of teaching and learning among that are "virtual laboratories".

The experiments made in many universities and scientific researches proved the importance of virtual labs in teaching and researching. Studies have revealed that virtual labs help to solve many problems that face teaching science, in general. There are many advantages of using virtual laboratories, such as the ability of simulating dangerous experiments, which need complicated or expensive equipments and materials. However there are some difficulties in creating and using them.

3.1. THE VIRTUAL LAB CONCEPT

There are many definitions in the literature for the “virtual laboratory” concept. Although they are different, they have the same implications.

Woodfield and others [Woodfield, 2004] defined the virtual chemistry lab as an “open environment through which we can simulate a real scientific lab to connect the theoretical side with the practical one, teach thinking skills, and where the students can freely take decisions without any side effects”.

Zaytoon [Zaytoon, 2005] defined the virtual chemistry lab as “a virtual learning and teaching environment that aims at developing students' lab work skills. This environment exists on a web site and includes a main page with many links and icons which are related to the lab activities, their achievements and corrections.”

Zaytoon [Zaytoon, 2005] classifies virtual chemistry labs as “one of the virtual e-learning environments by which we can simulate the school / university actual learning by functions and actions, and in which the student can practice the lab activities which happen in the traditional lab”.

[Dillon, 2007] indicates that "virtual chemistry labs are e-learning labs by which we use the computer simulations to execute the practical experiments".

Al Bayati [Al Bayati, 2006] indicates that "virtual chemistry labs are the main base in e-learning education in both practical and applied fields. This is done by using different computer programs that simulate the experiments on computers, and using different pictures and paintings which describe the experiment that will be applied and executed".

From the above definitions we can conclude that:

- virtual laboratory is a form of eLearning and teaching used in applied and practical fields;
- it simulates a real laboratory with its functions and equipments;
- it is based on computer programs that allow simulating real experiments and obtaining results that are similar to those from the real laboratory.

Virtual labs have many features which assure their importance and the necessity to accept and adopt them as an important educational change in teaching scientific subjects and enriching the practical sides. Among that are [Zaytoon, 2005]:

1) Decreasing the time that a student spends in the traditional lab.
2) Applying experiments which are difficult to make in traditional labs because of their dangerous effects, or their high cost or because they take a long time to be performed in traditional labs.
3) Having the suitable feedback of the student performance as quickly and quantity he needs.
4) Making the practical sides more active and interesting.
5) The flexibility for students to use the lab activities at any time and at any speed which enable the students to do the activities that they missed.
6) The financial cost could be less than that of traditional ones.
7) The possibility to follow up with the students and direct them.
8) The virtual lab programs have instruments which help support the experiment such as graphics, animating and analyzing.

[Al Bayati, 2006] adds the following feature:

9) To get rid of the insufficient lab instruments, especially the expensive or non available ones. And to get rid of crowded students during experiments processing.

Martinez [Martinez, 2003] and others added two other features:

10) The virtual labs give the students an opportunity to self-evaluate their performance during experiments.
11) It decreases the time specified for teachers in experiments and use it in other theoretical studies to teach the students in classrooms.

Despite the many advantages of virtual laboratories, some researchers consider that there are obstacles in their use [Zaytoon, 2005]:

1) They need computers and specific characteristics to clearly perform the complicated phenomena.
2) Producing and designing these labs need a professional teamwork of programmers, teachers, curriculum experts, study subject experts and psychologists.
3) The lack of real interaction among equipment, tools, subjects, teachers and colleges.

Carnevale [Carnevale, 2003] also adds some obstacles:

4) It is impossible to establish a virtual lab which includes all possibilities that a student needs in a real lab.
5) It is probable that all students will be restricted to the virtual lab experiments only.

3.2. VIRTUAL LABS EXAMPLES

Many universities and research institutions created virtual labs where the students or researchers can complete their practical study or can make experiments and researches.

ChemCollective (http://chemcollective.org/home) is a **collection of resources to teach and learn Chemistry**, among that some ***virtual labs*** lessons that help students to learn Chemistry through simulations of some real experiments. It was developed by a group of faculty and staff at Carnegie Mellon University, USA. The purpose of this project was to improve teaching in Chemistry courses through completing the traditional teaching and to let students do experiments identical to the real ones. The students can also design and execute experiments quickly and witness examples that they couldn’t see in the real lab. Each student can download the virtual lab program on his PC or apply experiments directly on the project website.

One advantage of this virtual chemistry lab is that it is designed for 14 different languages. Yaron [Yaron, 2005] assured that there are real big winnings achieved by using the virtual lab in teaching Chemistry, how the students' participation in Chemistry courses changed and how effective was in understanding concepts.

The **virtual chemistry lab** [Dalagrano, 2003] **at Charles Sturt University (CSU)** in **Australia** was created to be used for distance education in Chemistry. The CSU virtual chemistry laboratory (accessible at http://anpsa.org.au/links.html)is an accurate 3D model of the undergraduate chemistry teaching laboratory at Wagga Wagga campus. Its initial aim was to allow students to become familiar with the layout of the actual laboratory and to find out information about laboratory procedures. It has been developed using the Virtual Reality Modelling Language (VRML) and is accessed through a web interface.
Students can do experiments through the virtual lab where the teachers and researchers noticed that there were many benefits such as [Dalagrano, 2003]:

- Time saving.
- Using tools in the right way.
- Increasing knowledge related to work steps in the lab, which increases the safety environment.
- The students' concentration on understanding the theoretical principles increased through the virtual lab.

This **Virtual Labs** site (http://www.vlab.co.in/ba_labs_all.php?id=9) was developed at an Initiative of Ministry of Human Resource Development in **India**. It allows remote-access to virtual labs in different disciplines of Science, among that Chemistry. This virtual laboratory meets the needs of students in distance learning at the university level and school level. The virtual labs contain different tools for learning, including additional web-resources, video-lectures, animated demonstrations and self evaluation (see figure 3.1).
Among the reasons to use this virtual labs are the time constraints of students and geographical distances for traditional laboratory, and not all time can find a good teacher to help students to understand the concepts of chemistry.

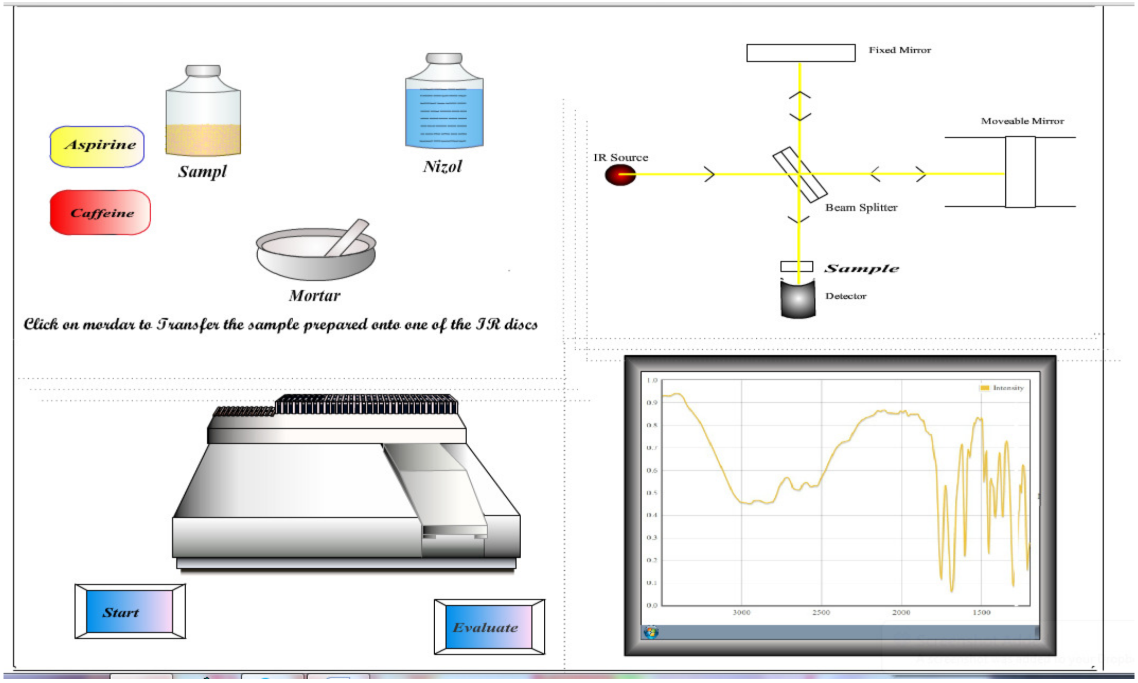

Figure 3. 1.A virtual experiment in the Virtual Labs from India

In the Virtual Labs the user can obtain the result of an experiment by one of the following ways:

- Modeling the physical phenomenon by simulations and a set of equations.
- Providing data previously obtained by real lab.
- By carrying out the actual lab experiment remotely.

Virtual Chemistry Lab 2.0 is free software that can be downloaded from Internet (http://www.softpedia.com/get/Others/Home-Education/Virtual-Chemistry-Lab.shtml).
Virtual Chemistry lab can be used in English and Spanish languages. The student can combine different substances with the aid of an “assistant”. The lab contains many resources and learning tools such as: important information about the chemical elements, a glossary, self-test facilities, interactive reactions with chemical compounds, and a lab log, advanced unit converter, an equation editor, a help file, and many other features, by an attractive interface.
This program can be updated over the Internet, and chemistry teachers can manually add more substances and reactions. Also the students can save their data for a long time and update it any time. The interface is easy to use and students can get help from special software that give him answer to any question.

The application comes with a Periodic Table of elements with valuable information on every single element, like physical attributes, history, facts, pictures and many other details.

The virtual lab has the same tools as the traditional lab, where there is a worktable to conduct Chemistry experiments. The student can use burners and a few other tools to perform the best reactions. To satisfy the requirements of students in chemistry, the program contains not just information about elements, but there are also several other reference tools included the solubility table, Oxidizing and Relative activity of some of the substances.

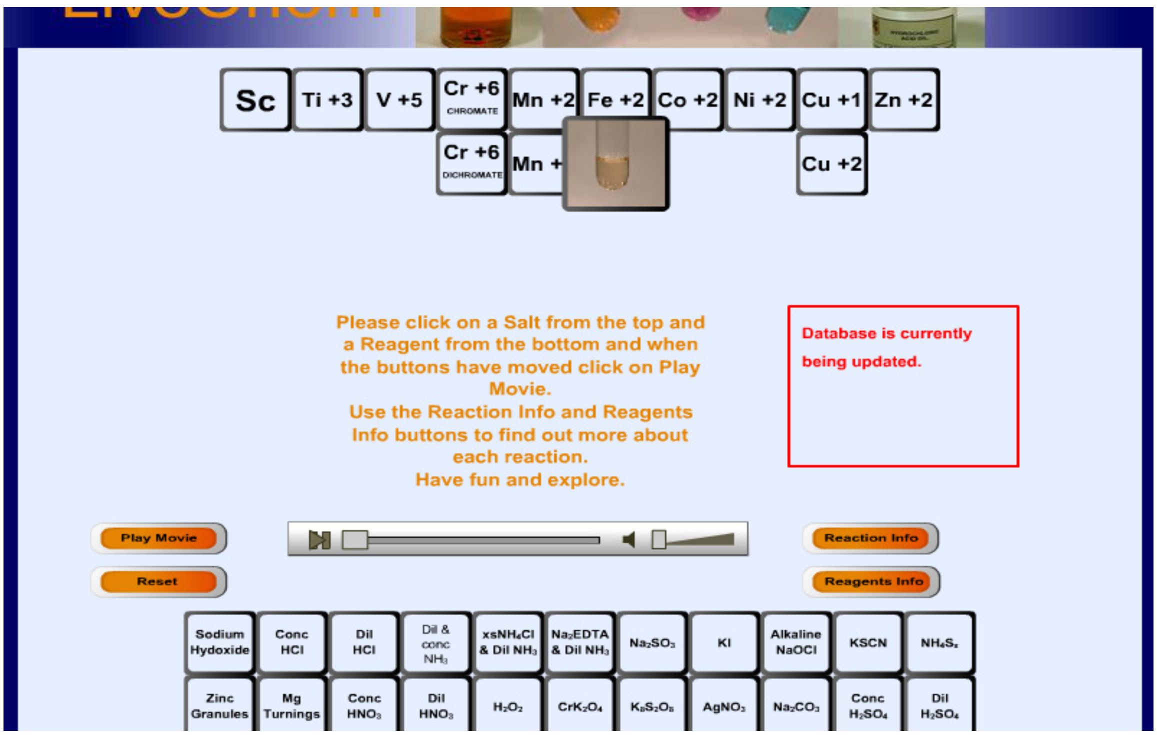

Figure 3. 2.Experiment from LiveChem.

The **LiveChem virtual laboratory** at **Oxford University** was developed to supplement their first year undergraduate teaching: http://www.chem.ox.ac.uk/vrchemistry/.

The students can choose chemical elements to combine and then they can see the video about the reaction between elements (see Figure 3.2).

Balmush [Balmush, 2005] indicates that in USA there are 25 states that have school systems which depend on Internet as a means of education. The American North Council assured that there are 60000 students registered in virtual labs chemistry and other science courses. The teachers of Science said that electronic simulation could give good results where they could be used as additional work to those students did in a real lab, and it also concentrates on supporting students who have no practical experience in real labs.

3.3. STUDIES ON EFFECTIVENESS OF USING VIRTUAL LABS

Different studies have been conducted to investigate the effect of the use of virtual labs, especially in chemistry education. For example, [Kristensen, 2006] aimed to investigate the effect of computers in teaching chemistry through the application of SimuLab which simulates a 20 hours laboratory tasks.

One of the most important goals of the study was to increase the student experience for chemical reactions and increase their knowledge of inorganic chemistry. The most important result of the study recommended the use of simulations through virtual lab. Students tended to enjoy working with it, they found it interesting and the level of students' expertise increased.

There are many universal studies on virtual labs. One of them, done by Change [Change, 2002] in Taiwan, aimed to investigate the impact of using the virtual lab based on students' results and directions towards Science. The most important result was the difference between the average scores of the standard group and the experimental group, who used the virtual lab.

Martinez [Martinez, 2003] and others made a study in Spain that aimed to expose the ability of using the virtual lab in Chemistry as a complementary part of the traditional study, and to know if the virtual lab has any effect on the students' results. The experimental group who used the virtual lab exceeded the standard group, who used the traditional lab, in results and understanding the basic styles and scientific concepts.

Jensen [Jensen, 2004] and others made a study in Germany, which aimed to recognize the impact of using the virtual lab on the students' results in chemistry. The results of this study showed that there was no difference between both groups' results. This study asserted that using the virtual lab encouraged the users to decrease teaching mistakes which improved teaching outlet and made students accept and interact with this technique.

Balmush [Balmush, 2005] studied the effect of virtual labs in chemistry for university students in Moldova. The most important result of his study was that the virtual labs have a positive effect on students' performance because it makes them deeply comprehend the physical phenomena with the ability to check on the hidden physical phenomena which cannot be recognized in the real lab, which in turn, improved their comprehension of physical phenomena.

[Woodfield, 2005] and others made a study in USA aimed at establishing a virtual lab for Chemistry students at Birgham Young university. The results said that the virtual lab was good for students because it gave them the freedom of discovering in a safety environment without any material loss which built self trust and contribute to more understanding in basic of Chemistry.

[Woodfield, 2005] and others made another study aimed at establishing a virtual lab for Organic Chemistry to relate theoretical performance in the classroom with practical one in the lab. It also aimed at teaching analytical thinking skills through the virtual labs, in addition to evaluating the students' results and performance after they use the virtual lab. The most important result of the study was that the effect of teaching using virtual lab increased students' results levels and improved teaching. There was also a positive effect on teaching Chemistry in virtual labs on both teachers and students. This study also proved that the students saw that the virtual labs saved time and effort and eliminated disorder and potential risks which may result from using real labs.

[Al Radi, 2008] made a study aimed at recognizing the impact of using the virtual lab technique on the students' results in the third high school class in science, Chemistry subject, in the Al Qusseim educational sector. The statistical analysis using "one way ANOVA" method resulted in the following: there was no difference in the average results of the achievement test at the level (0.05) between standard and experimental groups. The study asserted that the students' study level did not descend when they studied by using virtual labs. This indicates that the study by virtual labs affected the study results the same as the traditional study.

A study done by Payne aims to explore the views of 1205 second year students of secondary schools, in the state of Wisconsin–Madison of America, about the importance of using virtual laboratories in online learning. The study has shown that 53% of the sample rejected learning in this way, while 47% responded with acceptance [Payne, 2005].

The objective of Shih study is to strengthen the role of virtual laboratories in the educational process, by taking the views of the 1898 high school students from public schools in the state of Utah, U.S. It became clear from the results that 73% support this trend, and they believe that virtual laboratories are a new step toward distance learning to solve a large part of the suffering in some schools related to laboratory schedules or cost of raw materials [Shih, 2005].

The study of Carl analyzed the views of 578 sciences teachers and 2012 students from secondary schools, Ohio, on the use of virtual laboratories in e-learning. It became clear from the results that both teachers and students support the new experience, but they are not comfortable with their results, especially as they may not achieve the immediate objectives of the educational process [Carl, 2006].

Ritzema and Harris [Ritzema,2008] have created a virtual laboratory for digital circuit design using Second Life and asked students to do their laboratory assignments within this lab. Their aim was to evaluate how effective using Second Life was in distance education. The results of their study showed that 83% of the group would like to see an increased use of Second Life in Computer Science courses and on a scale of 1 (being easy) to 5 (being the hardest), 76.5% of the participants ranked the Second Life user interface three or less in terms of its usability.

Change and Chun-Yen [Chang, 2002] aimed to investigate the effect of the virtual laboratory technique in problem solving, and on the Taiwanese high school students' science achievements and attitudes towards science.

Jensen [Jensen, 2004] aimed to identify the effect of using the virtual laboratory on students' achievements in the field of natural sciences and engineering. Results showed no statistically significant differences between the experimental group (which used the virtual lab) and a control group (which studied using the traditional methods). Studies also confirmed that the use of the virtual laboratory encourages users to minimize the mistakes of education, thus improving educational outcomes and leading the students to accept this technique.

Herga [Herga, 2012] conducted his experiment in Slovenia with 109 students from seventh grade for the year 2012. He applied his experiment on two groups: the first experimental group, which studied Chemistry through Laboratory Crocodile Clips, and the second group, which studied chemistry using eLearning materials without multimedia elements. Using the SPSS program to analyze the data, the results were clearly in favour of the group that studied chemistry through Virtual Laboratory.

Bilek, in his study on the process of virtual education [Bilek, 2011], ascertained that it strongly depends on the efficiency of the teacher. Through his observations from the questionnaire about the virtual laboratory, he confirmed the importance of preparing teachers capable of using the tools of modern technology. The virtual laboratories need teachers to have the skills to deal with this environment to be able to help students get the best results.

Martinez et al. [Martinez, 2003] referred to the importance of the virtual laboratory for simulating hazardous experiments or those that make use of complex hardware. Through such a laboratory, the difficulties of making real experiments can be overcome, by simulating reality without problems in the process. The virtual experimental simulation in an interactive environment is considered as one of the leading fields in adopting virtual reality technology and adapting it to overcome educational problems.

Napier, W. & Waters, L [Napier, 2001] aimed to discover the extent of effectiveness of students' cooperative and interactive experiences in a virtual classroom and compare them with traditional classes at the University of Hawaii, Manoa. The results of their study revealed that the virtual classroom is one of the most effective means to improve learner's performance, and that it can be used at any time or place, with the lowest cost.

Georgouli [Georgouli, 2011] argues that interaction in the virtual learning environments offers much more than multimedia. He refers to the levels of interaction resulting from experiencing the virtual environment, ranging from just checking around what this environment contains to interactions that enable influence on those contents either by change or amendment.

From the above mentioned researches we can conclude that using virtual laboratories in e-learning and in educational institutions would improve the quality of education, if some obstacles could be overcome.

3.4. REAL LABORATORY VERSUS VIRTUAL LABORATORY

Virtual labs are the scientific practice of virtual reality. Virtual labs have a lot of advantages. Through virtual labs, we can repeat the experiment many times and have the same initial result, as well as, we can make them without risk. Simulations in virtual labs help to realize the goals behind the establishment of these labs.

Despite the many advantages of virtual laboratories that have been highlighted in this chapter there are some disadvantages that favor the experimental work in real labs. Below, we try to make a comparison between the two alternatives, by summarizing their advantages and disadvantages.

Real labs:

Advantages:

- Provide practical training skills.
- Learning occurs through a practical approach.
- Provide guidance on how to conduct experiments.

Disadvantages:

- They need advanced preparations.
- They need expensive chemical materials.
- Some experiments are dangerous.
- The results can vary when repeating the same experiment.
- They require physical presence of the student in the lab for doing experiments.
- The number of places in a real lab can be insufficient and not all students can see the experiment executed by a teacher.
- They require the supervision of a teacher during the experiments.

Virtual labs:

Advantages:

- Provide learning through the scientific method.
- Materials and tools are inexpensive.
- Experiments are conducted away from danger and health damage.
- Simulations and 3D visualizations allow understanding some phenomena that cannot be explored in a real lab; also, some simulated experiments cannot be executed usually in school laboratories.
- Experiments can be repeated many times without a change in the results.

- A student can focus on a particular part of an experiment as long as he needs to understand the phenomenon.
- Users need less time to conduct experiments than the time needed in real labs.
- Can be used from any place and at any time.
- Can be used for teaching and learning or for self-learning (don't need the presence of a teacher).

Disadvantages:

- May cause the removal from reality and indulgence in virtual reality.
- Could be only a complement for real labs, but not a substitute.
- Negative effects on users when staying on computer for long periods of time, such as lack of movement and lack of activity.

CHAPTER 4. SOFTWARE TOOLS FOR DEVELOPMENT OF VIRTUAL LEARNING ENVIRONMENTS

4.1. EON TOOLS

These tools, created by EON Reality, allow defining the lesson procedure, the 3D environment, include the mixed 3D and other types of multimedia content and define the event handling. In the end, everything is compiled into an executable, allowing rapid publishing of the application. The visualization is available either on simple monitors or on HMD or other stereoscopic displays.

Basic mode just makes the application available for download and run to any authorized user, but without sharing a common VR space with other users (single user mode). In advanced multiuser mode, the teacher and students can attend together the same lesson, sharing the same virtual space.

The usage is quite easy, suitable with the capabilities of any teacher or student: the teacher creates the meeting and after that sends a special number, "meeting ID", to the students, by e-mail or SMS; with this token, the students are able to enter the meeting in the VR application, at the scheduled time (see figure 4.1.).

4.1.1. EON Creator

To assist users in building their own customized virtual environment in no time, EON creator is provided as a powerful tool, which has direct access to interactive learning contents and can display contents in stereoscopic 3D (see figure 4.1).

[Jamie Justice, 2012], inventor of EON, describes their 3D interactive creation tool as focused to motivate the beginner to create his own learning environment. Moreover, it enhances one's learning experience by immersive and interactive activities. It can help educators to develop own learning modules and applications to tie-up the developmental gap.

With EON Creator, a 3D Lesson can be easily created from existing components or by modifying an existing 3D scene from the thousands available in the 3D library. EON Creator enables to enhance the 3D Lessons and scenes with different kinds of media (videos and sound effects) and other resources, such as: Wikipedia, PowerPoint, Qwiki, YouTube, annotations, quizzes. The 3D lessons can be uploaded to the EON Experience Portal, in this way becoming available to anyone who needs the 3D Lesson. Thus, anyone can use the thousands of 3D resources available on the EON Experience Portal. Once a 3D lesson is ready, it can be distributed to anyone, which can use it on a laptop or on a stereoscopic 3D display, anywhere in the world.

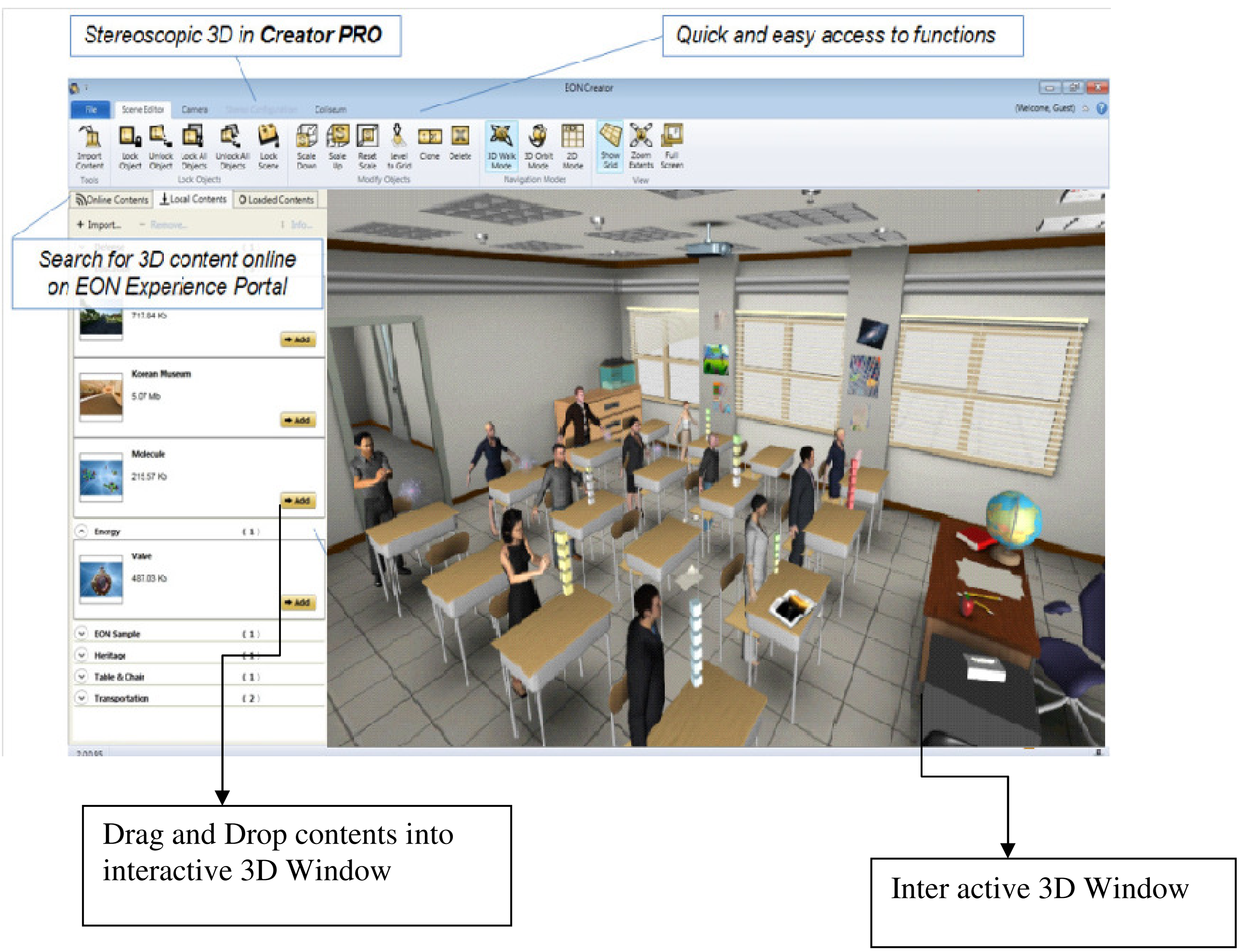

Figure 4. 1. EON Creator

EON Creator is free, easy to use software with key features for effective 3D learning environments creation:

- ➢ Support for some 3D /CAD data files.
- ➢ Import of interactive 3D objects from EON Experience Portal.
- ➢ Scene editing, including position, rotation and scale of objects.
- ➢ Triggering interactions of objects with conjectural pop-up menus in 3D window.
- ➢ Faster authoring of environments.
- ➢ Placement of presentation surfaces for video, PowerPoint, and 3D objects for use in the EON Coliseum [1].

4.1.2. EON Coliseum

EON Coliseum provides a framework for multi-modal communication on different systems, which enables users to interact each other, to offer their thoughts and communicate to understand complex concepts and collaborate using rich media objects such as web pages, presentation slides, video, live feeds and interactive 3D content.

After a virtual classroom has been created, can use EON Coliseum to create a multi-modal communication between all users of the virtual environment. EON Coliseum has many features that can be used to build a cooperative virtual environment. Such are:

- ➢ Interactive 3D Avatars.
  - Avatar public library for unique representation, which can be customized.
- ➢ VoIP Nodes for a peer-to-peer communication.
- ➢ Virtual Presentation Surfaces for text and pictures.
  - Main document formats like PPT, PDF and JPG to give user automatically maps.
  - During presentation, user can switch between various applications.
  - The user doesn't need to restart the software, when he run-time update of the Virtual Presentation Surface for last-minute edits.
  - Numerous options for advance slides.
- ➢ The Data link can connect virtually to any software via TCP/UDP.
  - Readily configurable data structure for general communication.
  - Backing communications with any software that uses TCP/UD.
- ➢ Network structure management for multi-user environment.

- The client-server design brings virtual environments to life by interacting between virtual entities such as avatars in real-time.
- Voice or texts are the functions to connect users, but the messaging function provides users with extra communication channel on top of voice [2].

4.1.3. EON Experience

User can create 3D objects and can also share 3D experience. The virtual environment contains interaction of 3D with video, audio, and other tools like power point, etc. The global community of 3D learners can also be joined together for free. 3D learning can be made easy by EON lessons which may contain many subjects.

- Biology 3D Lessons.
- Engineering 3D Lessons.
- Science 3D Lessons.
- Geography 3D Lessons.

The creation of virtual 3D lesson is very simple, which start from just searching and dragging objects from 3D library to screen. These objects can be combined with videos and sound effects. Once the project is finished, you may start another project and it's even easier for re-creating, because objects can be taken from previously created.

Multi users can interact with the virtual environment you created, once you publish your project with EON coliseum. The interaction can be made using voice or text from anywhere.

Many students can share your 3D project any time and from anywhere with anyone in the world. They can have multi-user learning meetings and actively immerse themselves in the 3D environment with the use of 3D avatars, voice, chat, and 3D hands-on interactions [3].

4.2. OPEN SIMULATOR

4.2.1. OpenSim Concepts

The following terms and concepts are commonly used in 3D MMO Open Simulator framework:

- Entity: something that exists in a 3D simulation. It has a position in the virtual world, rotation speed, etc. It has the responsibility to provide a proxy for physical configuration that can be passed to the physics engine.
- Primitive: common entity in OpenSim, with a simple procedure for shape generation and efficiently serialized representation; implements all the concepts of an entity, plus specific concepts of LLUDP (Link Layer Discovery Protocol**.** In addition, some generic concepts as well as implementing the script container.
- Mesh: any entity that encompasses geometric information in place of the procedural geometric generation instructions. Depending on the implementation, a mesh can implement interfaces or not, additional script as well as container and LLUDP concepts.
- Avatar/stage Presence (presence Scenes): another type of entity that represents a character. These interact with the scenes and their entities by generating events and "subscribing" to the generated stage. Due to the high number of events occurring within a scene, they are divided into subsets, which can be deployed at the choice of the stage presence.
- Agent: the internal representation of a client that connects to the simulation using the network. It can be:
  - a user connected through a viewer;
  - a search engine that wants some data acquisition;
  - a proxy that controls multiple connections;
  - an external engine that sends data and receives data from the simulation;

The agents are identified through the communication protocol that they implement.

- Client: any program that connects to an OpenSim server through a network.

- User: a person who connects to a server through an OpenSim client program. Optionally, it can have an account and support the persistence of its information.
- Viewer: an application used to view the status of a simulation.
- Service: is a system that provides data to one or more simulators. An example is the data media services (Asset Services), which provide data for objects such as textures and scripts, and inventory services that provide inventory for a user organization.
- Session: connection between a viewer and a region.
- Assets: may include textures, sounds, scripts or notes which can be transferred to other users.
- Verb: the action of initiating an object in the simulation, either directly from pre-existing primitives or from an existing object stored in the user's inventory.
- Region: has a position (x, y) in the grid and an identifier of the region (region-handle) calculated according to the position. Unique ID of a region is the UUID (Universally unique identifier), and if the region changes its position, the multi-stop slider (region-handle) will be recalculated because it uniquely identifies the item in the grid.
- Simulator: a program that manages several regions.

4.2.2. Presentation of OpenSim

Open Simulator (http://www.opensimulator.org) is open source software with the goal of creating 3D virtual environments that can be accessed through an assortment of clients on multiple protocols. Many users can access OpenSim and improve their virtual world in many applications, such as virtual learning. OpenSim is an open source virtual community platform that has been widely used in education, games, business, tourism, cultural heritage protection and many other fields. An OpenSim 3D virtual teaching platform takes advantage of Virtual Reality in immersion, interactivity and imagination; it enhances the interaction and experience in the teaching process, which can improve the students’ interest and initiative in the whole learning process.

The Open Simulator project (OpenSim) [4], is being developed as an open source, freely available as an alternative to Second Life. It has the advantage of being able to use the same client-viewer as Second Life which is also open source. This is not necessarily an alternative for all those who wish to use virtual worlds for education and like most open source projects, it requires a degree of technical expertise to deploy and maintain. It is of considerable interest, especially in Computer Science and other ICT oriented disciplines which typically have the appropriate local expertise to install and exploit open source software.

Open Simulator can be run on Windows and on UNIX since it is written in C#. Currently there are several representative sensors implemented in the OpenSim environment. These include pressure sensors, radio frequency identification tags and readers, and security keypads. The default OpenSim scripting language, Linden Scripting Language (LSL), allows sensors to be efficient and it is similar to Lua or JavaScript.

Open Simulator can be used to create virtual environments comparable to Second Life, which specifies that it supports the core of SL's messaging protocol. In addition, this virtual environment can be accessed by the regular Second Life viewers. Open Simulator is not a rewrite of Second Life's server Second Life does it aim at becoming a clone. Quite the opposite, Open Simulator lacks support for many of the features from Second Life [5].

Open Simulator is a framework and an implementation of virtual 3D MMO space. It is a very well defined framework of entities, functions and services that provides the basis for such a simulator. This simulator is referred to as a region, and contains most of the architecture of the virtual world. Simulators of regions interact with other simulation and other clients via the communications services and entities. Together, these services are known as grid services, and include a service user, service grid, service assets, inventory and customer service and the messaging service. An OpenSim instance consists of a layer of regions, grid layer and an application layer. The application layer, in addition to the regions and the grid could be thought of as containing one or more clients.

4.2.3. Open Simulator's login process

How does a viewer log into an Open Simulator grid? All the regions and grid services are running under a single OpenSim.exe process (See figure 4.2).

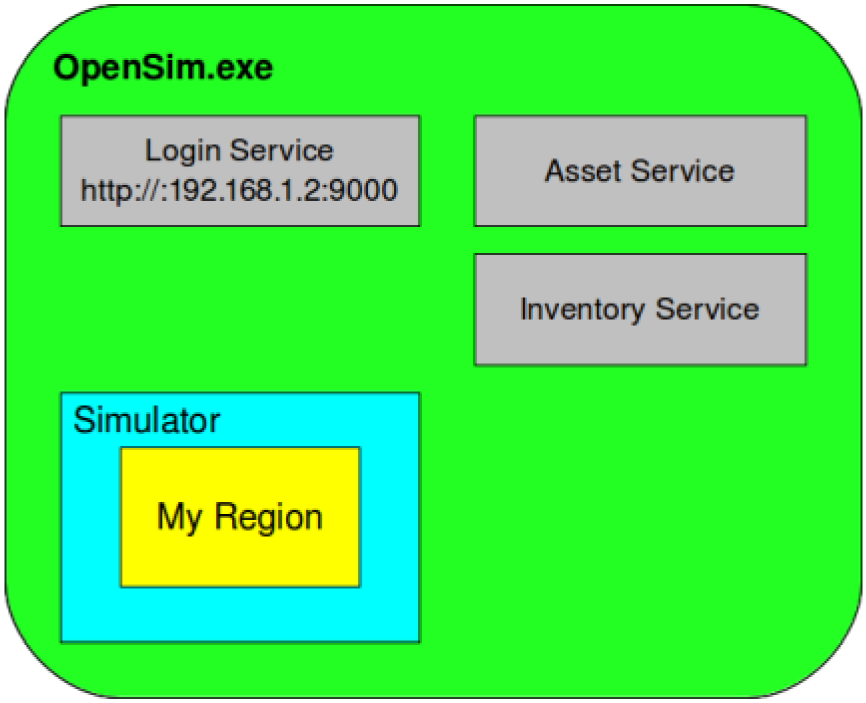

Figure 4. 2.OpenSim.exe process.

Step 1: The user sends an XMLRPC message to the Login Service URI; where in the message the name and password are contained.

Step 2: After logging in the user goes to the simulator where he has only one region called "My Region". He can set up that Region by logging and recording the code 'agent'.

Step 3: The simulator returns a randomly generated login service with the IP and port address of the region. The External Host Name and Internal Port entries are found in the bin/config-include/Regions.

Step 4: When the user receives the XMLRPC answer, it extracts the simulator IP and port.

The contact with the simulator starts and then the simulator sends back Ack packet, and the two starts talking to each other [6].

4.2.4. The Components of the Open Simulator

To start using the OpenSim you should choose a client to access the server provided by Linden Labs. In figure 4.3 the interface of OpenSim is shown and you can see the navigation region as the main operating area, with texture-mapped and box and an open window to show an overhead map and text communication window in front of the avatar.

There are three key terms used for people who interact with this type of environment:

- User: the person who is the user of the client software
- Agent: the user's identity in-world
- Avatar: Visual image that represents the user in the virtual world [Paul, 2009].

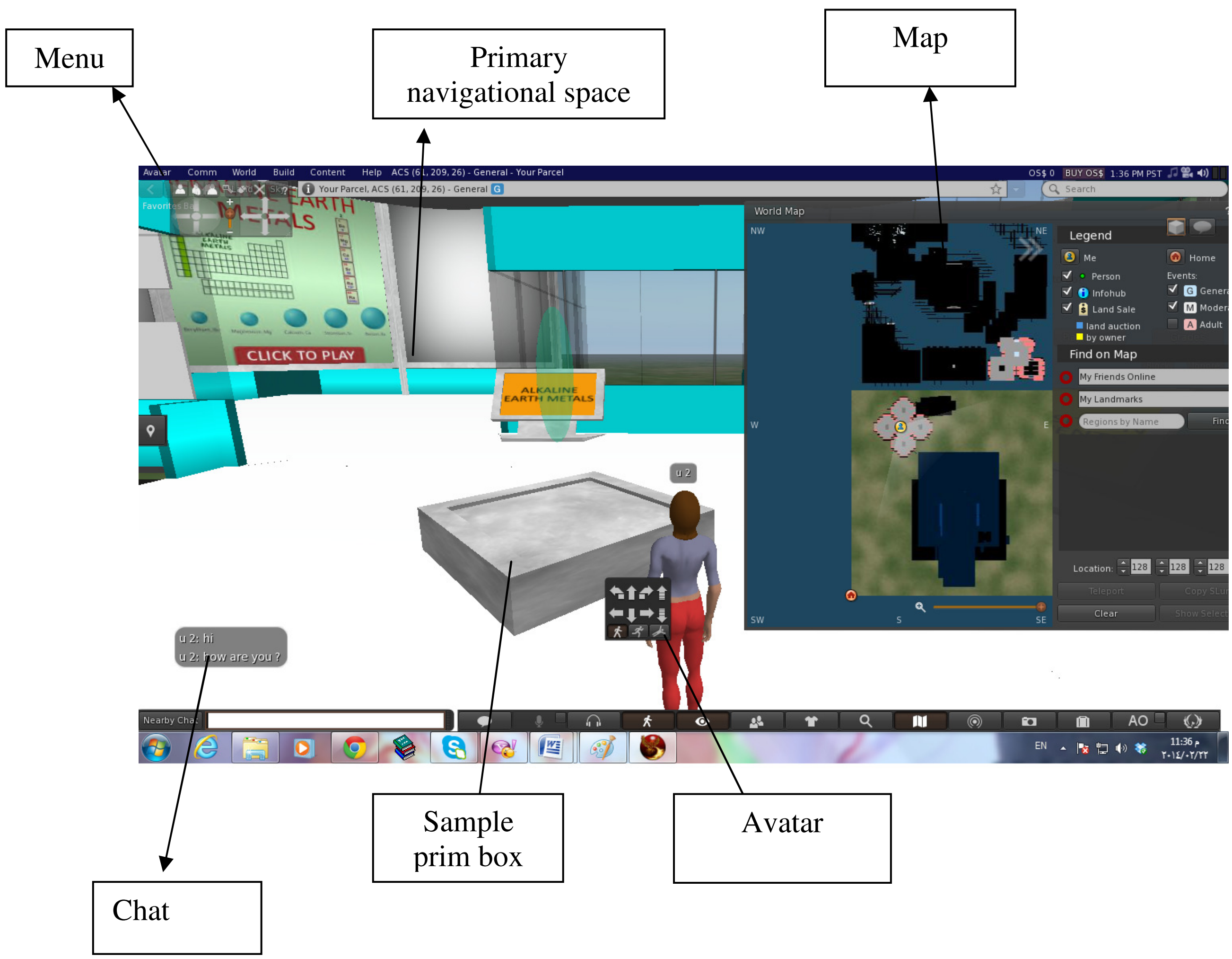

Figure 4. 3.Typical interface for OpenSim in the client software.

4.2.5. Server

An Open Simulator server consists of regions (run on simulators of the region) and data services (such as user name, assets and inventory management). The server can run in multiple configurations:

- Single server (standalone) - in this configuration, the types of persistent database supported are SQLite and MySQL. A database of MSSQL type is there and should work, but is not officially supported.
- Grid (multi-server) – in grid mode, persistence is officially supported only for a MySQL database, and in an informal way, and can be one of the MSSQL.
- Hyper Grid – This is a non-orthogonal architecture (independent of the other two), which allows users to visit the other OpenSim completely separate environments, while it maintains its appearance, identity and inventory.

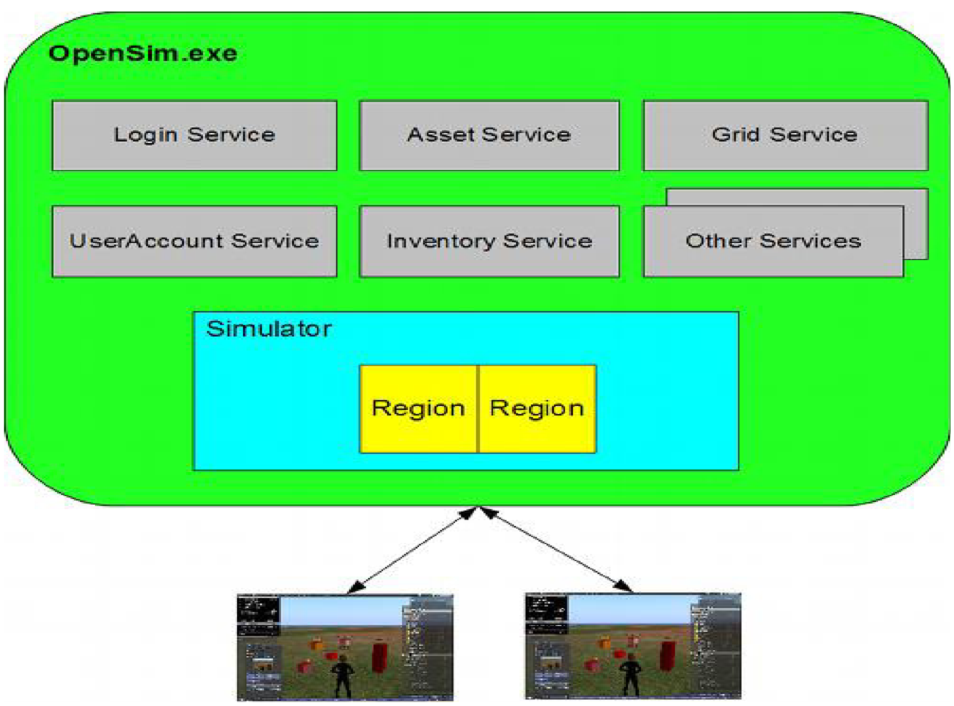

Figure 4. 4.Stand alone Architecture [1]

A system running in standalone mode runs so the region Simulator as well as all services of data in a single process when running OpenSim.exe (see figure 4.4).

In Grid mode, data services are not portion of the trial dealing with the regions. But, these end runs in a separate Robust.exe executable file. ROBUST process can run all services or they can be distributed among multiple instances of the process, be they on different stations. In this way (Grid) the process of OpenSim file has only the role of a server, which manages one or more regions. Thus, you can run multiple processes on different machines to avoid the overloading of stations and to ensure performance (see figure 4.5).

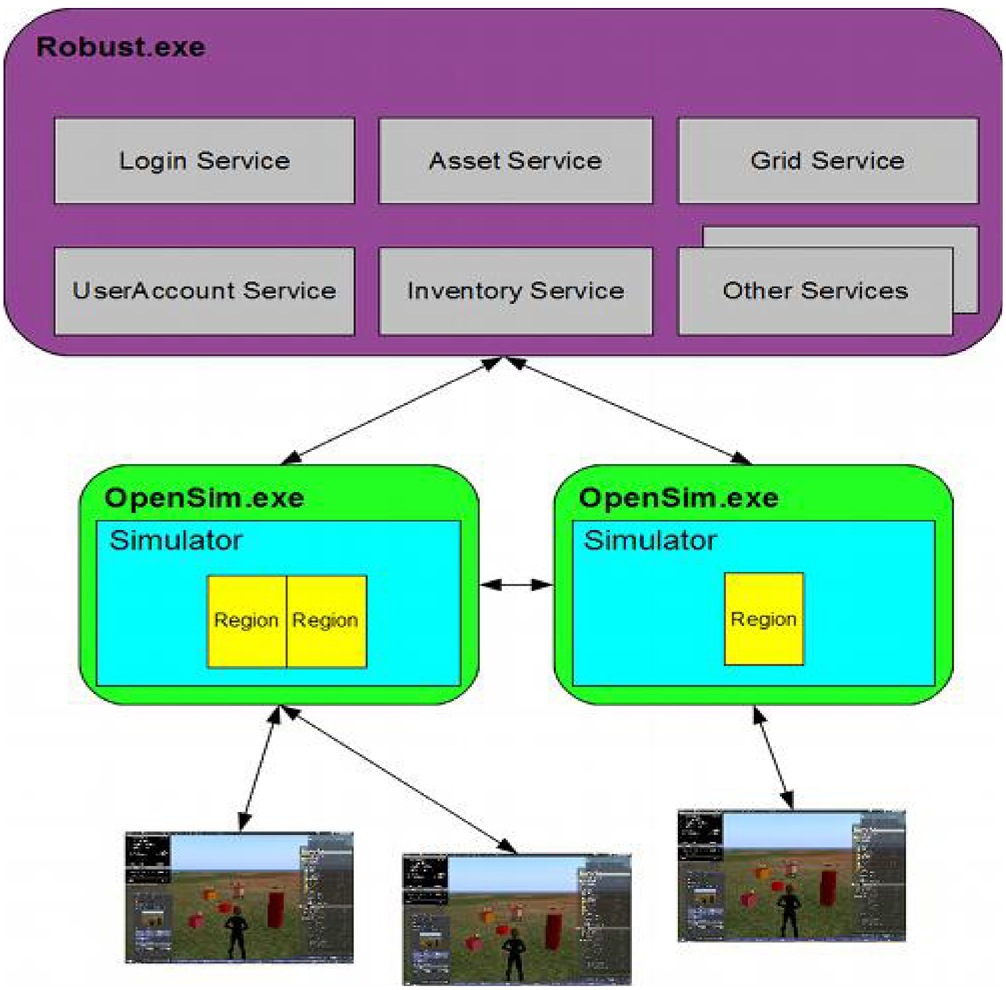

Figure 4. 5.Grid Architecture [2].

Running in network mode (Grid) is more complicated than in stand-alone mode. It takes an understanding of concepts such as the UUID, X, Y, location, server handshake, domains, landlords and others [6].

Main features of the server

Primitives:

- Create/change/move/Delete primitives
- Persistent Inventory of primitives
- Groups of objects
- Basic types of assets
- Media content Placement on a primitive (web browser, streaming, etc)
- Dynamic Textures
- Mesh (in beta version)

Users:

- Chat
- Instant Messaging
- Friends
- Groups
- Profiles

Worlds:

- Sound
- Mini map
- World Map
- Neighboring regions
- Parcel Management
- Regional settings
- Teleportation

Others:

- IRC
- Permissions
- Statistics
- Capture voice (microphone)
- Web Interface
- Search Mode

Server:

- Local console
- Remote Console (remote)
- Remote Admin (unsecured)
- A Journal

Architectures:

- On a single server (Standalone)
- Multiple servers (Grid)
- Hyper grid

Configuration

The configuration is done using the OpenSim file. It covers other configurations from the config-includes. Information about the detailed settings is commented in the file or in the OpenSim.

It is possible that the file to be distributed into several parts when it is desirable to run processes in which the OpenSim settings are largely identical.

The database configuration depends on the DBMS (Database Management System).

OpenSim supports the following systems:

- **SQLite** (default)-a simple database, which comes bundled with Open Simulator and can be used without requiring any additional configuration. This is mostly intended for quick installation and not for production use. It is significantly slower than MySQL and the disadvantage is that it does not have yet fully implemented some features (such as the persistence of attachments).
- **MySQL** (fully implemented-with all the features)-this is the database recommended for any use beyond experimentation or small self application in its own right.
- **MSSQL** -persistence for some features in the recent Open Simulator It is still being implemented, although the vast majority of them are supported.

Already compiled distributions are configured by default to run in Standalone mode.

However, if you build your application from the sources they will have to be made a few changes:

1) To enter in the bin directory of the server.
2) To copy or rename the file OpenSim. Example to Opensim. This ensures the setting up 3D Simulator itself.
3) To enter the directory bin/comfit-includes.
4) To copy or rename the file in Standalone Common.in.example Standalone Common. This ensures that the configuration of data services used in Standalone mode.
5) In the section [Architecture] of win.ini, OpenSim file near the end, Removes the comments in the line containing Standalone. To uncomment a line of code, delete the first symbol (at the beginning of the line;) so set up to reach Includes-Architecture = "comfit-includes/Standalone"

Running the Simulator has been then just a matter of running OpenSim executable.

However, it is necessary that all its prerequisites are installed before this:

- For Windows:
  - The .NET Framework 3.5 (Windows 7 and Windows Server 2008 have already installed this); version 4.0 is not supported yet
  - Older versions, 2000 or NT is not supported, while Windows XP must have at least Service Pack 2
  - To execute in the command line: OpenSim (x 86)
  - Opensim. 32BitLaunch (x 64)- for 64-bit Windows, ODE cannot be compiled yet, so to be able to use this plug-in you need run in a compatibility version.
- For Linux: Mono 2.4.3 is required-or higher (preferably 2.6 or 2.10. x). Supported and tested on various distributions:
  - Ubuntu
  - Debian (version 5 or newer)
  - RedHat Distributions

If we run Open Simulator, for the first time we will have to introduce more configurations in the initial console, which will define a single region, and a domain user. The configuration options that you enter will be written in the bin/Regions/Regions, we can subsequently change, where we need to make changes. Many of the settings have default values specified in a square bracket.

In the order that they are displaying it is required:

- New region name –The name of the region is mandatory.
- Region UUID –A unique identifier for your region. Will usually accept the default value that is generated randomly in square brackets.
- Region Location-this is the location of the region in the grid. In Standalone mode, you can leave the default value (1000, 1000). However, we must make sure that when we add the other regions they have been coordinated differently (for example 1000, 1001). Open Simulator regions can be placed on a grid of size 65536x65536.
- Internal IP address-in most cases you can leave the default value of 0.0.0.0 (this is a wildcard that allows the Simulator to listen to UDP connections any network interfaces). If you want the restriction to a single UDP connection network

interface, you can specify an explicit IP address. The address is only used internally.

- Internal port-this is the port that is used for all client connections. Misleading name because it used both externally (a Second Life viewer, for example) as well as internally. Can be used on any port, but the default is 9000. Each region must have a unique port.
- External host name-the default value for this setting is SYSTEM IP, which means that it will take the value of the local network address (LAN-for example 192.168.1.2). This is useful as long as we connect to the server from within the local network. If you want to connect to the internet, you have to assess our IP address from an external router.
- Allow alternate ports are a setup which is still experimenting. It should be left the default value (False).
- New estate name-The name of the domain in which it will be included in .
- Estate owner first name-The name of the user that will manage the domain. The default Value is a test.
- Estate owner last name-name of the user that will manage the domain. The default Value is the User.
- Password- The password for the domain administrator.
- Email- the Email for the administrator. You can leave it blank and it is optional.
- User ID-A unique identifier for the administrator of the domain or region. You can leave the default value in brackets.

Not to be forgotten the details first introduced user, whereas only it will be able to initially modify the settings of the simulator for the region and for the whole field. You can define other users using the console commands (user created).

4.2.6. Client

Content creation (building): there are many options in building tools: build, elect build too, link, unlink, and select linked parts, objects, scripts, path finding, options, upload, undo, redo, and all these tools help the user to create a virtual environment in OpenSim.

*Select Build Tool***:** to choose one of the options which are: focus tool, the move tool, edits tool, create tool, land tool?

Focus Tool: includes the options: zoom, orbit and pan. These help the user to focus on the 3D objects he creates in OpenSim.

Move Tool: includes: move, lift, and spine.

Editor Tool: move, rotate, stretch, select face, align, edit linked, stretch both slides, stretch texture, snap, edit axis at root and show highlight.

Create Tool: includes keep tool select, copy selection, center, rotate copy. Here are many 3D objects , and the user can just choose anyone he desires such as a cube , a prism , tours ,cylinder ,tree, hemicy linder, tube, pyramid, ring ,tetrahedron ,sphere, ,hemisphere, grass.

Land Tool: includes the options to Select your land, buy land, and subdivide land and another option that is used when you want to create your land to revert, roughen or smooth land.

Upload Tool: The user can upload images, sound, animation, mesh model, bulk.

General tab: Shows the name of objects in front of the user in a virtual environment, and it contains description about the 3D objects such as who created it, who is the last owner and he can also share with groups within this environment. In the general tab anyone is allowed to copy or move objects and modify them.

Object tab: There are many options here that you can use to create objects. Some examples are: locked, physical , temporary , phantom, other effects in building object path cut, hollow, twist shape , taper , top shear , silica , and radius. Another option is to determine the position of the object, its size and the ability to rotate your object.

The Features tab: Here the user can select only one primitive to edit features, in a flexible path there are a lot choices of softness, gravity, wind, drag, tension force x, force y, force z, light and physics shape type. If you want you can also identify gravity, friction, density or bounciness.

The Texture tab: It allows you to make a texture for your object and you can choose the colour with transparency or glow effect. Other options are mapping, shininess, bumpiness, repeats per face (horizontal, vertical, rotation, and repeats), and media.

The Content tab: Here you can see your script, permissions or refresh the script .In the permissions sections you can edit the content permissions or add new content permissions and determine the group, another person or the next owner.

Avatar: Here you can determine the avatar and have options such as: buy, preferences, profile about avatar itself, many options to move in the virtual environment, and of course you can upload your avatar.

Movement of the avatar: After the user finishes the procedures for grid connectivity, he can see that up on the screen, in front of him appears the virtual environment of Opensim. In this environment, he can see his avatar which he has chosen and also the personal appearance incarnated onto him. Now the user can control the avatar through the keyboard, mouse or the mouse wheel to zoom in and zoom of the screen. Here are numerous options that allow you to control the avatar through the menu tools. With this tool the avatar can choose one from several options of movement in a virtual environment. You can choose for example to: sit, or if you would like to move faster you can choose: fly, run, quick jump. The user determines the movement which he wants, because the Avatar represents him in this environment, so therefore he can totally control it.

Personalized avatar: In the virtual world you cannot see the real user, but you see the avatar that represents the real user in the virtual world. Therefore, any user with access to OpenSim should choose an avatar that represents him and that avatar must and will be unique. All the activities or chat and any dialogues from the avatars in the virtual world are done by the real user, but you cannot see him as if you would in reality.

The appearance: The user can make appearance choices for his avatar. He can choose clothes to for his avatar to wear, also the default skin, shape, hair or eyes and after finishing he saves this appearance in the avatars' profile.

Editing the avatars' shape: You can by default shape the avatars' body , head , eyes , ears , noise , mouth , chine , torso , that means that you can create a special avatar of your liking as you would prefer the avatar to appear.

Uploading the avatar: With this tool you can customize the avatar with several options that allows the user to upload it, for example, an image, sound, animation, mesh, bulk and sets the default upload permissions.

The Communication tool: is an important tool in virtual worlds since with this tool many users can communicate with each other through tools such as chat or voice communication. The user can choose what his online status is and determine his friends or a group of people that he communicates with them. If there are many users online at the same time, they can simultaneous conversations together online. The most important characteristic of an OpenSim is that it allows communication between avatars.

Chat: By using the keyboard the user can write a text message to other users and he has the possibility to see previous messages that were written, like a history feature of communication. If his friend is not available at that time he can send him a message and when he comes online he can read it.

Group: When your friends come they can see it, and you can send them through chat, contacts or contacts with audio. You can also expose the group to determine if your teleport will join you. In this virtual world you can only accept friends or you choose who will join your groups and whether there will be one group containing all its members, so that all can reach each other with the same messages. Additionally, there is the option to cancel your connection with a user by utilizing the block list, if you don't want the presence of a person in your virtual world. Furthermore, you can join another group and interact with them .We can notice that in this kind of environment, there is a high degree of social interaction between the users. OpenSim has similar options such as Face book, Messenger and other social media of showing and specifying your status.

The virtual world in OpenSim: mini-map, world map, teleport home, environment editor, area search and many other options.

The World map: From the world map you can see your position in the virtual world, and give you information about your position.

The Touch tool: In the virtual world the OpenSim is large and the 3D objects in its' space, so there are several ways to help you to identify these 3D objects and easily access them.

The Buy tool: In a virtual world, you can live like you would in real life and do common things such as the possibility to buy what you need or what you want such as clothes, land fields and so on. By clicking with the mouse on buy, you can afford to buy from stocks in OpenSim from the internet. Currency in OpenSim is Linden Dollars (L$) the same currency as in Second Life. On the bottom you can see how much the item costs and after that you can decide if you want to buy it or not, save it or take copy of it in your inventory.

Snapshot: If you would like to take photos of what you see in your virtual world, you can do that with the Snapshot tab. After taking the photo you can send it to your friends by Email, or you can save it in your computer, or keep it in your flicker and at the same time store it in your inventory in your world. See figure below. That means that you can modify a photo album of your life and activities in the virtual world, a feature that attracts many young users and strengthens the communication between them through such virtual environments (see figure bellow 4.6).

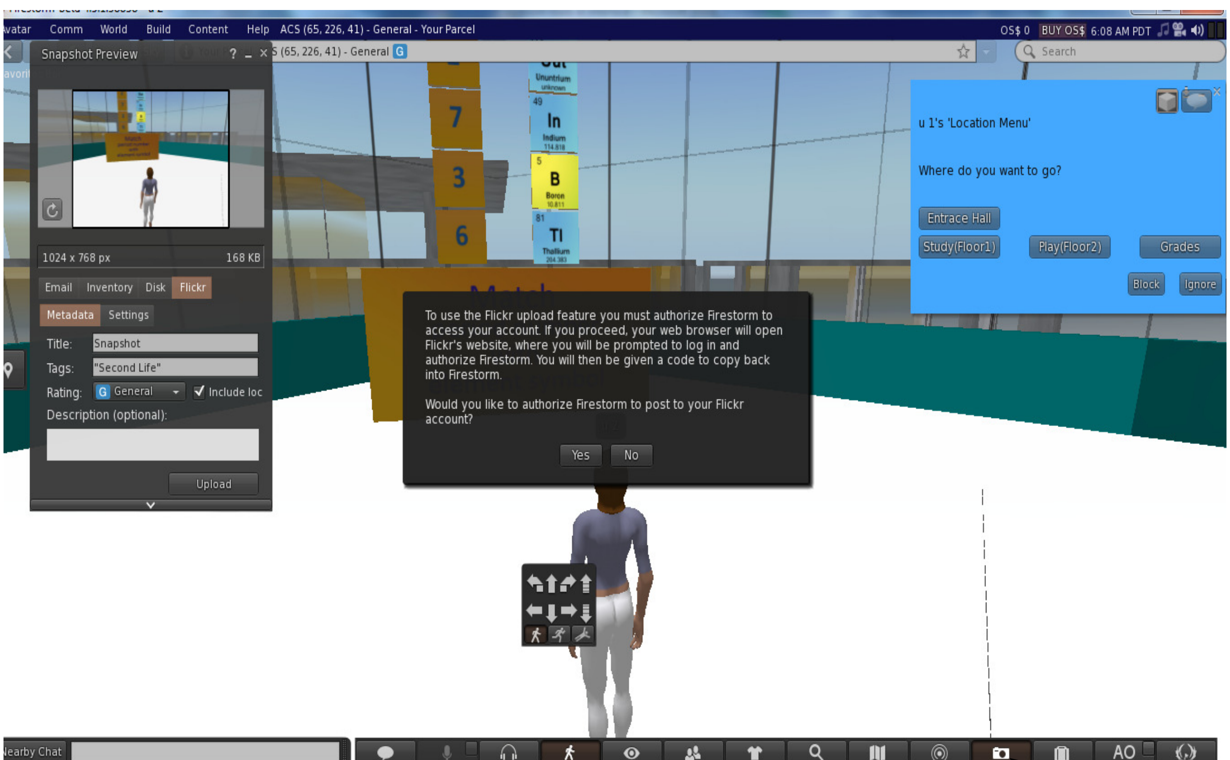

Figure 4. 6.Snapshot

Snapshot

The Map: With the map you can determine your location and therefore to determine your destination path. The map will show you your location and other avatars positions. There are also a number of tools on the map to help you make the transition easier. With the teleport you can move very easily throughout the virtual world and you can save a place in your inventory of your map so as to return to that place some another time . If you want to search a friend or land you can use the world map for that.

The content tool: The search tool, the script library which helps the user to create a special 3D object, a blog from firestorm, show content from YouTube of any video clip and firestorm from Twitter or Plurk.

The Help tool: The OpenSim tool helps the user to create his virtual world, so he can find the help option when he needs help with his work. Some of the help is available for when there are problems like the inability to view the UI hints, firestorm Wiki, to report bug and others.

The Firestorm search: In OpenSim you can search the web, search for people, groups, places, land sales, events, and classifieds.

The Inventory: Here you can see everything you save it in your inventory. In OpenSim you can store your 3D objects in the inventory. Each avatar has an inventory and all the 3D objects in the inventory were created by the user or he purchased them. Many things can be stored in the inventory such as: texture, animation, clothing, script, body part, and others. You have the possibility to organize your items in the inventory, sell them or maybe wear it and in case that you don't need, you can delete it.

Quick preferences: you can add quick preferences in your virtual environment in the OpenSim world.

CHAPTER 5. PRACTICAL CONTRIBUTIONS

In this chapter we describe four applications developed by the thesis' author. All of them contain 3D virtual environments with multiuser facilities. Their objectives, content, implementation and evaluation were presented in papers published by the author of this thesis: 5.1 [Shudayfat, 2012], 5.2 [Shudayfat, 2013], 5.3 [Shudayfat, 2014-30], 5.4 [Shudayfat, 2014-32].

5.1. A 3D VIRTUAL CLASSROOM FOR TEACHING CHEMISTRY

Have you ever wondered what your students would say about your class if they could hide behind an avatar in this class? Or, if they can choose the appropriate time for them to enter the class, a place where students can study more and find out information from different sources of information? What your students would say about a place where they can learn and act freely, without embarrassment, which is one of the biggest factors which hinder the study process? A place where students can access many types of learning objects, articles and multimedia educational application, like in a virtual library.

The major challenge that confronts Chemistry teaching is how to teach and explain the main concepts using innovative methods and how to make the chemistry lesson more attractive for the students. Instructors may improve the lectures by merging traditional boards and audio with visual tools, that makes chemistry more alive to the students, as our future students are mostly dependent on visual learning due to the image-centric visual world in which they are raised.

The 3D perception can also improve the understanding of a chemistry lesson (e.g. the 3D molecular forms of atoms). Also, a 3D virtual environment for teaching chemistry adds more advantages to a traditional way of teaching. These environments are simulations where instead of being an outside viewer the student is part of the simulation, allowing him to explore, discover, and create goals of his own within the simulation. We believe that a virtual environment with a high degree of interactivity is substantially better than one without interactivity.

The aim of this application was to create a friendly, collaborative and innovative virtual environment in the field of Chemistry, a fundamental discipline that accounts of life at the molecular level.

Our virtual classroom offer a combination of different resources, all in a 3D environment: from creatively displayed web links to instructional video clips, learning objects, text based documents, interactive spreadsheets, blogs, wikis and branching stories. We tried to create such a wonderful place for students, where learning is fun and motivating.

The 3D virtual classroom implemented by this application offers some advantages over traditional teaching and learning methods and tools:

- Provides 3D representations of the objects for each lesson of the course.
- 3D Avatars are used to represent teacher and students.
- Both the specific 3D objects and the avatars are mixed in a 3D environment, which leads to user immersion into the subject of the lesson.
- Provides a high scale communication channel such as, instant messaging, voice over IP systems similar to a face-to-face conversation, giving students the ability to collaborate, discuss and chat about the events and artifacts within the virtual world. Although the students will appreciate if they can develop relationships with other students. Our 3D environment allows students to leave messages for teachers and other students using documents, links to web sites or videos. It can also serve as a meeting place for live discussions instead of threaded text in the forums or a place for students to work on an application together.
- Provides and supports the teacher and students with a collection of resources such as: electronic documents, forums, videos, PowerPoint presentations, and links to Web sites.

For the creation of our virtual environment, we selected the software package named EON Creator. We found it suitable for our case. Thus, it offers extremely easy-to-use modeling and composition using the 3D editor with direct access to a large database of interactive and optimized 3D content on EON Experience Portal. It is a tool that allows users to build engaging, interactive learning simulations for training, education and presentation purposes.

After we created the Chemistry virtual lesson we published it on the EON Experience portal (http://www2.eonexperience.com/eon-models/details.aspx?cid=5163) and we received a "Meeting ID", which allows the users to connect and participate to the lesson by using EON Coliseum.

The first experiment that we have implemented in our virtual environment is a lesson about the periodic table.

5.1.1. The Chemistry Periodic Table lesson

We created a virtual classroom presenting all the objects that can be found in any normal class (see figure 5.1).

In our virtual class we have many 3D animated/dynamic objects such as chemical elements, atoms and the Periodic Table.

Figure 5. 1.3D Virtual Environment representing a classroom with all possible objects.

For the atoms we tried to go deep to present all the atom's main components which consist of three main particles located in two regions: the nucleus, containing protons and neutrons, and the second region, which surrounds the nucleus and is termed an electron cloud. The cloud holds the third particle which is a negatively charged electron. So, in this virtual space the students will notice, determine the location of the electrons in "P" orbit and "S" orbit and make a comparison between them (see figure 5.2).

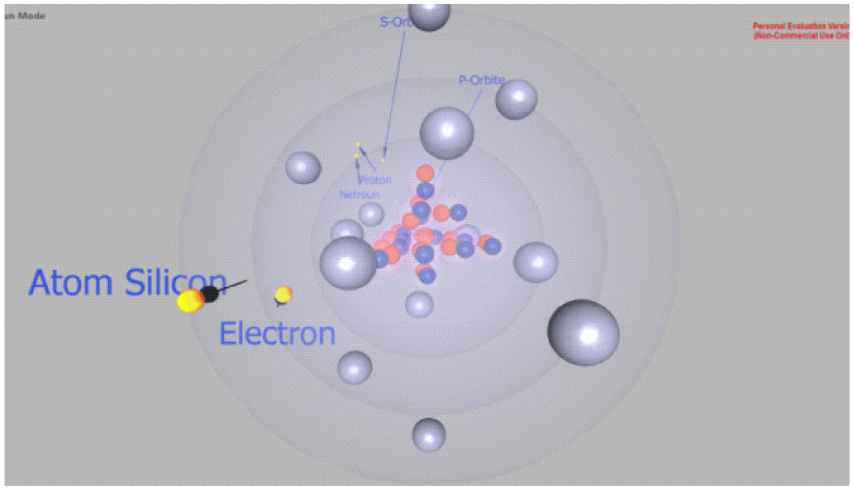

Figure 5. 2.3D dynamic multi-layer representation of Silicon atom.

Thus, we introduced a new way of representing chemical elements. Unlike the existing way, which is two-dimensional, this new way is a three-dimensional one. It arranges the elements in a structure with more levels, giving a clear, spatial perception of different relations within the chemical elements.

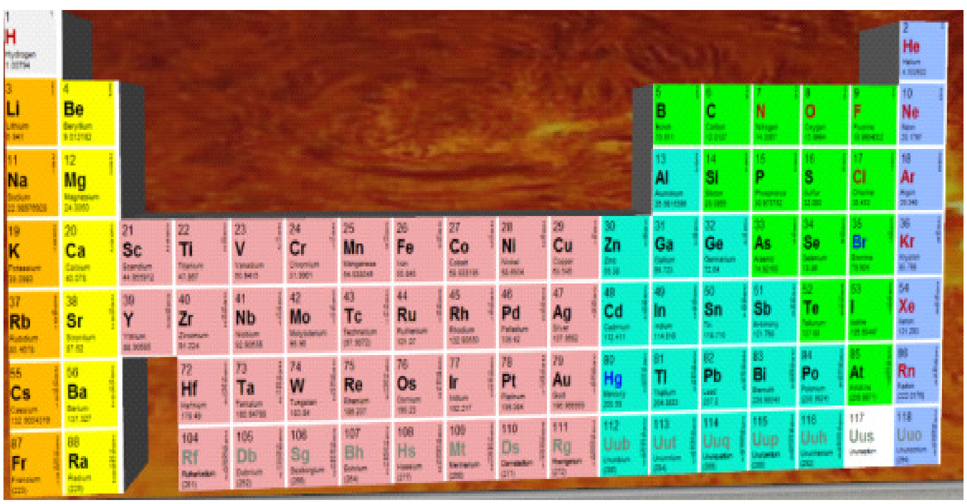

Figure 5. 3.Interactive Periodic Table.

In this virtual lesson we represented the Periodic Table in full format and also we divided it into many groups. We put every group in front of a student avatar. The student can explore the components of each group, to recognize the chemical specifications for each element. The student can compare atoms based on atomic numbers and recognize the item code number and the electronic number. By clicking on an element of the Interactive Periodic Table (see figure 5.3), the student obtains further detailed information.

Our **Periodic Table** lesson key features are:

- Extreme ease-of-use
- Easy to manipulate and run interactions with the objects from the virtual class
- Rich surface for video, PowerPoint, and 3D objects
- Support for stereoscopic 3D presentations.

The teacher set all or some of the authoring options for each object of the virtual space, using the Interactive Authoring Configuration Tool supported by EON Creator (see figure 5. 4). Students will try to check those at run time, to explore more information about a specific object. The Interactive Runtime Tool (see figure 5.5) appears for each object so the student can navigate all the available options (including PowerPoint, Video, 3D animation, Quiz).

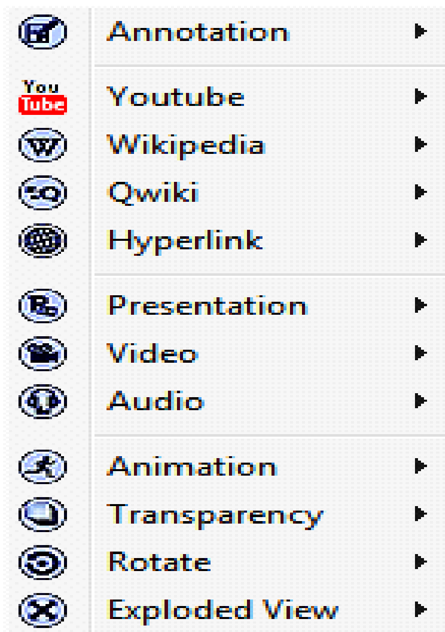

Figure 5. 4.Interactive Authoring Configuration Tool

Figure 5. 5.Interactive Runtime Tool.

For more dynamic and more attractive environments, EON supports many animation options especially for avatars. We used these options to make our 3D virtual class more fun and interesting (see figure 5.6).

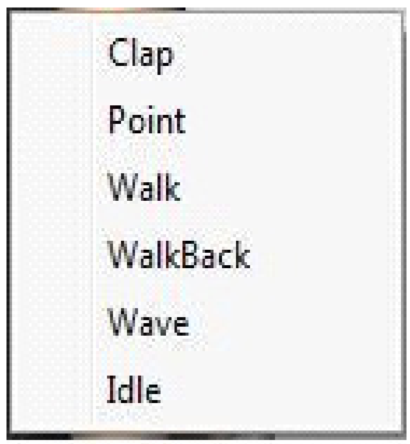

Figure 5. 6.Avatar's Options Status supported by EON run time.

Our chemical lesson has a VR interface that provides rich representations in colors, textures and behaviors, and allows for real-time navigation within the 3D virtual space. This enables students to engage and interact with visual graphics, images and 3D shapes in a virtual space, at different levels of representations. And also it supports online, interactive 3D meeting services that allow students and teachers collaborate in a more effective way, using the power of interactive 3D and multi-modal communication.

5.1.2. Using the lesson

The students need to download the software "EON Coliseum" to connect to the lesson and participate in our virtual class. The download site (no need to register), http://www.eonreality.com/eon-coliseum/, offers support for students and teachers with a ready to use virtual meeting environment, with a clear VOIP service in unlimited meeting space, one to one and one too many. The software and minimal hardware requirements to use the virtual class (at least) are:

- Microsoft .Net Framework 3.5 and later installed.
- Windows XP/ Vista/ Windows 7 (32-bit and 64-bit).
- Intel CPU 1GHz CPU with 2GB of RAM (Vista and later).
- Participants wishing to connect to audio using VoIP will need a fast Internet 384 kbps (connection upstream or more recommended) a microphone and speakers.

By using the tool which comes with EON application, called "Coliseum 2.0", the students and teachers have the ability to communicate virtually anywhere, anytime. The student does not need an EON Coliseum account to attend an online meeting; he can participate, just as a guest or an attendee at totally no cost to him. And also our virtual lesson is designed for small to medium group multi-user environments (up to 30 users/students). Performance may vary according to network traffic conditions and the attendees' hardware capabilities.

The teacher invites the students to participate to the lesson by sending them the "Meeting ID" by email or SMS. After the students receive the "Meeting ID", they can run EON Coliseum 2.0 on their PC's to participate in the classroom. The main screen will appear on the desktop and then the student must enter the "Meeting ID "exactly the same as he received from his/her teacher (see figure 5.7). The student chooses a Nick Name, and any Avatar from the sliding list. After that, he/she can join the virtual class.

Before continuing with the lesson the student need to know what we mean by the word "Avatar". Because direct experience seems to act as an exceptionally strong catalyst for learning, providing a learner with an avatar, a physical embodiment of the learner in the 3D world appears promising from an educational perspective. In addition to the direct pedagogical benefits, lifelike avatars offer significant motivational promise.

When a student joins our virtual classroom, he/she will directly be in the virtual space and appear like the avatar which he/she selected in the join screen, with his nickname as a caption (see figure 5.8. a. and 5.8.b). The student can select any navigation method to go throw all the objects, but first he/she must set up his/her audio option (speakers, microphone). In such an environment all the users will see each other's avatars in the same virtual space.

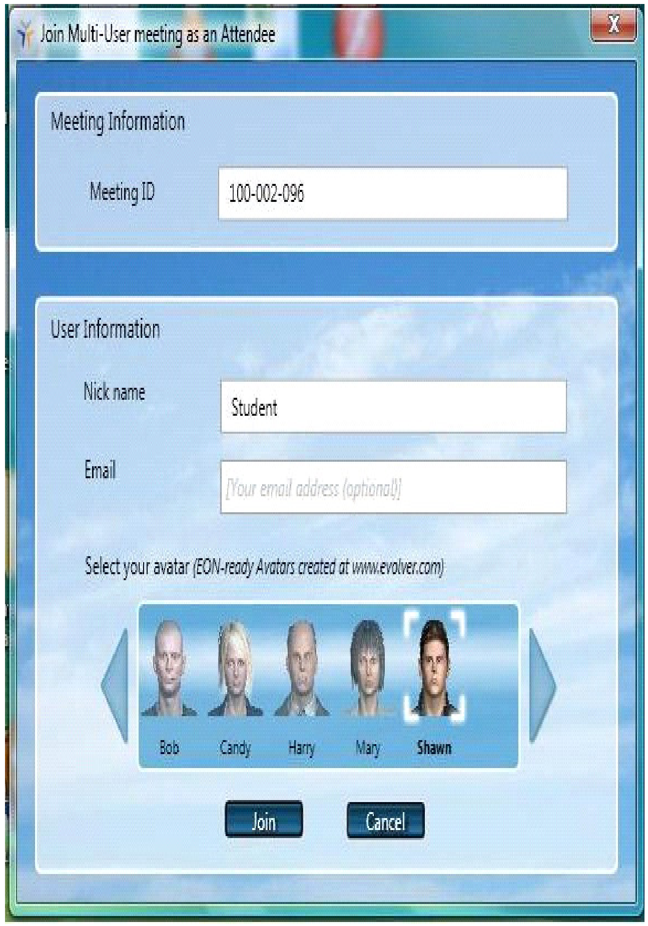

Figure 5. 7.The multi-user meeting interface for the students as attendees for our virtual class.

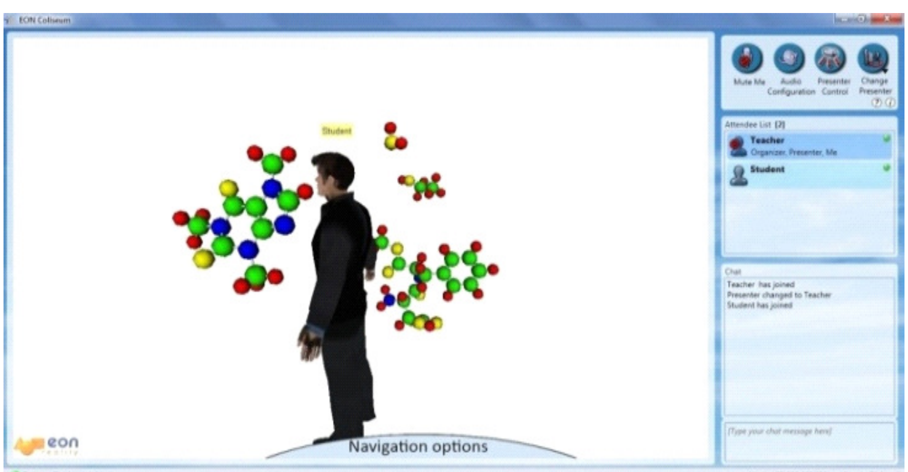

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Figure 5.8 a. The multi-user meeting interface for the students as attendees for our virtual class with navigation options.

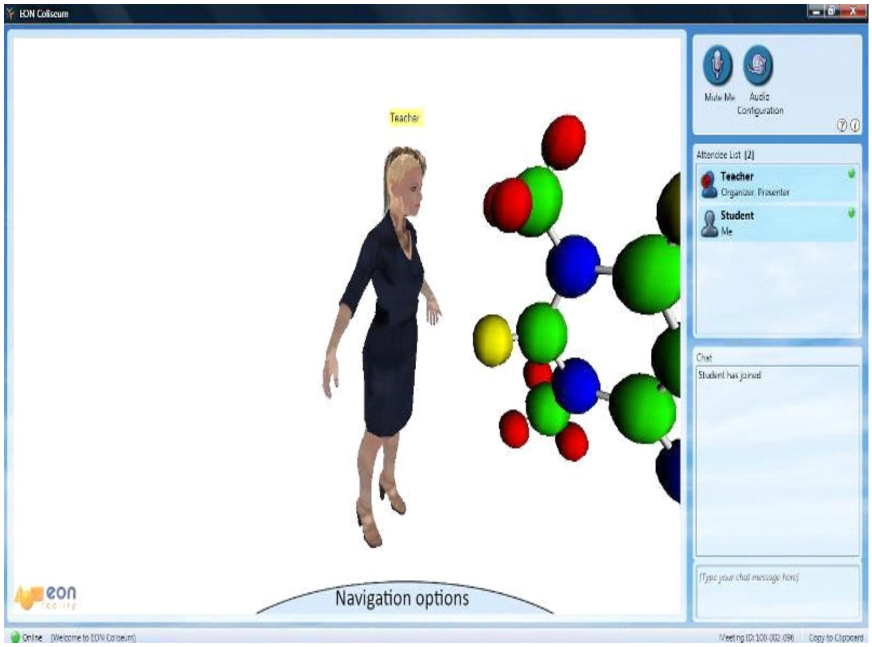


Figure 5.8.b.The Teacher avatar in the virtual space, as she is seen by the students.

The right side of our virtual space has three subscreens (see figure 5.9): the configuration subscreen, "Attendee list” and "Chat”. The configuration subscreen enables user (Teacher/Student) to configure his PC audio or he can just mute the sound. Due to the dynamic communication environment supported by EON Coliseum such as messages boards (chat) and voice broadcasting, there is an option on the configuration subscreen, “Presenter control”, which allows the teacher to relocate the control of the presentation in the virtual space between students. This control gives the teachers and students the power to broadcast voice throw the virtual space (Microphone), while the chat option is available for all the students in the virtual class.

The second subscreen, “Attendee List”, shows all participating users (teacher /students). The “Chat” subscreen is a sharing board for all users, in which they can chat.

The bottom part of our virtual space contains the "Navigation options" (see figure 5.10). The user can select one of the three different ways to explore and navigate through our virtual space: walk (the default navigation option), orbit (rotation on an orbit) and fly. Thus, in our virtual classroom, the students can travel through a 3D space, navigating all the available modules, such as atoms and the Periodic Table. Also, they can view and explore simulations for many types of atoms in an attractive 3D space. In an atom simulation, the students have the power to orbit deep inside the atom nucleus, explore how the electrons orbit surrounding the atom nucleus.

Figure 5. 9.The right side of our virtual space.

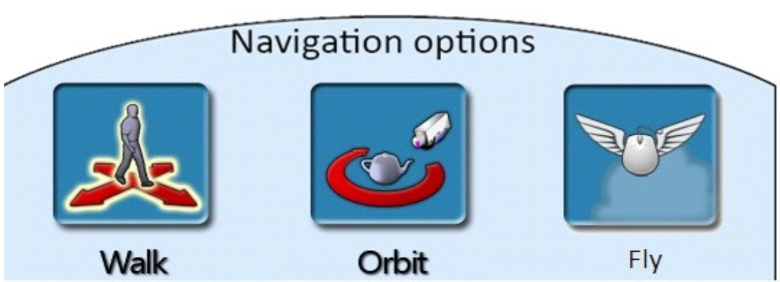


Figure 5. 10.The three different ways of navigations.

One of the most important new aspects of this educational environment is the 3D representation of molecules. Presenting 3D representations proved to be a powerful mean to visualize and describe complex abstractions in a high attractive way (see figure 5.11). By clicking on a 3D object (like the 3D representation of a molecule) the student can obtain information, choosing between many visualization options:

- Texts
- Sound
- Still Pictures
- Motion Picture (Video)
- Graphics
- Animations
- Hyper Links

5.1.3. Experiments and results

We have made a first experiment with our Chemistry lesson, trying to analyze the pedagogical, educational, psychological and other aspects of using the virtual space versus the traditional method of teaching.

We used two distinct groups of tenth grade students in an experimental course. For the first group we used the traditional way of teaching. For the second group we tried to teach and explain the same subject using our virtual lesson. For a while we noted the difference between the two teaching methods, the traditional and using the virtual 3D environment. After the completion of teaching with both groups we conducted a simple test for comparing the results between the two study groups.

We found that the students from the second group not only have attained most of the lesson goals, but they start to interchange information and the knowledge they achieved through the virtual environment between each other. Also, they appreciated this new teaching way (virtual), being more time flexible, because the student can participate in the lesson at any time as he wants, depending on his free schedule time. They like the idea of using visual elements in education through attractive 3D objects.

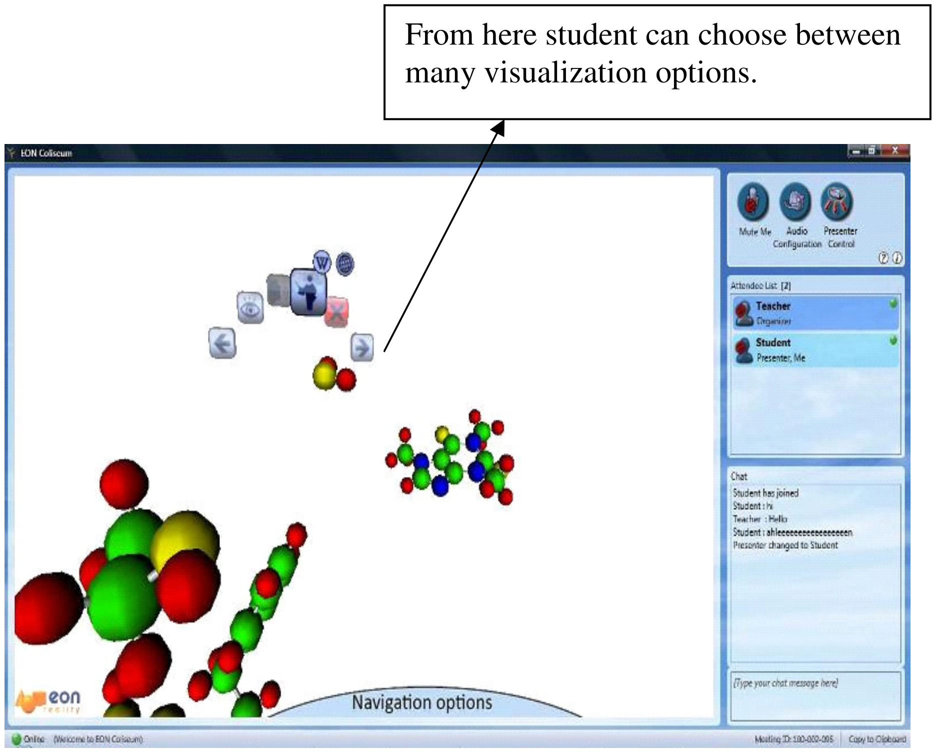
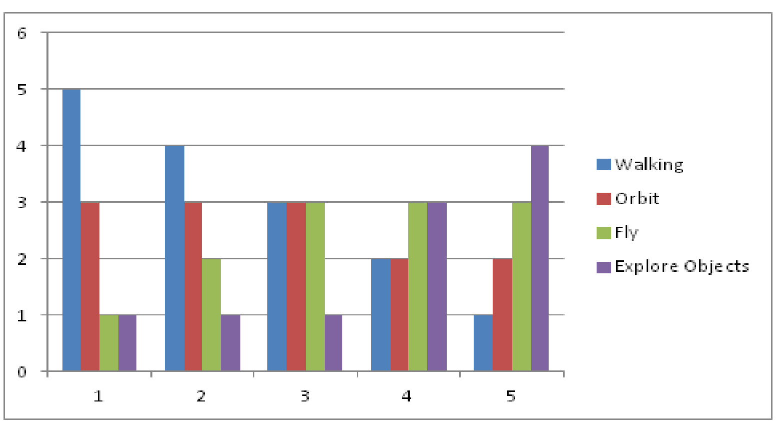


Figure 5. 11.The virtual space options and tools to explore our 3D objects

We have also made an analysis of the ease of navigation in the virtual space (see figure 5.12). Feedback on navigation was mixed. Those with experience in 3D computer games found navigation easy while to novice users took some time to master the controls. In particular, some of them found it difficult to navigate between objects into the classroom.



Level of Difficulty: 1 = Very Easy, 5= Very Difficult.

Figure 5. 12. Feedback on navigation.

We asked the students what they liked most of our virtual lesson. Many of the students mentioned they enjoyed activities within virtual class, such as being able to move and fly and explore objects in the world (“flying without wings”, “you get to go anywhere”, “explore and interact all the objects”). Many others commented positively about the experience of being immersed in a virtual world (“experiencing a new place without going far”, “being in it, and not seeing it just on a screen”).

On the other hand, we asked what the students liked least to our virtual class. Some of them told: the screen resolution (“the screen was kind of fuzzy”).

All participants used the communication facilities. Although test users found them easy to use, some of them experienced difficulty with the audio communication. In particular, some users could hear an echo. This can be caused if the speakers are too close to the microphone, and clearer instructions on this could reduce the echo in the future. Text-chat proved most popular for collaboration; however, this may be largely due to the problems experienced with audio communication.

5.1.4. Conclusions

Our conclusion from the first experiment with this application was that VR is a significantly compelling creative environment in which to teach and learn. We agree that the teaching of sciences in general and chemistry in particular comes with both risks and complexity. Using a 3D virtual word to overcome the teaching problems, as our lesson is, provides more potential.

And we notice that the interaction in a virtual world increases student engagement in an online class and also it is impacting the students’ sense of community with the class. The students are more likely to engage in discussions in a virtual world than they would be in a face-to-face class.

The most important benefits of using virtual worlds are to provide learning options that are not available in some face-to-face settings such as using discussion boards, instant messaging or e-mail. And finally, they present many interesting opportunities for instructors interested in exploring the use of virtual worlds in teaching.

On the other hand, many of the potential benefits and uses of virtual worlds in teaching have yet to be explored.

From our experience with the creation of the virtual chemistry classroom, we concluded that:

- ➢ The use of 3D graphics seems to be a powerful tool for visualizing and understanding complex abstract information. Immersion is an aspect which has to be better explored and evaluated.
- Before trying to design a virtual word for interactive learning, we must understand the main concept of the lesson. Also, we must implement suitable methodologies to create such worlds.

Other conclusions regarding the efficiency of using this application in teaching and learning are described in chapter 6.

5.2. A 3D VIRTUAL CLASSROOM FOR TEACHING BIOLOGY

The goal of this application was to create a biology lesson that contains VR simulations of various organs or cells found in the human body.

The main educational issues addressed in this application are drawn from the following observations:

• We have found that the student faces great difficulty to comprehend pictures in the traditional book, especially in identifying the internal parts.

• The main difficulties that face biology teachers using traditional methods, is how to present a lot of concepts through dictation.

Our virtual class helps teachers by displaying a 3D object with associated information, allowing the students to comprehend its shape, structure and functional aspects.

This virtual lesson has many features for students, who can see the cells of the human body and wander through them, providing an opportunity to learn the basic components inside the cells.

One of the options in the lesson is to allow 3D cell separation, where the student enjoys this presentation viewing the different parts of the cell. Studying through fun achieves higher goals in comprehending a biology lesson.

Our lesson includes a range of multimedia elements:

- Text
- Acoustics: special audio effects, voice, sound effects generated by instruments.
- Digital images: from digital cameras or scanners or digital archives
- Computer animations
- Live video

Studies show that a human remember 20% of what he hears, 40% of what he hears and sees, and 70% when he hears, sees and does [Roussou, 2004]. We tried to make use of these findings in the design of the lesson.

5.2.1. Application description

Most VR applications rely on immersion: make the go to another world, the virtual one, be in it. For example, the user can "see" he wanders inside the heart, moving between different cells, while his body is actually sitting on a chair in front of the computer. In VR, the human consciousness is focused on an environment formed electronically.

Traditional trends in VR focus on the sensory input substitution, with sophisticated VR equipment. Modern VR acknowledged the importance of the sensorial input, but also discovered the importance of the mental flow of the user to achieve high degrees of immersion. For example, many computer games with astounding graphics or sound have failed to attract players, while others, with simpler, less impressive graphics or sound, had huge success - only because better story and scenarios.

With VR, teaching is provided in a more attractive method: experiencing information. For the learner, the object of the study is vivid, either moving in "front" of him or him floating inside it.

This is a huge advantage in terms of a student's involvement, for teachers of science often face a problem of a student's non-integration with the subject, as it contains rigid information that do not encourage students to interact in the classroom, resulting in the sense of boredom.

In our application the user presence in the virtual space is accomplished through an avatar, a concept familiar to young learners. Behind the avatar and through it, the student has enough privacy to focus on the virtual environment and enough freedom of movement to explore the information.

In the next paragraphs we present some of the lessons included in our VR classroom and describe the general way of implementing them and interacting with them.

The heart lesson

Part of our experimental virtual lesson is a biology lesson dedicated to the heart.

The heart is a hollow, muscular organ that drives blood. It has four compartments: high left atrium, right atrium, bottom ventricle and right ventricle. Acer separates each atrium and ventricle valve, between the atria and ventricles a trio-ventricular septum (see figure 5.13).

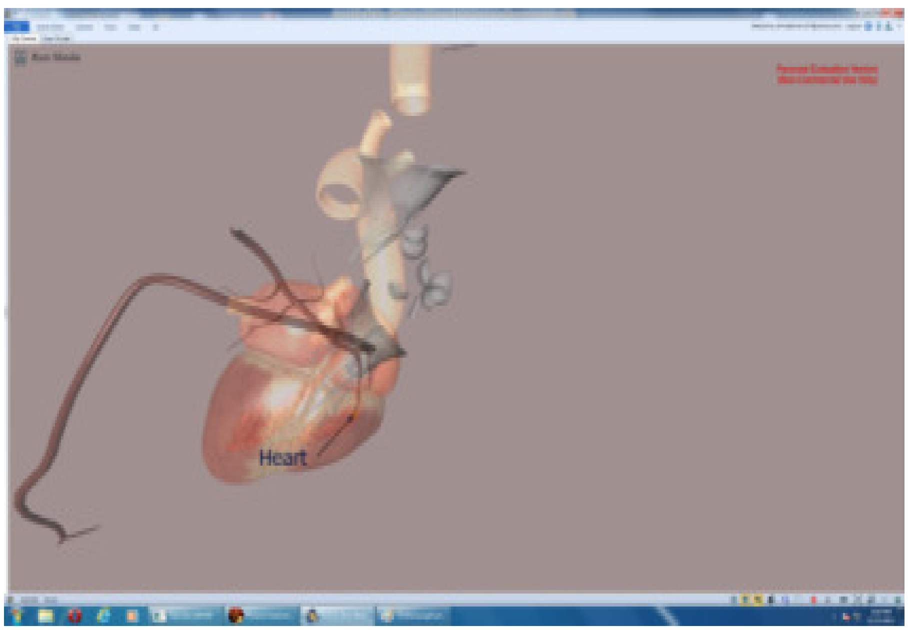


Figure 5. 13.Heart section.

In the traditional way of teaching this lesson, most students face difficulty in identifying the parts of the heart from two-dimensional image pictures presented in front of them in the classroom.

In this virtual class, the student can see a 3D section of the heart. The 3D model includes individual meshes for the internal parts. Advanced visualization options allow the student to explore the content, and easily learn and identify these internal parts of the heart:

- Transparency
- Rotate
- Exploded view
- Animation
- Explore
- Annotation (see figure 5.14).

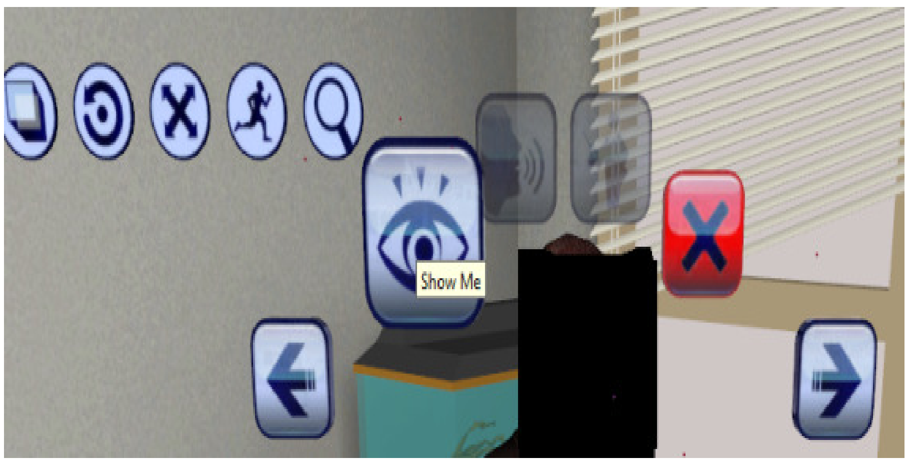


Figure 5. 14.Visualization options.

The bone cell lesson

For this type of cell we go deep to present all its main components: oval small lacunae cells &collagen highly organized acidophilus matrix, high cellular, large round lacunae, random orientation of cells & collage, basophilic matrix (see figure 5.15).

The student can fly through the 3D bone cell and observe in detail the structure of each component, or fly around and comprehend the overall bone cell composition.

The neuron lesson

A neuron is a body cell which contains all basic animal cellular organelles, but is characterized by owning many ramifications acquaintances with other neurons, and owning one long extension supported with hard sheath called the axis of the neuron.

Figure 5.15. Bone cell.

The neuron lesson allows the student to:

- 3D visualize the neuron cell
- Identify the nucleus
- Follow the neural extensions in the virtual reality through 3D (see figure 5.16)

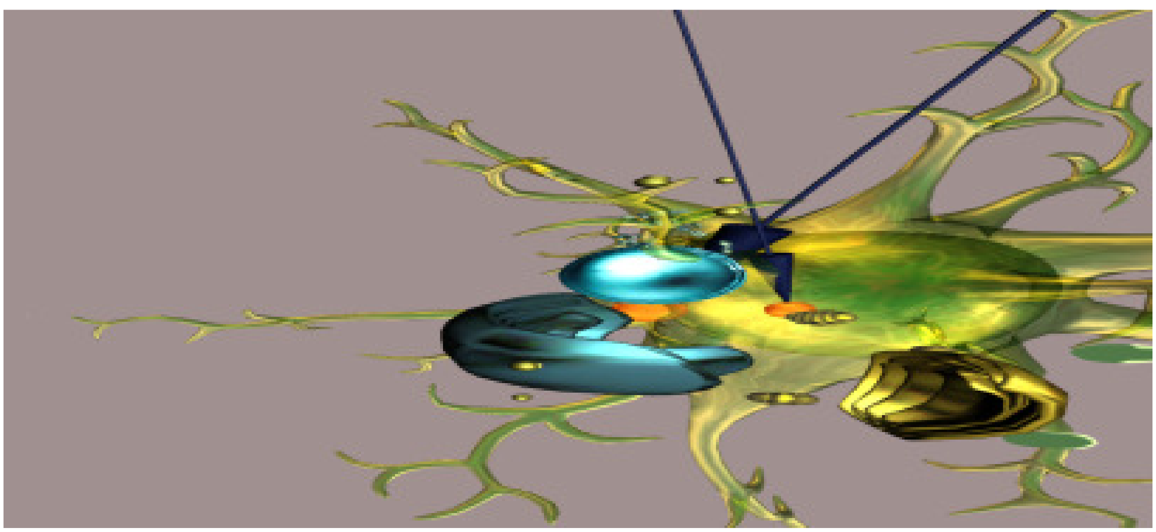


Figure 5.16. Neuron cell in the VR runtime.

5.2.2. Implementation

After the conceptual design of our virtual lesson in biology, we used EON Creator to implement it. The application was published on the EON Experience portal using EON Creator [http://www2.eonexperience.com/eon-models/details.aspx?cid=4574]

Figure 5.17. Biology virtual class.

A very important functionality allows creating tests (in the forms of quiz or actions-to-do) embedded in the VR lesson. In this way, the VR lesson can be used as a fully fledged educational environment. Using this functionality we created many multi choice tests and attached them to different 3D models. Students were asked to answer the questions and they received marks in the virtual space.

5.2.3. Using the lessons

As in the case of the application described in 5.1, the students need to download "EON Coliseum" (http://www.eonreality.com/eon-coliseum/) to run and participate in our virtual class. The minimal hardware and software requirements for running the application are the same as for the application 5.1.

The teacher invites the students to the meeting by sending them the "Meeting ID", by e-mail or SMS; with this token, the students are able to enter the meeting in the virtual class, at the scheduled time (see figure 5.17).

The students can control their avatar to navigate in the 3D virtual environment in a number of predefined ways: flying, walking or orbit.

The student can use commands to easily access various embedded multimedia information (YouTube, Wikipedia, PowerPoint presentation, Video, Hyperlink etc.) related to a selected 3D object from the VR environment. Such sources are available for student while interacting with cells displayed in the lesson, so it becomes easier to access them, without interrupting the VR interaction. Cooperation between students occurs in real time, synchronized multiuser mode, which is one of the most significant advantages of *virtual learning*.

The communication is supported through a text chat or audio through a microphone. Besides commands to control the movement of his avatar, the user has a few more commands to allow him to express visually in the VR environment, through gestures of his avatar.

From the standpoint of the teacher, the features concentrate on managing the students' activity.

5.2.4. Experiments and results

We studied the usability and performance of the virtual biology classrooms with a group of 20 students from the tenth grade and we have taught the first lesson in two ways. The first one was the traditional manner in the real classroom. The second method was in the same group of students in a virtual lesson. After the completion of each method, we tested the students to verify the understanding level of the lesson. The results of the test with the virtual lesson method were compared with the results for the traditional way of teaching in the classroom. Also the students were asked to answer the following questions:

QUESTIONNAIRE	
Question No.	**Question**
1	I found the computer program easy to use.
2	Virtual reality environment did help me understand the biology concepts.
3	The use of visualization tools increased my excitement about science.
4	I like computer games styled experiments to illustrate concept biology.
5	I would like to see more virtual reality environment.

The result of the questionnaire can be seen in figure 5.18.

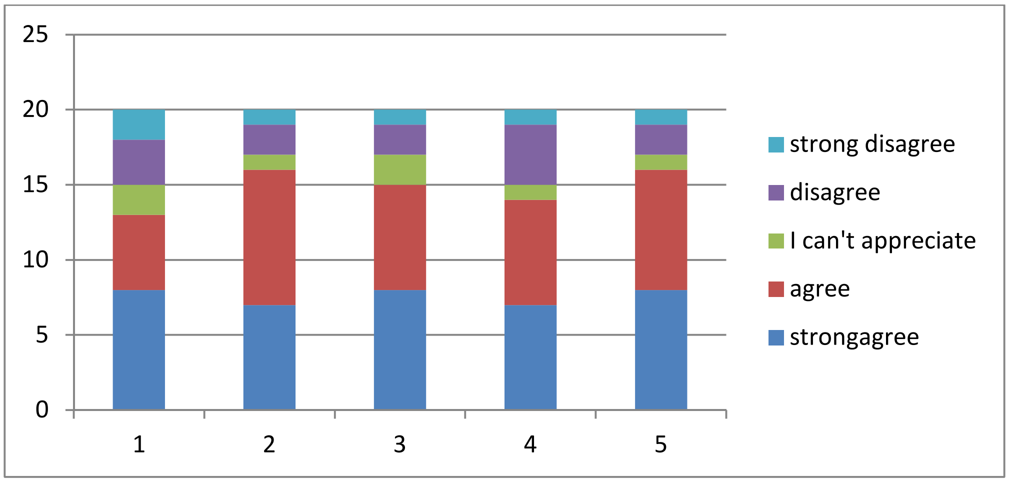


Figure 5. 18.Results of the questionnaire:

X-axis = the id of the questions,

Y-axis = number of students' answers.

Typical reported issues were some echo during the voice communication and small screen resolution being a problem in navigating through the 3D objects.

Besides the overall figures, some students' opinions are worth mentioning:

- "It was a fictional world revolving with cells where you can fly through like having wings; feeling like playing".
- "I enjoyed communicating with colleagues, hiding behind an avatar with a nickname".
- "I like the idea of not going to the virtual school wearing uniforms".

- "It is exciting to see parts of the cell divided in front of you, spin these parts in space and walk through the things you study.

5.2.5. Conclusions

In this section, we presented results of interest for designers of educational environments, programmers, teachers and students.

We found that virtual worlds have lots of privileges that recommend them to be used in teaching complex subjects, which was obvious in teaching biological science. Students found virtual environments, amusing, attractive and flexible, since many of them practiced interactive audio and video games, therefore, are perfectly able to master the virtual learning, without prior training. Text chat and audio communication techniques support the learning and communication.

A current drawback, that we expect to be lifted by the evolution of EON tools, is the long time required for implementing such software. Also the content creation can prove to be time consuming, but this will improve as the 3D resources will become better organized into libraries.

5.3. A 3D GAME FOR LEARNING CHEMISTRY IN A VIRTUAL ENVIRONMENT

In this section, we present a game designed for interactively learning chemistry. The game is integrated in OpenSim [Open Simulator] and exploits the 3D virtual reality environment provided by this platform to implement immersive, ’learn-by-play’ techniques.

5.3.1. Game Objectives

Our main goal was to create a chemistry game with learning potential where a student comes to enrich his knowledge about the world of chemistry.

The game contains the fundamentals of chemistry up to the tenth grade, such as interactions of chemical elements, notions about acids and bases, and the activity order of metals. Since the age group is between 13 and 14, and they often have great difficulties in understanding chemistry, we thought it would be possible to exploit the students' passion for games in learning chemistry. Nowadays, Chemistry teachers say that it takes a great effort to convince students to study chemistry from a book, because this does not attract them. 3D worlds, on the other hand, are funny and catchy. Users spend many hours in such worlds, so a game with a lot of chemical concepts which the student must understand could be the right approach for a better learning experience.

Self-education is one of the best tactics to consolidate knowledge. By using games as a virtual learning environment, the student can learn by himself.

A 3D MMO game might provide an ideal learning platform for learning chemistry as it allows active communication, social features and a personalization of the learning process. Also, many computer game environments nowadays have reached a high level of realism and immersion [Moldoveanu, 2011].

The idea for a chemistry game emerged from many observations. A game gives the user the freedom to enter it at any time he wants, to play and enjoy the virtual world and at the same time, to learn. A virtual world with beautiful environments where the students can fly, walk or jump easily interacting with surrounding objects, just like in an RPG game, makes learning enjoyable and fun.

In the virtual world, the student controls the game and solves chemical issues with relish and confidence in order to win the game. In the traditional classroom, sometimes there are few incentives for students to solve problems, but in a game there is always competition and there is a winning student.

We had chosen to use the OpenSim framework for developing our game. It is a free and open source and can be used to design or import 3D models for creating virtual environments. It runs on Windows, Unix/Linux and Mac Operating Systems. Most important, it allows access for a large number of users in a virtual environment and has characteristics that facilitate easy use of our game and evaluation of learners' performance for different contexts and teaching methodologies.

5.3.2. Game description

General Features

Immersive learning environment. The use of the 3D environment created with the OpenSim framework allows an immersive learning: the student is immersed in the learning environment in which he navigates by playing between different puzzles of the chemistry game that contain fundamental concepts. Players experience the virtual world through sight, sound, participation and imagination.

Massive multiuser online. The OpenSim framework allows hundreds of users to access simultaneously the virtual environment of the game, interacting through their avatars and multiple communication means.

Synchronous communication. The game environment includes local chat, instant messaging, chat groups and voice conversations. Students (and teachers) can easily cooperate and talk using these chat systems, solving quests together, making this learning environment more enjoyable and fun.

Content and rules

The game consists of three parts that cover important chemical topics. All parts have several levels, with gradually increasing difficulty. To complete a level, the student must solve correctly the tasks from that level.

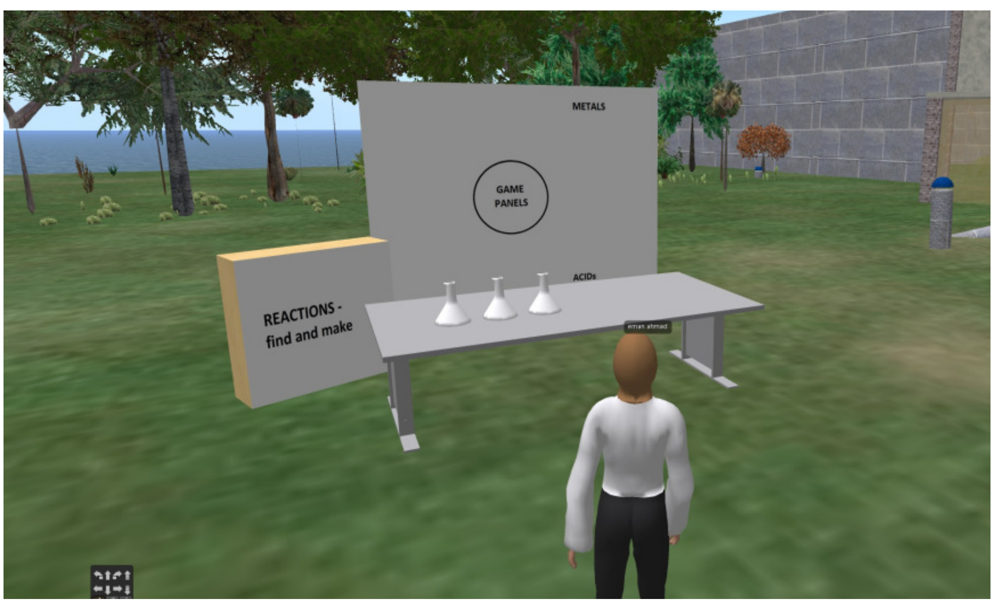


Figure 5. 19.Student main panel.

The content of the game is based on "chemical reactions". The reaction quests are provided from the main panel in the center of the virtual environment (see figure 5.19) .To solve them, the students must search in our virtual game environment for chemical elements or materials required for one or more reactions.

Yet, getting the elements will not be easy. The stockpiles are in storage buildings. To enter these, students must solve puzzles, based on level (see figure 5.20).

One of the puzzles requires arranging some elements in the order of chemical reactivity, in order to open gates and acquire required materials.
Another puzzle is about pH and the comparison between acidic and basal solutions. Knowing the solutions and their characteristics, in terms of whether a substance is base, acid or neutral, is one of the most important topics in learning chemistry. So the student will be asked, based on his level, if a certain solution is acidic, alkaline, or neutral and if it is weak or strong.

Figure 5. 20.Student in front of a puzzle.

Also, on higher levels, students need to know and choose the appropriate color for each solution and for the last level of difficulty they will need to know the exact pH value of the solution. Solving this puzzle will let the students get their final materials for the main quest and get to the next level or eventually win the game (see figure 5.21).

5.3.3. Game Scenario

In the beginning, students download an OpenSim client (viewer) free from the Internet and after that they can register by a special email and password. Upon entering the game using the OpenSim client, students can choose their avatar and make some customization to it.

The user (student) navigates freely and interacts with the virtual world by touching, moving or even flying. Apart from free exploration, he must solve quests and puzzles to access special area or objects, to finish each level and eventually win the game.

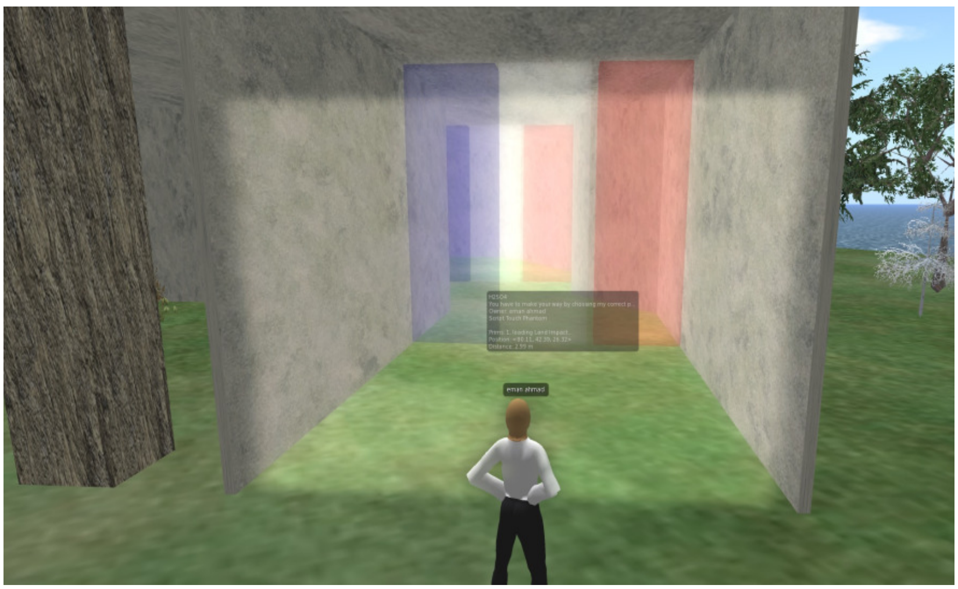


Figure 5. 21.Student in front of the PH puzzle.

Part I: Chemical reactions

In this stage, there are five levels of difficulty.

At the beginning, the student is shown a message that directs him to choose a chemical element to interact with or other material, for producing a chemical compound, and here in the virtual world of our game, the student looks for materials required for a chemical reaction. After he succeeds, he moves to the second level of this part and so on until he reaches the most difficult level.

Part II: Series activity of chemical elements

The student begins to play this game by searching for chemical elements.
In the first (easier) level, after finding the chemical elements, the student chooses them by their reactivity. If the student chooses correctly, a message tells him so (see figure 5.21). As the student moves to higher levels of this part, the number of elements to be arranged gradually increases (see figure 5.22).
The last and most difficult level includes ten chemical elements to look for in our virtual environment in a manner that ensures that the student will arrange them by chemical reactions from low to high (see figure 5.23). After successfully completing the second part, the student continues to the hardest and most enjoyable part.

Part III: Comparison between acidic solutions and basic solutions

Level I: the student looks for the particular solution he wants and then selects it. He is then issued a message asking him what kind of solution he wants: acid, base, or neutral. The student chooses to answer by selecting the proper gate (there are three gates: acidic, base, and neutral). If the student chooses the correct gate, he/she can continue playing and learning, going on to the second level.

Level II: the number of gates is increased: weak acidic, strong, and acidic, a strong base, weakly base or neutral solution. The doors here have different colors.

Level III: now using the same solutions, the students are asked to select the color resulted in the event of using a chemical reagent, with four gates representing different colors: red, orange, blue, and violet, and choosing the appropriate color for each reaction. The gate will open in the case of correct answer, in order to complement the virtual demand of the student.

Last level: the student must select the correct pH of the chosen solution, showing him several option gates: 1, 2-3, 7, 11, 12, 14. Now, if the player chooses the correct gate, he enters and is allowed to continue playing, choosing another solution to complete all solutions and win our game.

5.3.4. Experiments and Results

Our application's goal is to improve the students' knowledge and skills of chemistry. Therefore, our evaluation plan assesses the changes (pre- and post-usage of the system) in three key constructs: (1) self-efficacy in the ability to learn the subject of chemistry through game playing, (2) perceived subject matter learning, and (3) perceived skill development. In the fall 2013 semester, we introduced the virtual game in a school from Jordan. We selected 20 students in the tenth grade and asked them some questions about our subject, like series activity of chemical elements, comparison between acidic and basic solutions and chemical reactions, before starting our game. Then, we offered them our game.

Figure 5. 22.A student choosing chemical elements.

Figure 5. 23.A student choosing chemical reactivity for elements.

We asked 20 students a series of questions to get their opinions about our game and how it impacted their understanding of chemistry. 14 students strongly believed that the game held their attention; 15 students would like to play the game again; 18 students lost track of time because this group doesn't have a lot of experience in 3D gaming using a keyboard or mouse (we corrected this problem by encouraging them to play many more times); 17 students found the game challenging because the game requires they should know a lot more information in chemistry.

The following is the detailed list of questions that we asked our students to answer about our virtual game:

1. Did the game, hold my attention?
2. Did I put effort into playing the game?
3. Did I find the game challenging?
4. Did I lose track of time?
5. Did I feel the urge to see what was happening around me?
6. Did I find the game difficult?
7. Did I perform well in the game?
8. Was I emotionally involved in the game?

9. Did I enjoy the graphics and the images?
10. Did I enjoy playing the game?
11. Was I disappointed when the game was over?
12. Would I like to play the game again?

Responses to the questions are presented in figure 5.24:

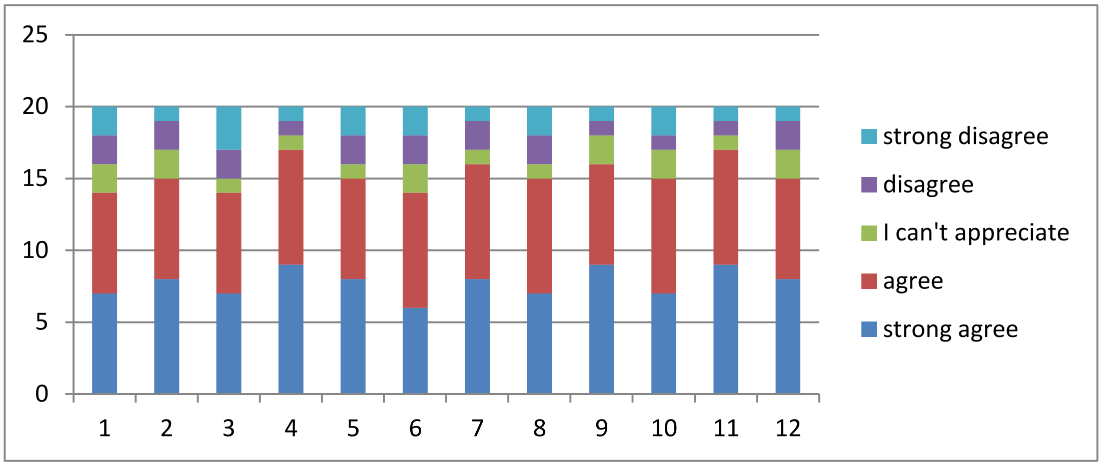


Figure 5. 24.Results of questions: x-axis = the questions' id, y-axis = number of students' answers.

Overall, the answers show that most students tend to learn through playing in the virtual world; they have felt the depth of information, where it was "easier to understand in 3D", the 3D effects were nice; engaging to play and the whole process was enjoyable.

Here are some particular feedbacks that we got:

- Student 1: the program was fun and made learning chemistry interesting.
- Student2: it was "easier to understand in 3D".
- Student 3: felt the game was like an interesting movie; like looking at another world.
- Student 4: the 3D effects were nice.

Most of the students have enjoyed the game but felt the graphics and sound effects could be improved.

5.3.5. Conclusions

In this section we have presented our work on VR-enhanced chemistry education using a gaming approach to improve the learning process. Our game was developed using the virtual reality environment provided by OpenSim. The reason for choosing OpenSim was mostly its MMO and inter-player communication capabilities.

This study found that this virtual game positively affects the cognitive and affective domains of chemistry learners. The students performed better in a virtual game based learning environment. Virtual game based learning has provided an invaluable learning experience for students. Results have shown that the student-centered learning approach using virtual game playing was effective. Students in the virtual game have a more positive state of emotion during learning. The distinct feature of a Virtual Reality game is the sense of presence or “being there” when the student interacts with the Virtual Learning Environment of the game.

Overall, the results suggest that it is more powerful to support chemistry learning with virtual game technology than with traditional learning methods. Such environments could easily be used to learn other subjects such as Math or Biology.

Virtual gaming proved “to be an excellent educational tool because it offers the opportunity to visualize, explore, manipulate and interact with objects and information within a computer generated environment” [Schaverien,2001], which allows for discovery and self-paced learning. Additionally, studies found that when using immersive environments, students show more improvement than when learning with other educational software [Virvou, 2005].

We suggest that virtual game technology should therefore be considered as an alternative way of providing instruction within secondary-school classrooms.

5.4. A 3D MMO Virtual Chemistry Laboratory

5.4.1. Our virtual chemistry laboratory

The goal of this application is to allow students to make chemical experiments like in a real laboratory, but without any danger, and help them to understand the components' properties and how they react. Our virtual laboratory helps overcome many of the disadvantages of a real laboratory:

- accidents with materials having dangerous adverse effects;
- fume inhalation;
- some materials are difficult to find and are expensive;
- Due to the large number of students, not all of them can participate effectively in laboratory experiments.

From the experience of chemistry teachers, using traditional books [Drury, 2001]; students can find it difficult to understand the equations of components' reactions, or to even imagine how they are manifested. We studied different virtual experiments to help teachers with this problem. The three-dimensional virtual lessons allow the student to interact and experiment with various objects [Caterina, 2006]. These objects could be important metallic elements which make reactions with some compounds.

Our virtual laboratory resembles a traditional chemistry laboratory with all its contents, such as chemical materials, but offers more sources of information and live interactions in an exciting and enjoyable way.

We implemented the virtual laboratory using OpenSim. We have chosen OpenSim to create a multi user online virtual environment because OpenSim is an open source virtual community platform and has been widely used in education [Pär, 2010], games, business, tourism, cultural heritage and other fields [Jensen, 2004]. As OpenSim 3D virtual teaching platform takes advantage of Virtual Reality in immersion [Zhao, 2010], interactivity and imagination, it enhances the interaction and experience in the teaching process, which can improve students' interest and initiative to learn [Gaddis, 2000].

Our Virtual Laboratory is extensible, it is designed to be an MMO virtual space and we can easily make future improvements: the virtual environment is an open space where many students can learn chemistry in a fun and interactive way. We can easily extend the current virtual environment so that there can be multiple buildings covering different chemistry chapters and also we can easily support multiple classes studying at the same time in parallel laboratories.

Therefore, the existence of the extensibility features and the MMOs support for a great number of users that interact in the virtual world are strong factors that favor choosing OpenSim.

5.4.2. Virtual laboratory environment

Our virtual chemistry lab looks like and has the same layout as a real lab, with all the shelves filled with chemicals and reagents, all with different properties (see figure 5.25). On the left wall there is a PH scale, which shows the acidity-basicity range of substances, reagents, compounds, and even the acidity-basicity change (if any) between the reactant side and the product side of reaction equations. Numbers from 1- 6 shows acidity or acidic property, 7 is neutral, like water, and from 8-14 has basicity or basic property. The more away from number 7, the intensity of either the acidity or the basicity increases.

The reagent bottles and the reagent colors show the pH of the reagent if it is acidic or basic. Students will use the chart on the wall to know if the reagent or a substance they have selected will have acidic or basic properties.

Also, in the Virtual Laboratory there are informative images such as a PH detector, which is used to detect acids and bases, and a panel that describes the general rules in a traditional laboratory, rules important to remember.

The role of a teacher in the Virtual Laboratory is almost the same as it is in the traditional laboratory; starting with describing the main purpose of the lesson, ending with question -answer session. In addition the virtual environment supports teachers with more tools, different ways of communications and elastic interactions between them and their students.

For the students, the virtual environment offers support with information resources such as videos, documents, pictures and others. Virtual Laboratory makes students “as we notice” more competitive and motivated in a positive way.

Figure 5. 25.Our virtual chemistry lab.

First of all, each student must register with a user name and password. The next is to login to the Virtual Laboratory application after selecting his/her preferred avatar from the available list provided by the application. As soon as the student login, he will be able to interact with other students, teacher, or any virtual object. The students themselves have the power to control their avatars to navigate in the Virtual Laboratory environment. By using the Mouse or navigation keys, they can explore the objects on the tables, shelves, charts and wherever they want. In addition, a group chat session is available for all the students, which include messages board and voice communication.

5.4.3. Activities in Virtual Laboratory

1. **The reaction of metallic elements.**

The reaction of metallic elements with water or hydrochloric acid is one of the most important subjects that a student in the tenth grade studies. Still, there are many problems faced by the students with these reactions. When does the reaction take place and when does it not? What is the rate of the reaction? One of the biggest problems faced by students using books is how to balance chemical equations of reactions occurring from the interaction of metallic elements and hydrochloric acid or the reactions that occur between water and metallic elements. We studied how the Virtual Laboratory can help students understand this subject in a pleasant and exciting way.

We added metallic elements with chemical activity, writing the name of each element on its recipient. We appended two bottles for two major reactions: water with metallic elements and metallic elements with hydrochloric acid. We created our Virtual Laboratory containers, chemical materials and characteristics similarly to those an in real laboratory.

The student (through his avatar) first selects the final compound recipient by clicking on it, then the bottle representing a certain metallic element (e.g. Sodium) and the bottle containing the substance that will interact with this item (e.g. Water) (Figure 5.26). The application will show to the student the chemically balanced equivalent reaction (Figure 5.27. a).

If the student wants to make a reaction between a metallic element and hydrochloric acid, he just chooses the metallic element by clicking on the "Return" button above this element and then chooses hydrochloric acid by clicking on the "Return" button above it. After that, the student will see in front of him/her the balanced chemistry equation of this reaction (Figure 5.27 .b) and then he/she sees a video from YouTube demonstrating the laboratory reaction (Figure 5.28).

Figure 5. 26.Bottles with different materials.

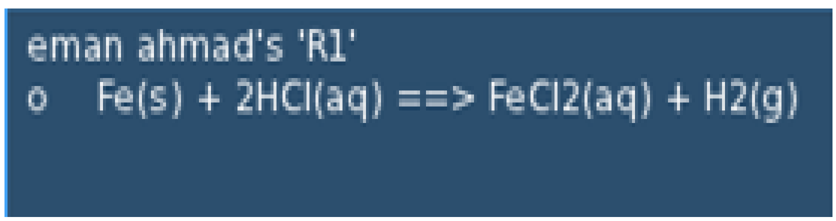


Figure 5. 27.a.Shows the balanced reaction equation between an element and hydrochloric acid.

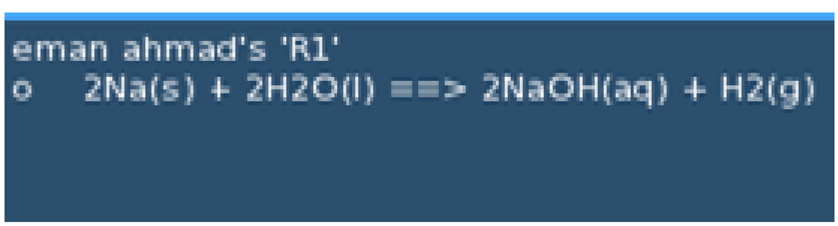


Figure 5.27 .b. Shows the balanced reaction equation between a metallic element and water.

Discussion between students and teacher in the virtual environment can explain the results of the reaction or predict the outcome of the reactions. The debate between students and teacher draws out frequently asked questions, such as: “What are the reagents?", “What materials result?”, and “What is the physical state of the material generated through the interaction shown in the video?”, “What is the rate of the interaction?”, and furthermore. The teacher has the ability to keep and save all the questions and the answers, results, which were discussed by the students in that session.

Figure 5. 28.Video from YouTube about a chemical reaction.

Information is very important. Students can access videos with the chemical reactions (Figure 5.29), can ask for help from the teacher or check material properties online. This activity helps the student learn about chemical reactions and their budgets, and at the same time watching the video shows the real interaction of these chemicals. There are many critical chemical reactions that cannot be done by students or in any traditional school laboratory, such as mixing sodium with water which consider being a very dangerous reaction. In the Virtual Laboratory, with the facility of “view videos “, the student can now watch videos for any kind of reaction without harm himself. On the other hand the student can mix and combine virtually different materials and check the reaction result.

2. The Periodic Table

The student reaches the Periodic Table (Figure 5.30) through his avatar, either by flying or by walking. In a few moments the integrated information from different sources about an element of the Periodic Table appears in front of the student, without having the burden of searching for the information. Interaction with the Periodic Table gives students a greater opportunity to study in a way that is different from the traditional one. The student clicks on the bottle of the metallic element, which opens with a front screen on the periodic table to indicate the location of this element in the Periodic Table. If he presses on the box that contains this element, it shows him a page from the Internet with the most important information about this element. This way allows him visually access to information and in 3D simulation, with more impact on the student.

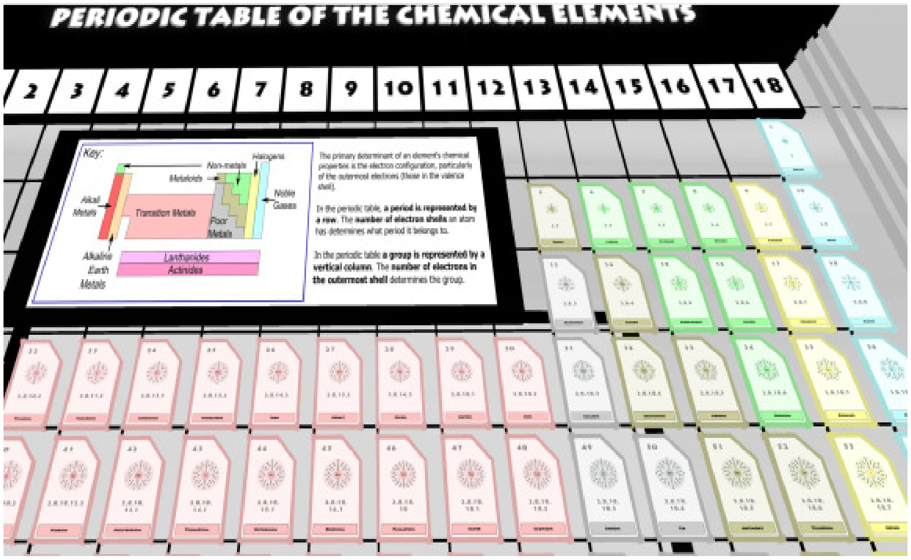


Figure 5.29 .The interactive periodic table.

3. The interaction with chemical compounds

In the Virtual Laboratory there are, on a table, bottles of color red, which refers to acids, and blue, which refers to bases.

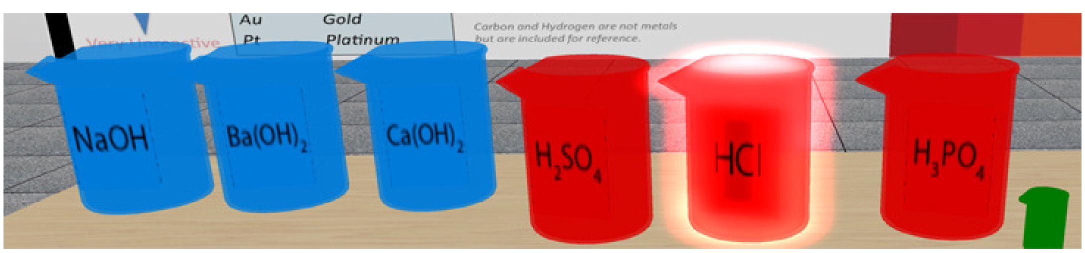


Figure 5. 30.Choosing an acid element.

These bottles represent different chemical compounds, which are displayed on the bottles. The student's attention is usually attracted by acids because of their glamorous colors, both in the Virtual Laboratory and in a real one. Clicking on any of these bottles, shows the panel that tells him what is the compound and at the same time the bottle takes the color that indicates the status of acid or base (see figure. 5. 30).

5.4.1. Evaluation

One of the aims of this application was to stimulate the learning and collaborative spirit among students with the aid of an interactive virtual environment and at the same time MMO (massive multiuser online), so that the participants have communications with each other, talking about chemical reactions by voice or by sending text messages through chat rooms [Valdez,2013]. Participants are present in our virtual environment in the form of avatars. This encouraged the students to acquaint themselves through a virtual environment and study together. We believe that the Virtual Laboratory application has an important role in social interaction and collaboration between students.

In the virtual environment, many users can interact together at the same time in what so called "Massively Multiplayer Online" (MMO). In our case this capability helps the students achieve the benefits of interaction between them by exchange of knowledge among themselves.

Discussions among the students help them to learn better than memorizing directly from the teacher. The greater number of students in the virtual environment implies more collaborative activities between them, especially when conducting any critical chemical reactions.

An important aspect of the evaluation was the efficiency of online learning in the 3D Virtual Environment and the use of simulations. When the virtual experiment began, every student chooses an avatar. He has to move between objects in our Virtual Laboratory, to move to the reagent bottles and containers and to know the important compounds in them. Then the student should start to make some virtual experiments with some compounds and see the results from these experiments. The use of YouTube to see videos about the real experiments, and then the discussions between the students and teacher are important for the student's understanding and, in the long-run, for the evaluation of our work.

Starting from previous studies on the importance of education using virtual laboratories, we tried to evaluate the impact of using our Virtual Laboratory on chemistry learning.

In our study, we used a group of 20 tenth grade students from a school in Jordan. Some of the participants had no experience whatsoever in virtual environments. But, most of them had an average experience in computer games. After using our Virtual Laboratory, students were asked a series of questions. The analysis of their answers underscored the importance of virtual reality in chemistry learning.

The Virtual Laboratory was made available on the Internet and we asked the students to register to use it. Then, they downloaded an OpenSim viewer to connect to it.

Through the assessment some technical problems were detected and we had to provide solutions to them. Several of the technical issues were noted during the assessment:

- Many students found it difficult to download and install OpenSim. The teacher helped them in doing that. The students who did not play computer games found it difficult to interact with the virtual environment, especially controlling their avatars' movement by flight or walking mode.

- If more students tried to speak at the same time, there was a noise problem. A solution could be that the student who wishes to speak with the microphone announces his intention to speak by sending a message to the teacher to allow him to speak. The teacher supervises the dialogues between students, and watching their answers and their interactions, has a record about his observations about the activities and answers of each student in the virtual laboratory.

After using the Virtual Laboratory, students were asked to express their opinion on the following statements, by answering within the range of "strongly agree", "strongly disagree" (see figure 5.31):

1) It was very easy to work with Virtual Laboratory.
2) Virtual Laboratory helped me to understand the chemistry better.
3) Virtual Laboratory is a fun way to study chemistry.
4) There are many advantages of the Virtual Laboratory that encourages you to interact with it.
5) Virtual Laboratory encourages me to work with other virtual environments.

6) Virtual Laboratory encourages me to learn without shame.
7) Virtual Laboratory helps me to learn at any time.
8) Virtual laboratory helped me meet friends.
9) Virtual Laboratory changed my view of chemistry from complex to easy.
10) Virtual Laboratory helped me to love the study of chemistry.
11) Virtual Laboratory was very helpful for solving the problems presented in the laboratory.

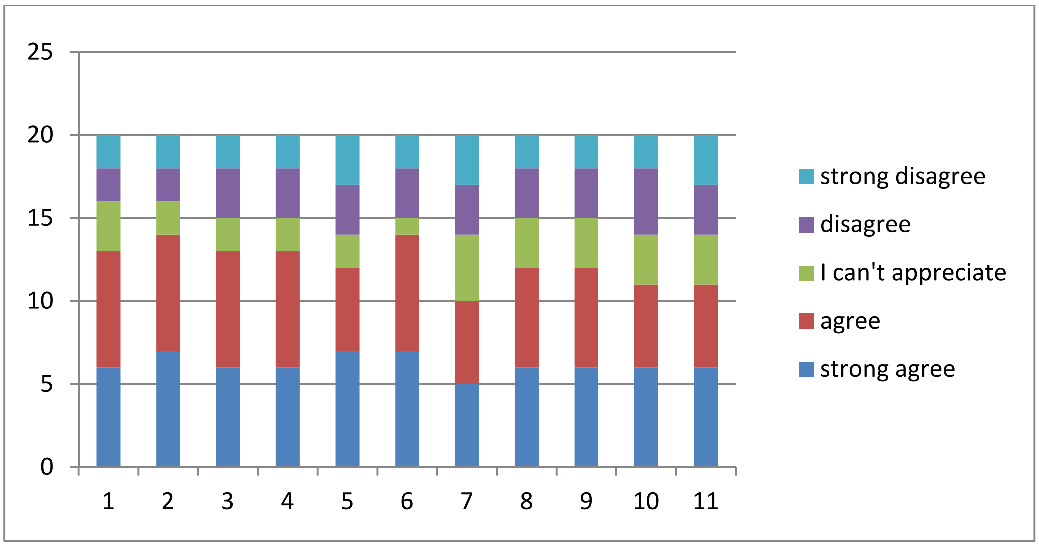


Figure 5. 31.Students' answers.

From the student's answers and live discussions with them, we concluded that:

- Many students tend to use and appreciate the virtual world in conducting chemical experiments.
- The student's level of interest in learning was greatly maintained at an enthusiastic, motivated level through the simulations in the 3D environment. The virtual world provokes students to discover a lot about the chemical elements and chemical compounds.
- The student's attitudes towards chemistry changed, becoming more interested in studying.
- The students did not feel the time passing during the lesson within the Virtual Laboratory.
- Some students gave opinions that working in the real laboratory are more enjoyable than sitting in front of their computers to conduct chemical reactions. Some students said it was

difficult to interact with the Virtual Laboratory, because they do not have enough experience and expertise in video games to use this application efficiently.

- The social purpose of the Virtual Laboratory was clearly fulfilled as shown by the results. The users related and interacted as a team, using the embedded social interactive tools, which most of them found easy to use. The knowledge of the fact that other avatars are present in the virtual lab gave the users the feeling of belonging to a group.
- Careful positioning of the information in the 3D space is of utmost importance for efficient user interaction, so that the useful information (e.g. Periodic Table, list of material properties) should be available at the right time.
- The overall design of the 3D space must be well considered, in relation to the scope of the lesson, so that the user can easily navigate it by walking; the optimal density and distribution of the information must be found through prototyping and adjustments.
- The negatives that I've found from our experiment about Virtual Laboratory, is that some of the students could not be present at the same time in the virtual environment and cooperation among themselves wasn't so easy because of the high number of users online. So we suggest that several time slots to be established by the teacher so that numerous groups of students will be able to enter the Virtual Laboratory at different times.
- A disadvantage of using a Virtual Laboratory could be that it does not encourage the physical activity of the students. This could affect the future physical condition of our students.
- Another important negative fact is that if there is a technical defect, for example a problem with the server, the students and the teacher are sometimes unable to repair this defect. So this is a point of challenge for virtual education. It's best to give teachers courses on how to deal with virtual reality techniques. This is in agreement with Bilek's results [Bilek, 2011].

5.4.2. Conclusions

Computer simulations of chemical experiments have many advantages over experiments in a real laboratory and we mentioned some of them in this section. In addition:

- Simulation encourages learners to stay longer within the learning environment , as it encourages their interaction with the studied subject, also giving students various experiences in learning that they cannot obtain using a book or working in a classical laboratory.

- The experiments done in a Virtual Laboratory are safe and students have a quick feedback to their actions.
- The experiments made in a Virtual Laboratory can help correct misunderstandings of scientific concepts. The Virtual Laboratory allows student's immersion in the virtual space and their participation and interaction with the chemical experiments through their avatars. Colours and animations enhance the perception of chemical phenomena and reduce learning time. Navigation in the virtual space is fun for students, making learning more enjoyable.

We have however seen some disadvantages of the Virtual Laboratory:

- Alienation from nature and from reality.
- It can be only a supplement and not a replacement of practical work. The student must go to the real laboratory, for example, to know and physically experience the feelings of real chemical reactions such as a change in temperature.

CHAPTER 6. A STUDY OF THE EFFICIENCY OF USING VIRTUAL REALITY AND COMPUTERIZED LABS IN TEACHING AND LEARNING

6.1. RESEARCH METHODOLOGY AND PROCEDURES

6.1.1. Research Methodology

Our experiment has been applied using the empirical approach to study and analyze the effects of different ways of teaching and learning chemistry in general and the acid- base reactions in particular. The experiment was conducted using a control group and two experimental groups (See figure 6.1). Each group studied the same subject from Chemistry but using a different style of learning:

- Control group: members of this group studied in the traditional manner, in the laboratory.
- First experimental group: members of this group studied in the chemistry laboratory equipped with sensitive devices connected to computers, which is what has been explained in chapter 2, a computerized laboratory.
- Second experimental group: members of this group studied using our Virtual Reality Applications (VRA), which were described in sections 5.1, 5.3 and 5.4 of this thesis.

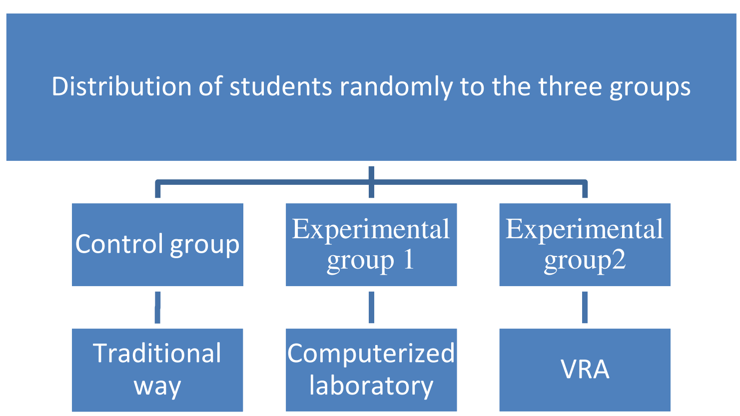


Figure 6. 1.The methodology used in the experimental research

The aim of our experimental research was to study the effect of different methods of learning chemistry regarding:

- Students’ achievement in chemistry learning.
- Students’ trends toward chemistry after using a particular method of chemistry learning; at the end of this chapter we compare the three groups to find out the students' attitudes.
- The impact of using a computerized laboratory for chemistry learning.
- The impact of using our Virtual Reality Applications for chemistry learning.

6.1.2. The target group of the research

The target group consisted of students of the tenth grade in a public school of Al Mafraq city. They were about 168 students. The selection of the school was due to the fact that I had cooperation of both the teachers of the courses and the management of the school in order to apply and execute our empirical research.

The sample of the research was composed of 51 students, selected randomly from the 168 students. We divided them into three groups: the control group, the first experimental group, and the second experimental group. Table 6.1 represents the three groups and shows the experimental factor for each group.

Table 6. 1.Distribution of students into the three groups.

Work group	Number of students	Experimental Factor	Applied tools
Control group	17	Traditional laboratory	Achievement test and questionnaires about trends towards Chemistry
First experimental group	17	Computerized laboratory	
Second experimental group	17	Virtual Reality Applications	

6.1.3. Course contents and the experiment steps

Chemistry course for the tenth grade includes acids, bases and chemical reactions to find their degree of hydrogen values (pH). These topics were chosen because of the possibility to make experiments in the school using the traditional way, the computerized laboratory and the VR applications.

The experiment steps

1) First, I have chosen the 51 students for the experiment randomly from the total of 168 students of the tenth grade and then I distributed them randomly in the three groups. The aim of a random distribution was to get a statistical equivalence among the three groups.
2) Before beginning the experiment, the students have been trained to use the VR applications and also the computerized laboratory.
3) I coordinated the teaching of both experimental groups and of the control group during the period from the first of April until the first of June, four hours per week.
4) After the completion of the teaching, I conducted a test to verify the scientific achievement of the students from the three groups and to measure the students' trends towards chemistry.

6.1.4. Teaching methods

6.1.4.1. Traditional way

In the traditional way, the students had to manually find the pH of their chemical reactions by using what so called "Litmus Paper". Litmus paper is a strip of colored paper which turns into a different color depending upon the pH value [7]. In the traditional lab, the students must know what is the value of pH depending on the new color, by observation.

After the end of this activity all students answered:

1) Questions from the exam, by which we verified the scientific achievement of the students.
2) Questions regarding the impact of the use of traditional laboratory on the students' attitudes towards chemistry. The students' answers to these questions can be seen in table 6.6.

6.1.4.2. Using Computerized laboratory

The first experimental group learned chemistry within a computerized laboratory. At the outset, the teacher equipped the laboratory with sensitive devices connected to computers, and then the teacher explained to the students how they will deal with these tools. We used in our experiments the DataStudio application from this site http://www.pasco.com/datastudio/.

After that, the students conducted their chemical experiments using the PH devices connected to computers. These devices were very useful for assisting the students to get information about the PH degree of their experiment. In the meantime, the teacher was watching the process, noticing the student's performance during the courses.

An example of practical experiment that has been conducted in the computerized laboratory is the interaction of magnesium with hydrochloric acid, to study the properties of acids and bases.

We want to explain how the students used the pH-meter with the DataStudio application:

1) In the computerized laboratory, each student has his own PC in front of him and also the recipients and chemicals used in their chemical reactions (see figure 6.2).

Figure 6.2 .The workplace of each student in the experiment with DataStudio.

2) DataStudio application is already installed and ready to run. On the desktop of each PC the student will find the DataStudio Shortcut (see figure 6.3).

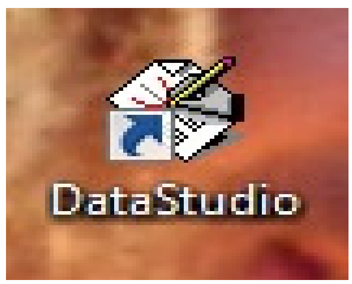


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Figure 6.3 .Data Studio shortcut.

3) When the student starts the DataStudio Application, a startup menu is activated (see figure 6.4). The student must select "Create Experiment".

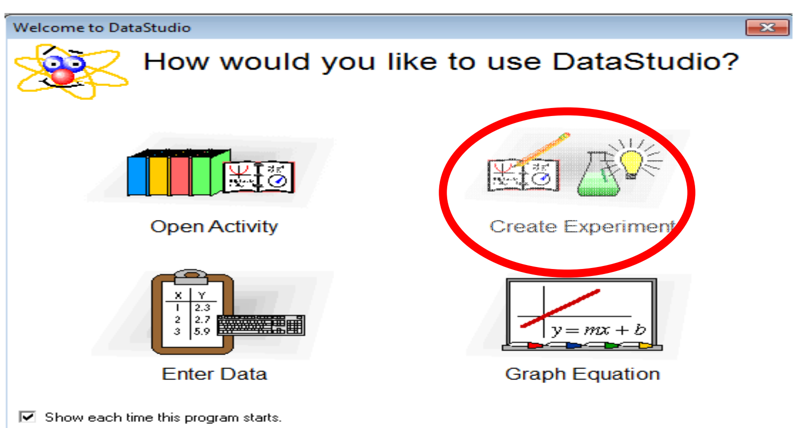
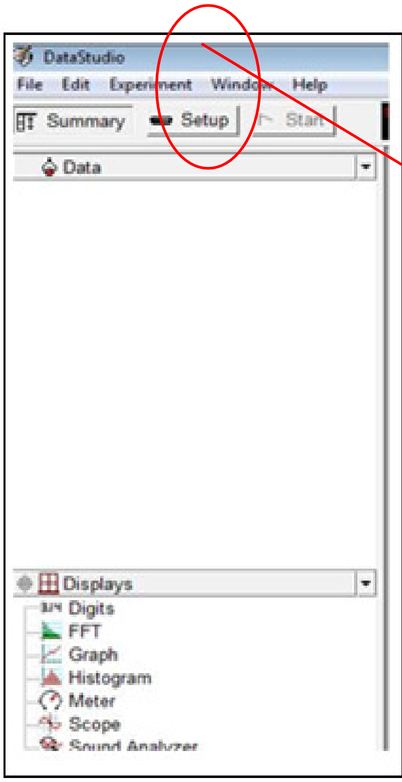


Figure 6.4 .DataStudio startup menu.

4) After the student has chosen the "Create Experiment" from interface in the DataStudio Application, the next step is to plug-in the pH-Sensor device into his PC (see figure 6.5).

Figure 6.5 .pH-Sensor device

5) After that he must select "Setup" option from the main menu (see figure 6.7). This option activates a popup dialog box in which the student can add the proper device or instrument. From the above dialog box, the student will select "Add Sensor or Instrument". This selection will activate a new dialog box which contains most of the known devices and instruments DataStudio can connect with (see figure 6.6). For our experiment, the student must select pH-Sensor.
6) When the pH-sensor is connected and ready to be used, the student inserts the "pH-sensor" in the chemical solution in which he/she wants to measure the pH degree.



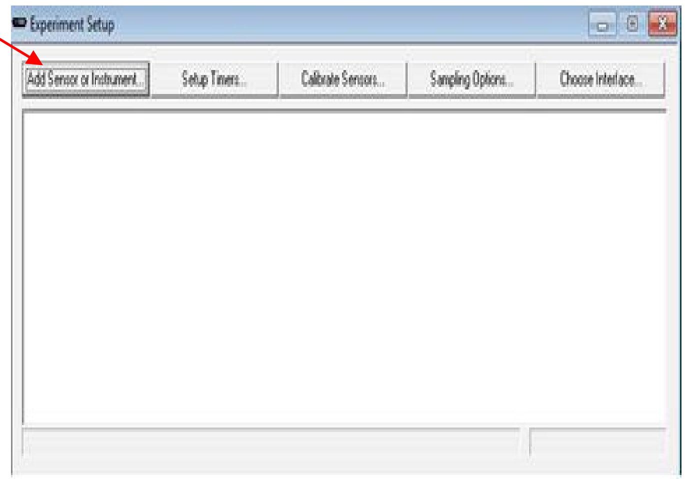


Figure 6.6 .Experiment setup.

Figure 6.7 .Start the experiment.

7) The next step is to select the "Calibrate Sensor" option; a popup dialog box for calibrating the pH-sensor device will appear (see figure 6.8). In this dialog box, there are many options, from which the student must select the proper setting –supervised by a teacher - to calibrate the sensor. Next, the DataStudio will present the pH degree measuring results for that solution (see figure 6.9).
8) Each student in the group has recorded and registered the pH degree using a form called "Result Report". In the result report the student answered many questions, such as:

- What's the pH of the solution?
- Is the solution acidic, neutral, or base?

At the end of the experiment, each student rinses the pH-sensor with distilled water.

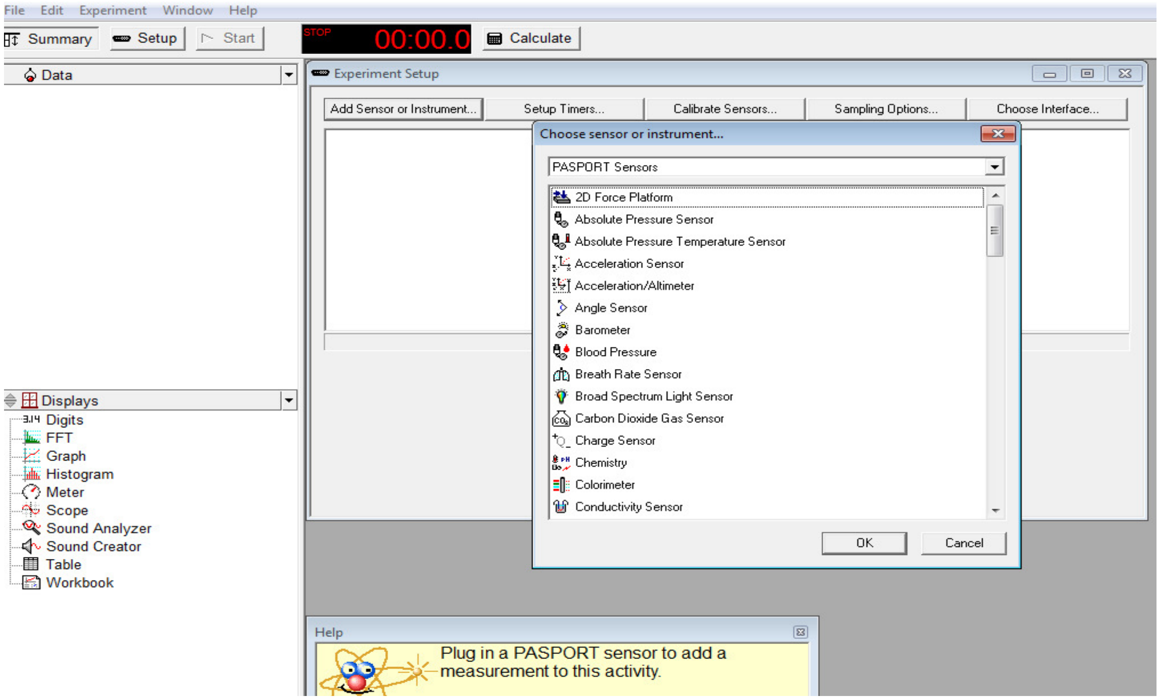


Figure 6.8 .Add sensor or instrument.

After the end of this activity, all students answered:

1) Questions from the exam.
2) Questions regarding the impact of the use of computerized laboratory on the students' attitudes towards chemistry. The students' answers are shown in table 6.7.
3) Questions regarding the trends of students towards computerized laboratories in the teaching of chemistry. The answers can be seen in table 6.11.

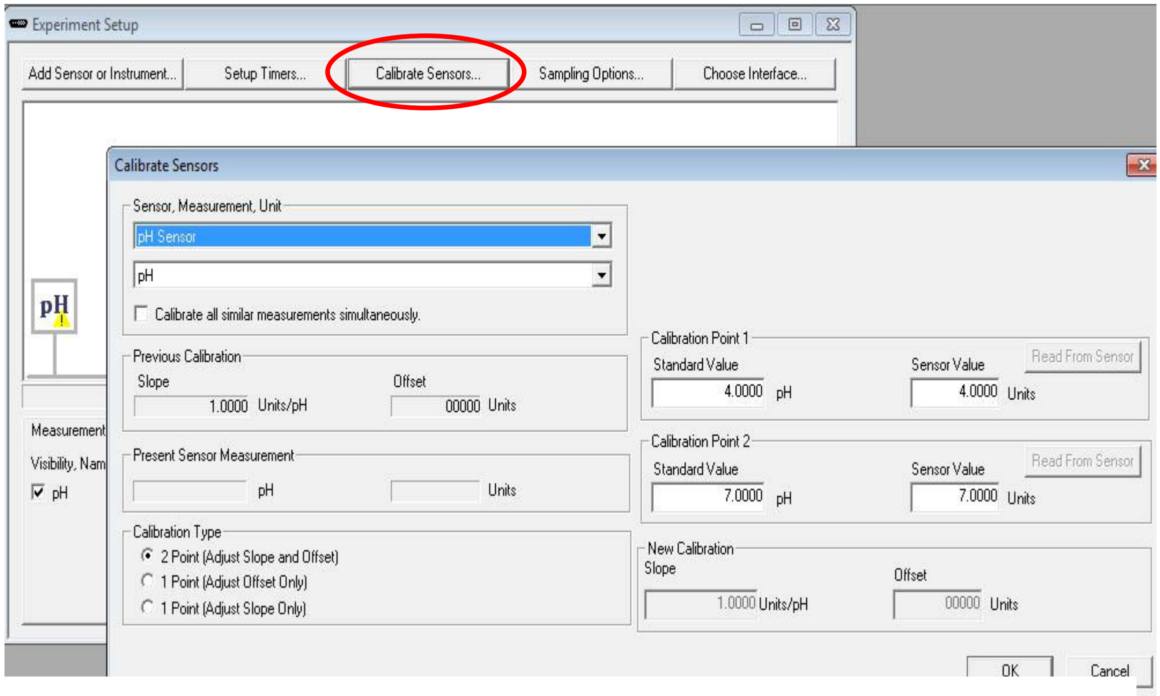


Figure 6.9 .Calibrate Sensor.

6.1.4.3. Using Virtual Reality Applications

In order to achieve the research purpose, the students of this group were instructed on how they can interact with the VRA.

We divided our experiment using the Virtual Reality Applications in two parts.

First part

The aim of the activities from the first part was to prepare students to answer to the exam questions that are to acquire the theoretical concepts and practical knowledge linked to acids, bases, their reactions and determining the pH degree of chemical solutions. The activities were carried out using our VRA, described in sections 5.3 and 5.4.

Second part

In this part of our experiment the students have used our VRA described in sections 5.1, 5.3 and 5.4. At the end of the activities from this part, the students answered the questions from the two questionnaires, concerning:

- The impact of the use of VRA on the students' attitudes towards chemistry; the students' answers can be seen in table 6.8.
- The trends towards the use of VRA in teaching chemistry; the students' answers can be seen in table 6.12.

Now we will discuss all activities in the both parts.

Activities in the first part of the experiment

In the VRA approach the students had two different ways to prepare for the exam, but both in a 3D Virtual Reality environment created with OpenSim. Each student has to choose one of the two applications(see figure 6.12) : the 3D MMO game described in section 5.3 or the Chemistry Virtual Laboratory, described in section 5.4. In both approaches the student need to open an OpenSim viewer (eg. Firestorm - see figure 6.10) as the main environment, and then login into the proper virtual application server (see figure 6.11). In the next sections A and B we will describe the steps which the students followed to make the experiment using the two VRA.

Figure 6.10 .3D Viewer.

Figure 6.11 .Virtual Environment Server.

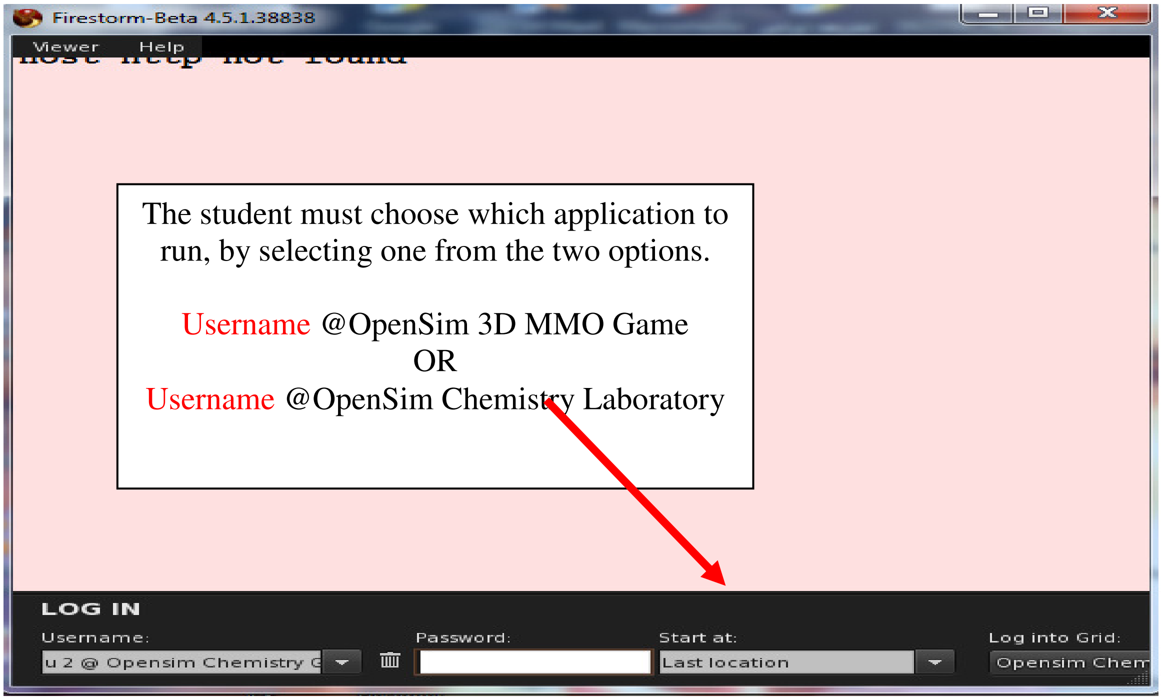


Figure 6.12 .The student selects the application he/she wants to use.

A. Activities in 3D MMO game

The 3D-MMO chemistry game contains many levels. All the levels have activities to compare between acids and bases and to determine the pH degree of the chemical solutions.

Level I

On level one, the game offers many chemical solutions and the student can select one of them, by clicking on a bottle. A soon as the student selects a solution, the game triggers a query message - "what kind of solution he selected: acid, base, or neutral". In front of the student there are three gates with different colors, each gate representing one answer: red for acid, blue for base and white for neutral. The meaning of each color (acid, base, neutral) is written on the corresponding gate (please refer to section 5.3 for more details). If the student selects a wrong gate (answer) the game will hold until the student selects the correct gate. Only after that he can continue to the next level.

Level II

On this level, the game displays five gates in different colors, each color having a specific meaning: green for weak acidic, red for strong acidic, blue for strong base, pink for weakly base and white for neutral solution. Like in the first level, the meaning of each color is written on the corresponding gate. The student has to select the gate corresponding to the solution he/she has chosen on the first level. Otherwise, the game holds until he/she selects the correct gate.

Level III

On this level, the students have to recognize the color resulted from the combination of the solution chosen on the first level with a chemical reagent. Again, the colors are associated with different gates, for: red, orange, blue, and violet. Only the gate corresponding to the correct answer will open and student can enter the next level.

Last level

The student must select the correct pH of the chosen solution, showing him several option gates: 1, 2-3, 7, 11, 12, and 14. Now, if the player chooses the correct gate, he is allowed to continue playing, starting again from the first level with another solution, until he finishes the solutions exposed on the first level.

B. Activities in Virtual Laboratory

The main activities each student has done in part one of the experiments using the Chemistry Virtual Laboratory was to determine the degree of pH for some solutions.

1. After student entered the Virtual Laboratory I asked him to go to the table from the virtual laboratory with bottles representing different compounds of chemical solutions, with colors red and blue corresponding to acidic or base solutions. The student learns the colors of different compounds by seeing these bottles. Then, using the pH scale from the laboratory he/she can determine the pH degree of the solution.
2. I asked the student to make chemical reactions between different chemical elements and water or hydrochloric acid and then determine the pH degree of the resulting materials.

After a student has made a chemical reaction, a video from YouTube is played in front of him, which gives him information about the chemical reaction and helps him to find out the pH degree of the chemical solution. All these activities in the Chemistry Virtual Laboratory and 3D MMO game are shared between students either cooperatively or in the form of competition among them, through the communication tools available from OpenSim.

At the end of the activities from part one of the experiment the students have answered the exam questions.

Activities in the second part

In this part, the students used our Virtual Reality Applications described in sections 5.1, 5.3 and 5.4.

A. The first application: A 3D Virtual Classroom for teaching Chemistry http://www2.eonexperience.com/eon-models/details.aspx?cid=5163

B. Every student using this application followed this procedure:

1) Downloaded EON Coliseum on his computers.
2) Obtained (from me) a "Meeting ID".
3) Chosen an Avatar to represent him in the virtual environment.
4) Interacted with existing activities in the virtual environment, focused on the Periodic Table and identified the chemical elements on it.
5) Interacted with the sources of information attached to each 3D object in the application.
6) Joined other students who participated in the virtual lesson at the same time.
7) Used communication tools, such as microphone or chat, to communicate with each participant on-line in the virtual lesson.

C. The second application: A 3D game for learning chemistry in a virtual environment.

Every student using this application followed this procedure:

1) Accessed the 3D MMO game application in OpenSim.
2) Chosen an Avatar to represent him in the 3D MMO game.
3) Played the game, which consists of 3 parts :

- The first part: chemical reactions

This part contains different levels of difficulty in learning about chemical reactions, student advancing in this part gradually in solving puzzles facing.

- The second part: Activity series of chemical elements.

Here, too, the student is graded in levels of the game up to even the toughest level; at the last level he arranged chemical elements according to activity to reaction.

- The third part: Comparison between acidic solutions and basic solutions.

In this part of the game the student answers all the puzzles encountered at different levels, learning a lot about the properties of acids and bases.

In this game, students are competing with each other to solve puzzles and communicate in order to compete not cooperate.

The game is described in details in section 5.3.

D. The third application: A 3D MMO Virtual Chemistry Laboratory.

This application contains a lot of interactive activities related to the Chemistry laboratory.

- **First,** the interaction of chemical elements with water and hydrochloric acid.

Students conduct several chemical reactions, including the interaction of water with organic elements or interaction with hydrochloric acid, in a virtual way, through 3D simulation.

- **Second**, learning about chemical elements from the periodic table.

The student pick an element of the periodic table from the virtual laboratory, learns its position in the table and obtains useful information about it directly from a web site or by watching a video from YouTube.

- **Third**, recognizing chemical compounds.

The student can pick any bottle from the shelf of the virtual laboratory and learns if the solution from the bottle is acidic or base. The information is done by a shining color and by a message.

After the students have finished working with these applications, I asked them to answer the two questionnaires, the first one about the students' attitudes towards chemistry; the students' answers are shown in tables 6.8. The second one was about the trends towards the use of VRA in teaching chemistry. The students' answers are shown in table 6.12.

6.1.5. The achievement test: acquirement of knowledge about chemical solutions

The achievement test was developed to include information about chemicals like acids and bases, and how to determine the pH degree for any chemical solution. The results of the test have been used as pointers to measure the students' achievement in the three groups. For the achievement test we performed the following steps:

1. **Define the test objective**: the objective of the test was to measure the impact of using the VR applications and computerized laboratory against the traditional learning in terms of the students' achievement, especially the understanding of acids and bases in the chemistry course of the tenth grade classes.
2. **Set up the test dimensions**: we have chosen the dimensions of the test according to "Bloom's Taxonomy", which is a set of factors to measure the cognitive content for our research domain. *Bloom's Taxonomy contains* six major categories, which are [8]:
   - Remembering
   - Comprehension
   - Application
   - Analysis
   - Synthesis
   - Evaluation
3. **Determine the type of test**: we have chosen the multiple choice test form to be used to measure the student's achievements in respects to our experiment. Multiple choice test forms have many features such as, they are easy to be measured with any statistical tool, also they give us the ability to represent their content in many different kinds of forms (charts, tables, excel sheet).
4. **Making the test**: the questions on the test were formulated according to many related sources in chemical domain, in addition to the personal experience in this area. The questions covered the six dimensions of the *Bloom's Taxonomy*. Examples are shown in Table 6.2.

Table 6. 2.Examples of questions from our *achievement* test

Test dimension	**Question**
Remembering	*What is the importance of acids and bases in our life?*
Application	*What is the pH degree of ammonia NH3?*
Comprehension	*What is the equation that represents the production of acid sodium hydroxide NaoH?*
Analysis	*What is the pH degree, when adding a buffer solution to the Hydrochloric acid solution?*
Evaluation	*Is the pH degree increasing, if the solution acidity is increasing?*
Synthesis	*What will be the solution description, when mixing a base solution with an acidic one?*

5. **Formulation of the test instructions**: the instructions were drafted and placed on the first page in the achievement test booklet; they included a brief description of how to answer, combined with an illustrative example.
6. **Determine the rating system grades**: grades were estimated as one degree for each correct answer. Annex 1 shows the grades in the achievement test for all students in the three groups.

6.1.6. The trend toward chemistry

The method which was used to measure the trend towards chemistry consisted of 28 questions with answers on a Likert scale [3]. The students had to select one answer from the following list: strongly agree, agree, neutral agree, disagree, and strongly disagree. The reasons behind using a Likert scale were: relatively easy in design, easy in implementation and correction. In addition, Likert scale is relatively comprehensive and accurate. Then, we analyzed these results statistically (see Table 6.10). You can see all answers to the "trend toward chemistry" questionnaire, of students from all three groups in Annex 2.a, Annex 2.b and Annex 2.c.

6.1.7. Students' views on the use of computerized laboratories in teaching chemistry

After the completion of the experiment, we applied a questionnaire session for each student in the group from the computerized laboratory.

The questionnaire quantified the students' conception about the use of computerized laboratory in learning chemistry. Then we analyzed these results statistically (see Table 6.11). In Annex 2.b you can find answers to the “Students' views on the use of computerized laboratories in teaching chemistry” questionnaire.

6.1.8. Students’ opinions about using Virtual Reality Applications in learning chemistry

This study helped us to know the students' attitudes towards the use of Virtual Reality Applications in learning and to make the proper adjustments to fit with their needs.

We used in our experiment the applications described in 5.1, 5.3 and 5.4.

After the completion of the experiment we applied them a questionnaire to conclude the impact of using such application in learning chemistry, and then we took these results and analyzed them statistically (the results are shown in Table 6.12). Annex 2.c shows the answers to the “Students' views on the use of Virtual Reality Applications in teaching chemistry” questionnaire.

6.2. Statistical analysis of results

The main purpose of the statistical analysis is to find the values of the most used empirical research coefficients, for the three groups:

1) Average
2) Standard deviation
3) Significant statistical differences

We used *one way ANOVA* (Analysis of variance) [9] model to calculate the significant statistical differences between the study groups, based on the variables ***achievement*** and ***trend***. These values were calculated using the SPSS software (http://spss.en.softonic.com/)

The empirical research coefficients were used to answer the following four empirical research questions:

1) What is the effect of using a computerized laboratory or a VRA for studying achievement?
2) What is the impact of the use of traditional laboratory, computerized laboratory and VRA on the students' attitudes towards chemistry?
3) What are the trends of the first experimental group (who studied using computerized laboratories) towards computerized laboratories in the teaching of chemistry?
4) What are the trends of the second experimental group (who studied by using VRA) towards the use of VRA in teaching chemistry?

6.2.1. First question

What is the effect of using a computerized laboratory or a VRA for studying student achievement?

The first hypothesis to give a possible answer to this question is as follows: there were statistically significant differences at the significance level α =0.05 between the average grades of students of the control group and the experimental groups in the achievement test for the chapter “the acids and bases in chemistry” for tenth grade students. Table 6.3 shows the average and standard deviation inside each group of students.

As can be seen, the arithmetic average of the first experimental group, which studied using computerized laboratory, is equal to 14.35, while it is 14 for the second experimental group, which studied using VRA, and approached the arithmetic average of the control group.

To finds out if there are significant statistical differences between the control group and experimental groups we calculated the variance (Table 6.4), using *one way ANOVA*.

Table 6. 3.Average and standard deviation inside each group of students.

Group	**Number**	**Arithmetic average of the grades**	**Standard deviation**
Control group	17	13.71	5.45
The first experimental group	17	14.35	5.87
The second experimental group	17	14	4.33

Table 6.4 .Analysis of variance in achievement among the groups.

Source	**Sum of squares (SS)**	**The degree of freedom (df)**	**Mean square (MS)**	**F**	**The value of significance p - value**	**Level of significance**
Between groups	2.0392	2	1.0196	1.5817	0.0216	Not statistically significant
Within each group	30.9412	48	0.6446			
Total	32.9804	50				

The data from the above table were obtained with ANOVA statistical model, which is used to test statistical hypothesis, to reach the statistical results in the experimental research. If a statistically significant result (p-value) is less than the significance level (α =0.05) the result is ***not statistically significant***, so that the hypothesis will be rejected. Table 6.4 shows that the value of "p" is not statistically significant at the level of 0.05. This indicates that there are no statistically significant differences among the three groups, in the average grades of the achievement test, so the first assumption is not correct, and thus it is rejected.

The reason for not appearing statistically significant differences among the three groups is due to a number of reasons:

- The most important one is the short time to carry out the experiment.
- The length of the course, which deals with a large theoretical subject.
- It has not been taken into account the time needed by the experimental groups for practical activity for each period. It was considered that the time for both experimental groups and the control group in the study subjects is the same, which resulted in the available limited time for experimental groups to carry out the experiments effectively, especially as it was a new experience for students. In addition, there were some technical problems in the program of computerized laboratories, which need a maintenance and calibration from time to time.
- The language of computer programs, which is English, is an obstacle to some students.
- The number of the students in each group was small.

6.2.2. Second question

What is the impact of the use of traditional laboratory, computerized laboratory and VRA on the students' attitudes towards chemistry?

The second assumption of a possible answer to this question is: there are statistically significant differences at the level of 0.05 between the average grades of the control group students and of the experimental groups of students on the scale of the trend towards chemistry. We used the Likart scale: Strongly agree (5), agree (4), neutral agree (3), disagree (2), and strongly disagree (1). Table 6.5 shows the scale which we used in the analysis of the result.

Table 6. 5.The scale used in the analysis of the result.

The items	Strongly agree	Agree	Neutral agree	Not agree	Strongly disagree
Arithmetic Average	5-4.2	4.19-3.40	3.39-2.60	2.59-1.80	1.79-1
Semantics	High positive	Positive	Neutral	Negative	High negative

Table 6.6 shows the attitudes of the control group students who studied using the traditional way.

Table 6. 6.The results of the control group's responses

Phrase	Strongly agree %	Agree %	Natural %	Disagree %	Strongly disagree %	Arithmetic Average	Standard deviation
I feel pleasure while I am studying chemistry activities	47.1	23.5	5.9	5.9	17.6	3.76	1.56
Chemistry study helps in the development of scientific thinking	29.4	47.1	5.9	17.6	0	3.88	1.05
My study of chemistry increase the understanding of natural phenomena	23.5	47.1	5.9	17.6	5.9	3.82	1.13
I do not think that the chemistry is necessary for life	17.6	47.1	11.8	23.5	0	2.18	1.07
Chemistry course is on the courses which I can pass the exam successfully	11.8	58.8	11.8	11.8	5.9	3.65	1.22
The study of chemistry is interesting	23.5	47.1	5.9	17.6	5.9	3.59	1.06
The study of chemistry helps me to understand some of the modern scientific issues	17.6	47.1	11.8	23.5	0	3.59	1.06
Chemistry is one, of course, which I like	11.8	58.8	11.8	11.8	5.9	3.53	0.80
I do not feel any interest in chemistry study	0.0	70.6	11.8	17.6	0.0	2.65	1.27
I wish to delete the chemistry of the courses of school	11.8	17.6	5.9	52.9	11.8	2.71	1.49
I meditate certain chemicals course in the home to know them better.	11.8	41.2	17.6	17.6	11.8	3.29	1.21
I feel I need to learn a lot about chemistry	11.8	41.2	17.6	17.6	11.8	2.76	1.64
The study of chemistry that we learn doesn't help to cope with modern scientific development	23.5	11.8	17.6	11.8	35.3	2.82	1.24
I 'm bored during chemistry periods	11.8	23.5	5.9	52.9	5.9	2.88	1.41

The reading of chemistry books is a waste of time	17.6	17.6	17.6	29.4	17.6	2.88	1.22
I do not care much about chemistry	5.9	35.3	11.8	35.3	11.8	3.00	1.46
The best school days when I do not have a chemistry period	23.5	17.6	5.9	41.2	11.8	2.94	1.39
Whenever I start studying I recall chemistry first	17.6	23.5	5.9	41.2	11.8	2.94	1.39
I prefer chemistry on another course	11.8	23.5	23.5	17.6	23.5	2.88	1.41
I would like to read the topics that are published in newspapers about chemistry	11.8	23.5	0	35.3	29.4	2.53	1.46
I feel tired when I recall chemistry	29.4	35.3	0.0	29.4	5.9	3.53	1.37
I do not want to specialize in chemistry at university	35.5	23.5	11.8	17.6	11.8	3.53	1.46
Chemistry is an undesirable course to a very large number of students	35.5	23.5	11.8	17.6	11.8	3.65	1.37
I see that chemistry is a very difficult course	29.4	41.2	0.0	29.4	0.0	3.71	1.21
Issues arithmetic that we are studying in chemistry are not important	41.2	17.6	23.5	17.6	0.0	3.82	1.19
I would like to keep the school chemistry books.	0.0	11.8	11.8	29.4	47.1	1.88	1.05
I 'm scared of chemistry test more than any other course	47.1	29.4	11.8	11.8	0.0	4.12	1.05

When I go to the library I try to search for chemistry books to have a look at them	0.0	5.9	11.8	29.4	52.9	1.71	0.92
Average rating from Arithmetic Average = 3.10							

It is clear from table 6.6 that:

- the general average of the trends in the control group is equal to 3.10;
- the Arithmetic Average ranged from 4.12 to 1.71;
- there is no questions which within the student responses have a high positive response;
- 13 questions had positive responses;
- 12 questions had neutral responses;
- 1 question had a negative response;
- 1 question had a high negative response;
- 64.7 % of the members of the group pointed out that their study of chemistry increases their understanding of the natural phenomena;
- 70.6 % of the members of the group pointed to that the chemistry is one of the difficult courses.

Table 6.7 shows the results of the first experimental group of student’s responses about chemistry

Table 6. 7.Results of the first experimental group responses.

Phrase	Strongly agree %	Agree %	Neutral %	Disagree %	Strongly disagree %	Arithmetic average	Standard deviation
The chemistry study helps to develop the scientific thinking	52.9	35.3	11.8	0.0	0.0	4.41	0.71
Chemistry is one, of course, that I like very much	52.9	35.3	5.9	0.0	5.9	4.29	1.05
The study of chemistry is very interesting	52.9	35.3	0	11.8	0.0	4.29	0.99
I feel pleasure while I am doing the activates of chemistry	47.1	29.4	11.8	5.9	5.9	4.06	1.20
My study of chemistry increases my understanding of natural phenomena	29.4	35.5	23.5	5.9	0.0	4.00	0.94
I feel I 'm boring during chemistry periods	11.8	5.9	5.9	35.3	41.2	2.12	1.36
The study of chemistry helps me to understand some of the modern scientific questions	23.5	35.3	29.4	5.9	5.9	3.65	1.11
I wish to delete the chemistry of the school courses	11.8	5.9	5.9	35.3	41.2	2.12	1.36
Reading chemistry books are a waste of time	0.0	17.6	17.6	23.5	41.2	2.12	1.17
The best days of school when I do not have any chemistry period	5.9	11.8	11.8	35.3	35.3	2.18	1.24
I do not think that the chemistry is necessary for life.	5.9	11.8	17.6	41.2	23.5	2.35	1.17
The study of chemistry that we learn does not help to cope with modern scientific development	5.9	17.6	29.4	0.0	47.1	2.35	1.41
I do not care much about chemistry	17.6	5.9	5.9	35.3	35.3	2.35	1.50
I feel I need to learn a lot about chemistry	23.5	23.5	35.3	5.9	11.8	3.41	1.28
I do not feel any benefit of the study of chemistry	5.9	29.4	11.8	11.8	41.2	2.47	1.46
Chemistry is one of the courses which I pass exam very successfully	35.3	29.4	5.9	11.8	17.6	3.53	1.55
I prefer chemistry on another course	11.8	47.1	17.6	17.6	5.9	3.41	1.12
I meditate certain chemicals course at home to know them	17.6	29.4	5.9	23.5	23.5	2.94	1.52
Do not want to specialize in chemistry at university	23.5	11.8	5.9	29.4	29.4	2.71	1.61

I would like to read the topics that are published in newspapers about chemistry	5.9	35.3	29.4	5.9	23.5	2.94	1.30
Arithmetic issues we are studying in chemistry are unimportant	17.6	17.6	29.4	5.9	29.4	2.88	1.50
Chemistry is an undesirable course to a very large number of students	11.8	23.5	47.1	11.8	5.9	3.24	1.03
I see that chemistry is a difficult course	23.5	17.6	23.5	23.5	11.8	3.18	1.38
I'm scared of chemistry test more than other course	29.4	17.6	11.8	35.3	5.9	3.29	1.40
I would like to keep the school chemistry books	11.8	23.5	11.8	11.8	41.2	2.53	1.55
Whenever I start studying I recalled chemistry first.	5.6	17.6	23.5	11.8	41.2	2.35	1.37
I feel tired when I recall chemistry	5.9	23.5	17.6	47.1	5.9	2.76	1.09
When I go to the library I try to search for chemistry books to have a look at them	5.9	11.8	17.6	29.4	35.3	2.24	1.25
The general average from Arithmetic Average =3.01							

It is clear from table 6.7 that:

- the general average of the trends in the first experimental group is equal to 3.01; this result indicates neutral trends according to Table 6.5;
- the Arithmetic Average ranged from 4.41 of 2.12;
- 2 questions had high positive responses;
- 5 questions had positive responses;
- 16 questions had neutral responses;
- 4 questions had negative responses;
- 88.2 % of the members of the group have indicated that the chemistry is one of their favorite courses;

  5.76 % of the members of the group feel pleasure while they are doing the activities of chemistry by using computerized laboratory.

Table 6. 8 shows the trends of the second experimental group, which studied by using VRA, towards chemistry.

Table 6. 8.Results of the second experimental group of students' responses.

Phrase	Strongly agree	Agree %	Neutral%	Disagree %	Strongly disagree %	Arithmetic average	Standard deviation
My study of chemistry increases my understanding of natural phenomena	29.4	64.7	5.9	0.0	0.0	4.24	0.56
Reading in chemistry books is a waste of time	0.0	5.9	17.6	29.4	47.1	1.82	0.95
The chemistry study helps to develop the scientific thinking	41.2	41.2	5.9	5.9	5.9	4.06	1.14
I feel pleasure while I am doing the activates of chemistry	47.1	29.4	5.9	11.8	5.9	4,00	1.27
I feel I'm bored during chemistry period	5.9	11.8	11.8	35.3	35.3	2.18	1.24
I do not think that chemistry is necessary for life	0.0	29.4	5.9	35.3	29.4	2.35	1.22
The best of school days when I do not have chemistry period.	11.8	11.8	11.8	41.2	23.5	2.47	1.33
The study of chemistry is very interesting	17.6	47.1	17.6	11.8	5.9	3.59	1.12
I do not feel any benefit of the study of chemistry.	0.0	29.4	17.6	23.5	29.4	2.47	1.23
I wish to delete the chemistry of the school courses.	23.5	5.9	5.9	23.5	41.2	2.47	1.66
Chemistry is one of the dear courses to me.	17.6	47.1	5.9	29.4	0.0	3.53	1.12
Chemistry is one of the courses, which I got a very	17.6	41.2	5.9	29.4	5.9	3.35	1.27

high grade in it.							
I do not care much about chemistry	0.0	35.3	11.8	35.3	17.6	2.65	1.17
The study of chemistry helps me to understand some of the modern scientific questions.	17.6	35.3	23.5	5.9	17.6	3.29	1.36
I do not want to specialize in chemistry at university	17.6	17.6	11.8	29.4	23.5	2.76	1.48
The study of chemistry that we learn does not help to go with modern scientific development	17.6	11.8	35.3	5.9	29.4	2.82	1.47
I meditate certain chemicals in the home to know them better.	17.6	35.3	5.9	11.8	29.4	3.00	1.58
I'm scared of chemistry test more than other courses	23.5	23.5	5.9	23.5	23.5	3.00	1.58
I prefer best chemistry on another course.	5.9	29.4	11.8	41.2	11.8	2.76	1.20
Arithmetic issues which we are studying in chemistry are unimportant	23.5	17.6	11.8	35.3	11.8	3.06	1.43
I feel I need to learn a lot about chemistry.	23.5	11.8	17.6	23.5	23.5	2.88	1,54
I see that chemistry is a difficult course	17.6	41.2	5.9	29.4	5.9	3.35	1.27
I feel tired when I recall chemistry.	35.3	17.6	5.9	35.5	5.9	3.41	1.46
I would like to read the topics that are	11.8	17.6	5.9	35.3	29.4	2.47	1.42

published in newspapers about chemistry.							
Whenever I start studying I recalled chemistry first.	0	17.6	23.5	29.4	29.4	2.29	1.10
I would like to keep the school chemistry books	0	5.9	17.6	35.3	41.2	2.00	0.94
Chemistry is an undesirable course to a very large number of students	41.2	35.3	23.5	0	0	4.18	0.77
When I go to the library to try to search for chemistry books to have a look at them	0	5.9	11.8	35.3	47.1	1.76	0.90
Average rating from Arithmetic Average = 2.94							

It is clear from table 6. 8 that:

- the general arithmetic average for the second experimental group is 2.94;
- the arithmetic average ranged from 4.24 to 1.76;
- 3 questions had high positive responses;
- 5 questions had positive responses;
- 16 questions had neutral responses;
- 3 questions had negative responses;
- one questions had high negative response;
- 94.1% of the members of the group have indicated that the study of chemistry increases their understanding of the natural phenomena
- 82.4 % of the respondents believed that the study of chemistry by using the computer help to develop the skills of scientific thinking
- 76.5 % of the members of the group pointed out that they feel interest while they are doing activities of chemistry, and this is consistent with the findings of the study of Alhudhaifi [Alhudhaifi, 2005].

To check the validity of the second hypothesis, the arithmetic average and the standard deviation were calculated and the results were in the table 6.9.

We can see from table 6.9 that:

- the arithmetic average of the first experimental group which studied using computerized laboratory is equals to 3.01;
- this trend is neutral according to the scale used in the analysis of the results in Table 6.5 ;

The arithmetic average of the control group and the second experimental group that studied using computer VRE is 3.01 and 2.94, respectively, and this trend is considered neutral, depending on the scale used in the analysis of the results in Table 6.5.

Table 6. 9.Averages and standard deviations of the three groups on the scale of the trend towards chemistry.

Group	**Number**	**Arithmetic average**	**Standard deviation**
The control group	17	3.1	1.26
The first experimental group (computerized laboratory)	17	3.01	1.27
The second experimental group (VRE)	17	2.94	1.24

To ensure the significant statistical differences, the analysis of variance was calculated, as in the table 6.10.

Table 6.10 .Analysis of variance of trends between groups.

Source	Sum of squares (SS)	The degree of freedom (df)	Mean square (MS)	F	The value of significance (Sig.) p- value	Level of significance
Between group	864.1569	2	423.08	1.2	0. 3098	Statistically significant
Within groups	16908	48	0.6446			
Total	17754.5098	50				

The results from the table 10 shows that the value of "p" is statistically significantly more at the level 0.05 and this indicates that there are statistically significant differences among the three groups in the scale of trends, and therefore the second hypothesis is accepted.

6.2.3. Third question

What are the trends of the first experimental group of students (who studied using computerized laboratories) towards computerized laboratories in the teaching of chemistry?

The question can be answered by observing the table 6.11, as it demonstrates students' attitudes towards the use of computerized laboratories in teaching chemistry.

Table 6. 11.Students' attitudes toward computerized laboratory

Phrase	Strongly agree %	Agree %	Neutral %	Disagree %	Strongly disagree %	Average Arithmetic	Deviation Standard
When the computerized processing laboratory I work experience myself	70.6	11.8	11.8	0.0	5.9	4.41	1.12

Computer program Easy to use.	64.7	17.6	11.8	0.0	5.9	4.29	1.10
Computerized laboratory has increased my desire to go to the lab	35.3	58.8	5.9	0.0	0.0	4.29	0.59
Computerized laboratory is more interesting than the average laboratory	41.2	47.1	5.9	5.9	0.0	4.24	0.83
Computerized laboratory has increased my convince of the importance of the use of computer in education	41.2	11.8	0.0	0.0	5.9	3.94	1.20
Computerized laboratory helped to conclude the results of the experiment in a better way	35.3	52.9	0.0	0.0	11.8	4.00	1.22
Computerized laboratory increased exploration skills	29.4	47.1	11.8	11.8	0.0	3.94	0.97
Computerized laboratory made scientific concepts more realistic	29.4	35.3	23.5	5.9	5.9	3.76	1.15
Computerized laboratory provided more time for critical thinking about the experience.	23.5	52.9	17.6	0.0	5.9	3.88	0.99
Computerized laboratory increased of the positive trends of the computer.	35.3	35.3	11.8	17.6	0.0	3.88	1.11
I have a great interest in the use of computerized laboratory	17.6	52.9	29.4	0.0	0.0	3.88	0.70
I think that my learning, increased by using computerized laboratory more than by using normal laboratory	17.6	58.8	11.8	11.8	0.0	3.82	0.88
Computerized laboratory reduced the needed time to	47.1	11.8	23.5	11.8	5.9	3.82	1.33

carry out experiments							
I can equip computerized laboratory myself.	35.3	29.4	11.8	17.6	5.9	3.71	1.31
Computerized laboratory changed of the monotony of teaching chemistry	17.6	41.2	35.3	5.9	0.0	3.71	0.85
Computerized laboratory made me understand the charts deeply	17.6	47.1	17.6	17.6	0.0	3.65	1.00
Computerized laboratory has increased my positive sight towards scientific courses	17.6	47.1	29.4	11.8	0.0	3.65	0.93
Computerized laboratory helped me to correct some scientific misconceptions	29.4	29.4	23.5	11.8	5.9	3.65	1.22
I do not see any advantage to excite experiments by computerized laboratory more than normal laboratory	11.8	11.8	23.5	35.3	17.6	2.65	1.27
Computerized laboratory helped me in understanding the scientific concepts better than the normal laboratory	11.8	52.9	11.8	11.8	11.8	3.41	1.23
Computerized laboratory has increased my interest in scientific research	5.9	58.8	17.6	5.9	11.8	3.41	1.12
Computerized laboratory has increased the skills of using computer	11.8	47.1	11.8	29.4	0.0	3.41	1.06
The use of computerized laboratory increased my convince in chemistry that I studied.	11.8	35.3	35.3	11.8	5.9	3.35	1.06

The needed time by computerized laboratory is not equivalent to the benefit of it.	5.9	17.6	35.3	35.3	5.9	2.82	1.01
Computerized laboratory has increased my desire to learn	23.5	58.8	11.8	0.0	0.0	4.12	0.60
Average rating from Arithmetic Average =3.75							

Table 6.11 shows students' attitudes towards the use of computerized laboratories in the teaching of chemistry. From table 6.11 we reached to this result:

- the general average has reached to 3.75 and it indicates that the trend is positive, according to the classification adopted in the table 5;
- the Arithmetic Average ranged from 4.41 to 2.65;
- this indicates that there are no negative responses to the members of the group;
- members of the group indicated that the computerized laboratory is more interesting than the traditional laboratory 70.6%;
- it is confirmed by the students that the computerized laboratory increased positive attitudes toward computer;
- it is indicated by 58.2 % of the members of the group that the computerized laboratory reduces the time required to perform the experiments; we find the same result in Alshaya study [Alshaya, 2005] ;

6.2.4. Fourth question

What are the trends in the second experimental group of students (who studied by using VRA) towards the use of VRA in teaching chemistry?

The answer to the question can be observed the table 6.12, as it demonstrates student's trends towards the use of VRA in teaching chemistry.

Table 6. 12.Students' attitudes toward using VRA in teaching and learning chemistry

Phrase	Strongly agree %	Agree %	Neutral %	Disagree %	Strongly disagree %	Arithmetic Average	Deviation Standard
The VRE program is easy to use	64.7	35.3	0.0	0.0	0.0	4.65	0.49
VRE increased my convince of the importance of the use of computers in education	52.9	35.3	5.9	5.9	0.0	4.35	0.86
VRE reduces the required time to perform the experiments	52.9	35.3	0.0	0.0	11.8	4.18	1.29
VRE increased the skilled of using computer	35.3	47.1	0.0	11.8	5.9	3.94	1. 20
VRE programs provided more time to think critically about the experiment	29.4	47.1	5.9	17.6	0.0	3.88	1.05
VRE have changed from the monotony of teaching science.	23.5	58.8	5.9	5.9	5.9	3.88	1.05
VRE increased of the positive attitudes towards the computer.	41.2	23.5	17.6	17.6	0.0	3.88	1.17
VRE programs increased of exploration skills	23.5	41.2	23.5	11.8	0.0	3.76	0.97
VRE increased of my positive sight towards scientific subjects	17.6	58.8	11.8	5.9	5.9	3.76	1.03
I do not see any advantage to excite experiment by VRE from the execution of normal laboratory	0.0	23.5	17.6	29.4	29.4	2.35	1.17
I have a great interest in the use of VRE	35.3	17.6	11.8	29.4	5.9	3.47	1.42
VRE has increased my desire to go to the laboratory	5.9	52.9	11.8	23.5	5.9	3.29	1.10
VRE helped to conclude the results of the experiment in a better way.	23.5	41.2	5.9	5.9	23.5	3.35	1.54
VRE helped to correct some scientific misconceptions.	11.8	29.4	41.2	11.8	5.9	3.29	1.05
VRE increased my desire to learn.	17.6	35.3	23.5	23.5	5.9	3.24	1.35

The use of VRE increased my conviction that I study science	11.8	35.3	23.5	32.5	11.8	3.24	1.15
I think that my learning by using VRE increased from the normal laboratory.	23.5	23.5	5.9	35.3	11.8	3.12	1.45
The time needed by VRE programs are not equivalent to benefit that we get from them	5.9	35.3	23.5	17.6	17.6	2.94	1.25
VRE programs are helping to absorb the scientific concepts better than the normal laboratory	23.5	17.6	17.6	23.5	23.5	2.88	1.56
VRE make scientific concepts more realistic	23.5	17.6	11.8	23.5	23.5	2.94	1.41
VRE has increased my interest in scientific research	11.8	29.4	17.6	17.6	23.5	2.88	1.09
VRE is more interesting than the normal laboratory	11.8	11.8	17.6	23.5	35.3	2.76	1.42
Average rating from Arithmetic Average = 3.44							

From table 6.12 we can conclude that:

- the overall average students' attitudes towards the use of VRA in the teaching of chemistry is equal to 3.44; this indicates that the trend is positive according to a rating based on table 6.5;
- the averages of the students' responses ranged from 4.65 to 2.35
- 58.8 % of the members of the group has pointed out that the VRA increased they convince of the importance of the use of computers in education, and VRA reduced the required time for the implementation of practical experiences;
- 41.2 % of the members of the group reported that VRA have increased their desire to study Chemistry;

- 41.2% of the members of the group confirmed that VRA help to correct some erroneous scientific misconception;
- 47 % of the members of the group has pointed out that learning by using VRA has increased compared to the traditional manner;
- 58.3 % of the members of the group emphasized that the normal laboratory is more interesting than VRA, and this confirms that the direct experience is not equaled by any other way in the educational value. Except that in the case of a lack of appropriate laboratory the learner could make some practical experiences using VRA or in the case to clarify some of the minuscule things that cannot be observed with the naked eye.

6.3. CONCLUSIONS

The results of this study can be summarized as follows:

- There is no statistically significant difference among the three groups in the average grades in the achievement test.

- There is statistically significant difference among the three groups in the trend towards Chemistry scale.

- The arithmetic average of the achievement test and the scale of the trend towards Chemistry of the experimental group that studied by using computerized laboratory is higher than that of the other experimental group that studied by using VR and computer simulations

- The average of the achievement and the trend towards Chemistry of both experimental groups are higher than that of the control group.

- There are positive trends towards the use of computerized laboratory and VR applications in teaching and learning**.**

CHAPTER 7. SERIOUS GAMES

7.1. THE CONCEPT OF SERIOUS GAME

7.1.1. Definition and scope

Clark Abt established the concept of "Serious Game" in his book "Serious Game" in the 1970s [Abt, 1970]. The definition of "serious game" from [Murphy, 2013] is: "the experimental and emotional freedom of active play" with "the seriousness of thought and problems that require it". And the same time, Abt adds that the seriousness of the games does not imply that they are boring, just that entertainment is not their main goal: the Serious Game activities "have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement. This does not mean that Serious Games are not, or should not be, entertaining" [Abt, 1970]. Serious Game is purpose-driven, playful environments intended to impact the players beyond the self-contained aim of the game [Clark, 2007].

A Serious Game is characterized by two main points:

1) It contains video game and one or several interest functions: broadcasting a message, providing training, facilitating the exchange of data.
2) It targets a market other than the only entertainment: defense, education, health, commerce, training, communication.

A Serious Play is part of an approach similar to the Serious Game but relies on the video toy instead of the video game: it thus does suggest explicit playful objectives to do in order to "win" or "lose" [Juliam, 2011].

Serious Games aim "to use new gaming technologies for educational or training objectives. It discusses the educational, therapeutic and social effect of digital games built with or without learning outcomes in mind." [Felicia, 2009].

"The Serious Games Initiative is focused on uses for games in exploring management and leadership challenges facing the public sector. Part of its overall charter is to help forge productive links between the electronic game industry and projects involving the use of games in education, training, health, and public policy"[10].

“Serious Game: a mental contest, played with a computer in accordance with specific rules that uses entertainment to further or corporate training, education, health, public policy, and strategic communication objectives“[Zyda, 2005]. Therefore, any video game that contains target objective information to pass across is considered a Serious Game. As for the educational games, the game must be entertaining to encourage players to progress in the game, and automatically learn through the game's story.

Serious Games are very interesting and contain joyful procedures for users. They are usually used for entertainment, but they allow getting a series of tools and ideas for users which help them to learn. Games are part of a virtual world within certain rules and assessment tools to support the users to teach [Sawyer, 2008].

Serious Games are considered successful in every time if they create a dialogue among the players and attract attention of players. The quality of the game is determined by its effect on players without control and its effect on the learning of the players.

If we need a Serious Game with useful tools to promote learning and to change social life of young people we have to assess its design. We usually assess its design through the quality of its components, not only in its design.

There are many ways to create and deploy a computer game, including an educational game. Nowadays, virtual reality and 3D game technology open new perspectives for 3D game developers. They allow a more immersive participation for gamers, on-line interaction of many users through the network, and a more active and unanticipated involvement of gamers in game evolution [Macedonia, 2007]. The improvement in the accuracy of audio-visual elements included in a virtual environment enables a high level of fidelity in reality simulation [Stewart, 2006].

Serious Games environments offer complex and diverse curriculum for active learning, which is favored by students. The student himself can control the process of learning by game through interaction with components of the game.

Serious Games give the teacher a chance to explain concepts which aren't illustrated clearly in real, such as the rotation between the electrons in the atom. The virtual world allows the user to interact with 3D objects which help him to imagine such scientific facts.

7.1.2. Features of Serious Games

Using games in harmony with the educational content and entertainment is the biggest challenge before us. The games should provide enough **entertainment for students** to get motivation to learn through the game, and also contain **educational components appropriate to the scientific curriculum.** Learning how to play in the educational games needs training to achieve the goals of the game.

A perfect educational game is a game which **allows the player to take decisions and gives him a chance to present these decisions in suitable time**. Also, it **allows him to experience and change his decisions in order to improve his performance** through repeating the game. This is the most important advantage of the game, thus **the game should have a high level of interactivity**.

Educational games should be amusing and exciting and enthuse the player to continue playing to the end. It **affects the player emotionally to support his educational experience**. Through the Serious Game the student communicates and interacts with many players in the same place, and so the Serious Game achieves **cooperation and competition among students**. **Enthusiasm** is a significant element, which increase the learning, so the game has to contain this element in its design.

Many Serious Games are designed to **reproduce educational experiences**, to **contain practical activities** in these games. **Multimedia elements** such as text, graphics, sound, animation and video are organized and programmed to allow the user **to interact with these elements and get feedback**. Through this multimedia the information is transferred to the learners in an entertaining manner [Rankin, 2006].

Any Serious Game has a **Graphical User Interface**, which allows the interaction through visual information, such as text, 2D or 3D graphic objects. All the components of the game are organized on the screen to be shown dynamically in front of the user. The user may benefit from special tools that help him interact with visual elements, such as a Heads-up Display (HUD) overlaid onto the game screen [Tang, 2005].

7.1.3. Related work on the use of Serious Games

Michael and Chen [Michael, 2006] presented a comparative study between two groups of students. The first one studied a subject in the traditional way and the other group studied the same concepts, but using serious video games.

The researchers concluded from the study: the first observation is that students who learned through the Serious Games were more interested in the subject that the students who had learned in the traditional way. The second observation is that Serious Games offer not only improved self-monitoring, problem recognition and problem solving, but also improved short memory and long-term memory, increased social relations among students and increased self-efficacy! Other researches on the role of Serious Games in education (e.g., [Annetta, 2006]) give the same result: such rich, simulation and gaming environments give complex and various interactive approaches to learning and outcomes and, the most important point we focus on, active learning.

The "Rainbow City" game [Linlin, 2013] is offered to students in higher education from ages 16-18 in College Reid and Bruce in China. The game allows students to chat and ask for help from another player on the chemical devices, and is highly immersive. This game focuses on virtual chemical reactions, a competition between players and cooperation among the participants.

In one of his articles, [Prensky, 2002] describes a few key elements necessary for a game to be used in education or training:

- The existence of a set of rules
- The existence of conflict/competition/challenge/opposition
- To have goals and objectives
- To assure interaction
- The existence of outcomes and feedback
- To have included representation or story.

Peng [Peng, 2010] addresses the value of the play in the Serious Games and suggests a new concept, "persuasive games" as a better solution. The aim to "persuade" the players does not apply to all Serious Games. The goal of persuasion is to raise the level of awareness among players, to challenge prejudgments, or to provide information in an attractive style.

Other studies of Serious Games in education ([Leal, 2013], [Mitgutsch, 2011], and [Chetwynd, 2011]) have led to similar conclusions: Serious Games, simulations and a rich environment have a high impact on learning, as it encourages active learning.

The main goal of Serious Games is impact-driven. Serious Games were designed to have a purposeful role in the player's lives beyond the self-internal aim of the game itself. In this sense, Serious Games are purposive by design [Jansz, 2010]. The Serious Game designer and artist Mary Flanagan [Flanagan, 2009] have the opinion that "Serious Games are among the most challenging games to design" because they try to be enjoyable and effective at the same time [Okojie, 2011].

In line with our approach, many studies about the impact of games in social trends were conducted in the last decade ([Clark, 2007], [Bellotti, 2013] and [Bogost, 2007]).

The study of Schaverien [Schaverien, 2001] aimed to identify the impact of children's computer games. The sample group consisted of children aged nine and twelve. The results revealed that computer games improve cognitive skills and provide children with various experiences that develop positive attitudes. The results also revealed that the degree of creativity increases with the complexity and ambiguity of the game.

The study of Murry T. L. [Murry, 2005] had the purpose to discover the psychological aspect of virtual world games' users, and the nature of the relationship between direct education and learning process at New York University. Also, the impact of technology on human dynamics, and whether such technologies have positive or negative impacts on the educational process based on education by playing through the virtual world.

In its study, Murry aimed to highlight the most important influences and psychological methods that may be an obstacle in linking teacher with the educational subject. A sample of the study included a group of students and teachers of undergraduates and post-graduates. The most significant tools used in collecting data for this study were interviewed and questionnaires including the reasons for studying in the virtual classrooms by playing and their opinions towards this process and their teachers. Results revealed that students and teachers feel an actual communion link, despite the perceived emotional interruption through teachers viewing the students and students viewing the teachers. The major results of this study are the nature of the educational setting and the interactive setting, which helped teachers and students to communicate and influence each other. The bottom line is that teachers and students have succeeded in establishing a cognitive concept and an effective means of communication, despite confronting some difficulties, which included absence, isolation and sometimes lack of interaction.

The descriptive study of Khalili, P. & Pete [Khalili, 2000] aimed to investigate the extent of the effect of playing in the virtual world in the traditional educational process, based on direct teaching and its improvement, at the University Of Natal, South Africa. This included studying all possible mechanisms to assess the impact of learning through the assessment of teacher, learner and usage of modern communication technologies, i.e., computer networks, multimedia, sound and image, graphics, search mechanisms, electronic libraries and others. A sample of the study included students in the third and fourth academic years at the Faculty of Information Technology and Computers. Results indicated that using the internet and virtual world service in education leads to amazingly fast progress and improvement in the educational process. It also positively influences teachers' and students' performance and achievements in the virtual class, through taking advantage of the World Wide Web technologies, in its various forms of publishing courses, exercises, activities, homework, and exchange of electronic messages between students

The serious game technique also had an influence on solving some of the educational problems, such as the problems of students who dropped out, or some students who are over the average age of studying, benefiting from the experience of experts and transferring them from different places around the world.

Other papers explore the use of Augmented Reality in educational games. Thus, the authors of the paper [Stefan, 2013] identify the essential aspects of game-based learning paradigm and of game design principles, which can be applied in the design of AR-based serious games. The paper presents a concept of an educational AR game for high school and undergraduate students, which can stimulate the students' 3D view, creativity, competition, social interaction and critical-thinking. The game is designed as complementary to in-class teaching.

In conclusion, virtualization proved to be a new method of action to engage and activate students. It can provide a collaborative team with an opportunity to explore and communicate, and thus provides an incentive for teaching and learning. The above mentioned studies highlight important opportunities to encourage students to participate in multiple ways to learn through having fun. However, this is still an almost unexplored land and turning these opportunities into effective ways of teaching requires a lot of experimentation and evolution of both existing tools and methods [Moldoveanu, 2008].

7.2. ADVANTAGES AND DISADVANTAGES OF GAMES AND SERIOUS GAMES

Games constitute a large part in our lives. They are in computers, devices in our phones, so the new innovations allowed the development of massive games to reach the largest number of users and be more enriching and fun.

Serious Games allow users to **simulate educational environments with certain goals**, for which the game was designed. Serious games are used in many fields of life, such as health, defense, communications, army and education.

A critical point in Serious Games in education is that the game is attractive and fun, but at the same time should achieve the goal of education and its usage. Therefore, games designers should be familiar with methods of teaching and knowledge of the educational curriculum which games aim to clarify. The student should get information from the games automatically by practicing the game interesting and by the end he has got a lot of learning and knowledge [Zyda, 2005].

The benefit of using the games depends on their effect on the students to increase scientific knowledge. Although a lot of games increase different skills, we actually know very little about the consequences for the student participating in the game with people who do not know [Barab, 2000]. But we affirm that **Serious Games and virtual environments include simulations that allow users to learn experiences impossible to take place in the real world because of safety, financial cost and the time to implement them** [van Eck, 2006].

Some studies prove the importance of games in education and illustrate **the negative effect of the games on users such as headache, stress, tiredness from sitting for a long time in front**

of the computer and mood changing. Other studies have shown **the negative social effects on the user such as depression, isolation, and the negative effects arising from the use of violence in games such as aggressive behavior** [Michael, 2006].

Serious Games have positive effects such as supporting a number of different skills for **example critical thinking skills, construction and installation skills and strategic analytical skills in addition to increasing the capacity of learning and memory**. **Serious Games increase the visual attention of the recipient student**, but even the violent games may be useful to the students that decrease frustration [Michael, 2006].

Other potential benefits of using games in education:

- develop student's confidence and increase his intellectual capacity;
- improve self-monitoring;
- help to identify and resolve problems;
- help to make decisions;
- improve memory;
- increase social skills such as cooperation, negotiation and acquaintance [Enochsson, 2004].

Also elements of the Serious Games, as competing at different levels of difficulty, play a significant role in increasing the user's skills.

7.3. OUR SERIOUS GAME

In this section we describe an original game, developed by the thesis' author and published in [Shudayfat, 2012-31].

The traditional teaching environments are often seen as boring, by digital students, because of lacking the effective participation of students. Today's students have a new mindset and new point of view on learning, and prefer to learn through doing and achieving the greatest degree of interaction during learning, so we consider that the experimental work is necessary for the success of the educational process. Millions of users spend long time in virtual environments, for example a virtual community in Second Life has more than 126 million in 2009, and ordinary users spend an average of 22 hours online every week in such virtual communities [11].

7.3.1. Game objectives

Studying chemistry in a safe environment and without a properly equipped laboratory is quite hard. Also, there are lots of hazardous elements which cannot be exposed or have practical experiments with. Theoretical knowledge must be mixed with fun and practical experiments to be more attractive and interesting to students. A solution to this problem could be using Virtual Reality for simulation and Serious Games for the fun part.

Therefore, **our purpose was to create an immersive, 3D virtual environment with learning features, experimentation and also with some Serious Games to test the students' knowledge.**

In our experimental work of using games in learning chemistry, we observed the importance that **the students can interact with virtual communities** to discuss shared information, also students' interests for the **development of social relations** among them and exploring new hobbies which users have in this virtual environment. So we selected a development tool to help us create such environments and this is OpenSim. We started thinking about how can we exploit the potential that exists in OpenSim to teach chemistry.

Another objective of our Serious Game was **to allow students to explore the components of the game (objects, places, situations) through multimedia elements**, **while they are immersed in a virtual world similar to reality**, being in the same physical place but passing imagination and mind to another world.

As communication means, we decided that our Serious Game offer chat, **audio dialogues and messages to keep users in touch.**

Our Serious Game **should offer attractive ways of learning**, for example, knowing that atoms are small in size and cannot be seen, so difficult to imagine, the virtual environment should help students to understand such concepts **through simulations and 3D intelligent visualizations.**

Among the purposes of virtual learning environments in Serious Games is **exchanging ideas**. Our Serious Games should allow students to get the multiple points of views from one scenario in the game.

Our Chemistry game should provide several **activities to encourage active learning experiences**, through challenge and competition among students, **stimulating students' curiosity, imagination and social fun.**

7.3.2. Approach

OpenSim provides an enhanced virtual environment, with massive support of 3D objects. Each user in OpenSim is symbolized as an avatar which is a visual representation of the participating students. OpenSim is a free networked multi-user three-dimensional (3D) environment, where users, in the form of 'avatars' (a graphical self-representation) can interact with other avatars and also with many virtual 3D objects. Recently there has been increasing interest for teachers in using this simulator for educational purposes [Prendinger, 2009] besides entertainment.

OpenSim enables us to determine how an object looks, moves, communicates and interacts with avatars. It also allows the import of images, video animations and 3D objects from external sources. The overall functionality of OpenSim supports experiential and virtual learning. In the context of this paper, a crucial ability of OpenSim is its support for scripts. More precisely, OpenSim comes with LSL (Linden Scripting Language), so it is possible to program extremely rich and diversified animations or functionalities and then attach them to any object in the scene. Scripts are pervasive in OpenSim as they represent how an object looks, moves, communicates and interacts with avatars or other objects.

To integrate the problem-based learning in our game, we have included different problems that address more objectives of the virtual chemistry game. Using features provided by OpenSim, we tried to create a game aimed to resolve most of the students' problems in terms of understanding the science of Chemistry.

When designing the virtual environment, we take advantage of the level of immersion that can be provided to the user so that he can enjoy the scientific process to learn about chemistry and also provide him with a challenge through competition inside a virtual game.

Our game achieves its MMO goal by allowing a great number of users to interact at the same time (see figure 7.1). The interactions include competition, cooperation, information sharing and social networking between users. The students can navigate freely in the virtual environment by moving, teleporting or even flying.

The students' actions in this game are executed by their Avatars, chosen by them at the beginning of the game.

To run the game, students need an OpenSim client. They can download a free one from the Internet. We used Firestorm in our experiments. You can connect your OpenSim client to the **OpenSim Chemistry Game** Server using a dedicated URI, like 3d.pub.ro:12003.

Figure 7. 1.On-line students navigating freely in the virtual environment of our game.

7.3.3. The game's 3D environment

Our game runs in an immersive virtual world, which is visually rich and allow students to interact with various 3D objects. The user feels that he is in another world, far away from the real world in which he/she exists. Immersion in this virtual environment encourages the user to stay in it and to continue to interact within it, also encouraging other users to enter into this virtual environment.

Our virtual environment has many buildings. Each of them represents different elements and information (like organic chemical elements).

The main building for this experiment covers the organic elements. It has two floors, each floor having four rooms. Each room represents a specific group of organic elements that share some properties: alkali metals, earth alkaline metals, transition metals and boron group.

Figure 7.2.The entrance hall with many students.

The first floor has a big entrance hall (see figure 7.2) leading to each of the four rooms. Here, the rooms are intended for study and have rich information support. Each room is provided with three big panels. The main panel in the center provides information about the group of elements, like the position of this group in the periodic table, and is featured with interactive buttons for details on each element. So, if a user clicks on one of the elements, the left and the right panels will provide detailed information about the selected element: the left panel has text and images and the right panel will play a movie clip with detailed facts about that element (see figure 7.3). Also, each room is featured with a picture gallery on the walls with interesting pictures about the elements in the represented group in that room (how the elements are found in nature, common real life usage etc.).

In the lower part of the main central panel there is a big red “Click to play” button (see figure 7.3). When a student clicks on it, he is instantly teleported to the upper floor in the same position so he can start testing his knowledge about the related group of elements on the first floor by playing some interesting and fun mini-games.

Figure 7. 3.Avatar, after clicking the TI element on the main center panel, has access to detailed information about the Titanium element.

All the rooms have the same principle, making the game easy to use and helping students to accommodate faster. We can also mention that the users have a quick teleport menu (see figure 7.4) for easier movement in the virtual environment. Clicking on one of the locations instantly teleports the avatar to that specified location. There is also a Grades option in this menu that displays the current total amount of points gathered by the avatar by playing the mini-games.

The second floor contains many mini-Serious Games, also divided into four rooms. Each of them represents one of the elements groups. For instance, in the alkali metals room, students will find games about this specific chemical group. Each room has one or multiple mini-games.

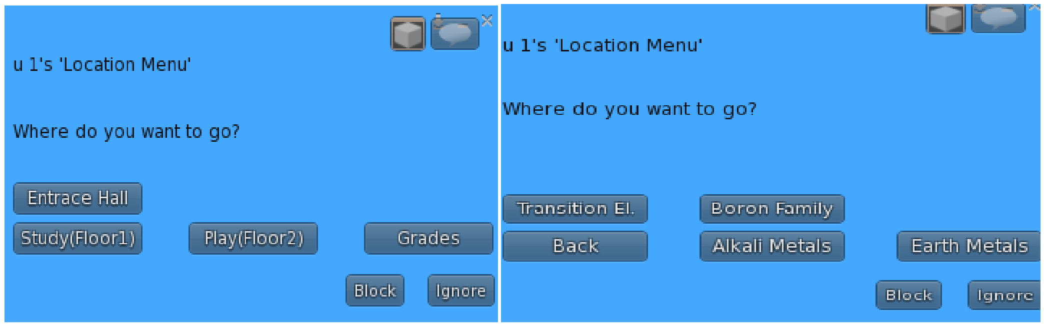


Figure 7. 4.Quick Teleport Menu.

7.3.4. The mini-games

To stimulate the students, we have created a rich virtual environment, with various types of games, increasing this way both the fun and the immersion. We started with some simple single-selection games where the users have to click and select the correct answer from a set of multiple options. For example, the students must select the correct element symbol for one specific element like Rubidium (see figure 7. 5).

A more complex, but still simple game is match-pairs. The user has to match image-pairs from two columns (see figure 7.6). For example, the first column contains elements symbols (like Ca for calcium) and the second column contains images that represent real life usages of the elements in the first column. The user must select an element by clicking on it and then he must select the appropriate image for the real life usage of that element: for example Sr (Strontium) with toothpaste. The selection is indicated by glow colors so that the correct matched pairs have the same color (see figure 7.6).

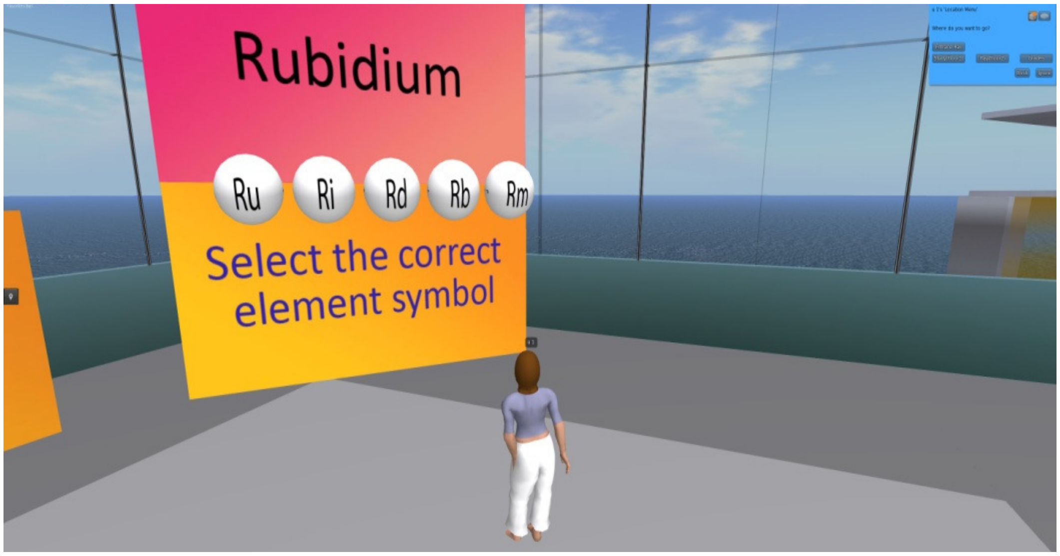


Figure 7. 5.Single-selection game.

Figure 7. 6.Match-pairs game.

One game request students to know the electronic configuration of the elements. The students must identify and select from the list the correct element for the displayed electronic configuration (see figure 7.7).

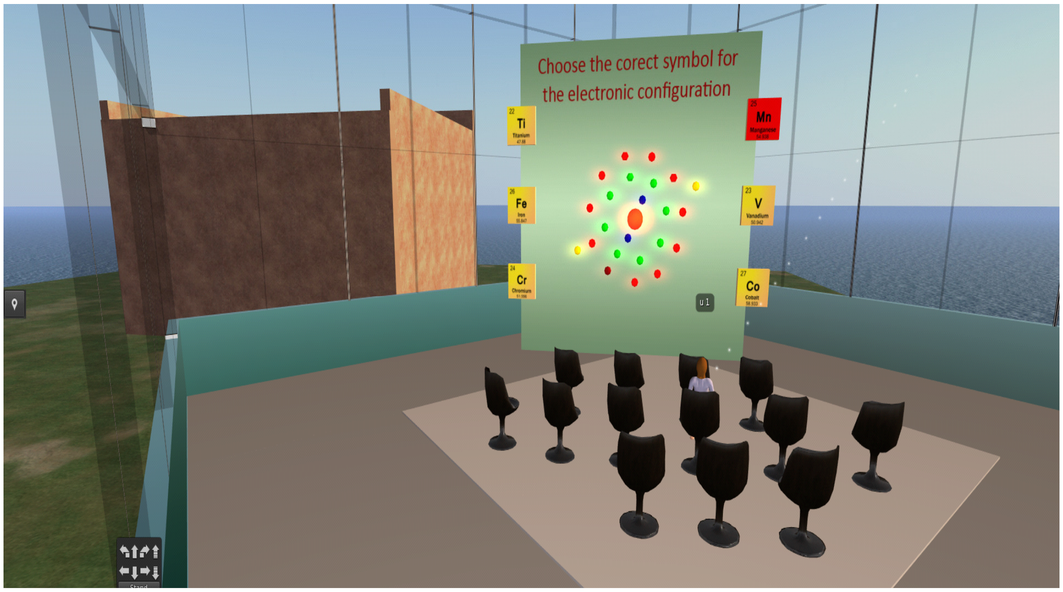


Figure 7. 7. Electronic configuration game.

Figure 7.8 .The teacher observing students during the experiment with our game

For a more immersive experience, the games have some competition features. So, there is a general score for each user. For one correct answer, the student receives his marks. On the other hand, if someone selects a wrong answer he will be punished and will have to wait for a few seconds before making another selection. Each game has many questions, so even if someone selects the correct answer, the game will restart with another question, but just after a specific period of time to raise the challenge level. As it was said before, the total amount of points can be viewed by clicking on the Grades button on the Location Menu. The teacher can record and monitor all the results (see figure 7.8), the total points and the final level for each student (see figure 7.9).

Figure 7. 9.Total Points.

7.4. GAME DESIGN AND IMPLEMENTATION

7.4.1. Game play

For the client side of our application, OpenSim compatible Viewer software is needed. In our experiments we used Firestorm Viewer which offers a rich interface with various functionalities.

In the virtual environment, each user is visually represented by a 3D avatar (see figure 7.10). Avatars are controlled by users using the mouse, the keyboard, the microphone and by accessing other in-world features. Each avatar can interact with other avatars, with other 3D objects and with the virtual environment in various ways. For example an avatar can touch a specific object by clicking on it or it can sit on a specific object by using a predefined action menu on that object (see figure 7.11).

Figure 7. 10.Avatars

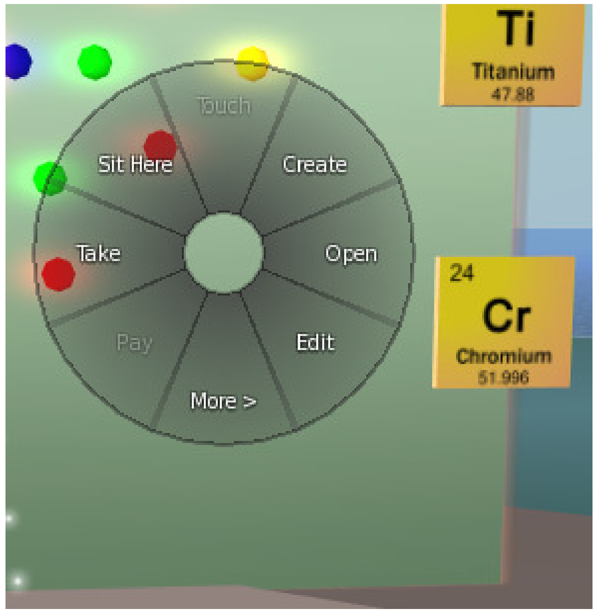


Figure 7. 11.Right click action menu on an object.

Avatars can navigate through the virtual environment by walking, running or flying. These movement types can be changed easily from a specially designed menu (figure. 7.12).

Figure 7. 12.Movement modes menu (walk, run, fly).

Also, avatars can be instantly teleported from one location to another using custom scripts or by accessing the map menu and double click on a location (see figure 7.13).

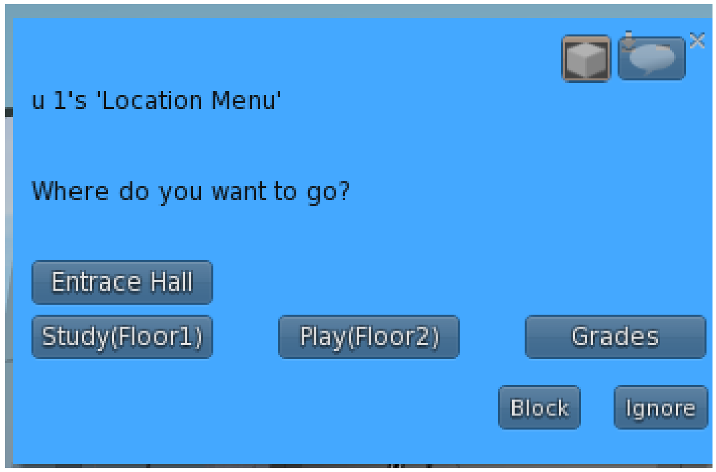


Figure 7. 13.Map menu. Teleport.

Regarding interaction between users, the client software offers support for multiple types of communication. In the first place, there is a text chat with custom commands to control the privacy of your messages. For example, you can send a message to an entire region, to whisper only to close avatars or to send a message just to specific users. Another option is to use your microphone to speak directly in the virtual environment (see figure 7.14).

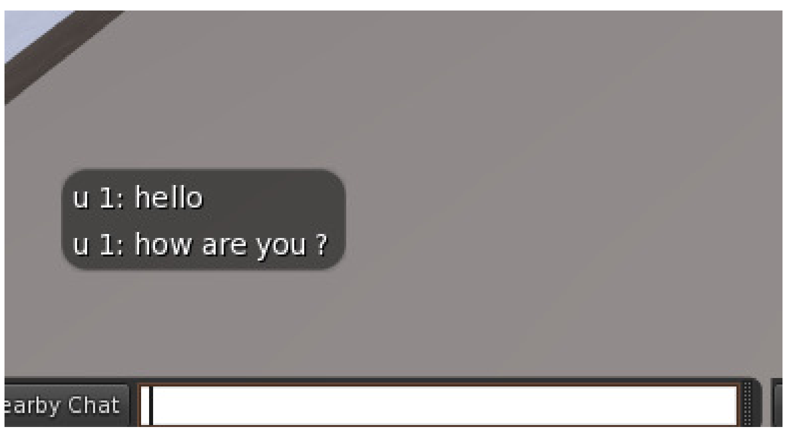


Figure 7. 14.Chat and microphone.

Advanced or custom interactions between avatars and objects from the virtual environment can be accomplished by using scripts.

7.4.2. Level/environment design

Building the virtual environment was one of the most time consuming part of this research experiment. The environment must be on one side complex, full of information, but on the other side it must be fun, attractive and easy to use.

The OpenSim Viewers have an integrated in-world building tool so the client itself is like a 3D environment modeling tool, which is quite helpful and easy to use. With this tool you can add primitives directly in the virtual world and alter them to suit your needs.

The basic building block in OpenSim is called a primitive or prim. Using the building tool we can model just anything out of prims. A primitive can have different shapes, like box, sphere, torus, cylinder, etc. It must also have a name and a description. Each primitive has multiple sides that have separate color, opacity or texture.

An object in OpenSim can be considered a single primitive or can be made by linking multiple primitives together.

Using the building tool we can control the position, rotation and scale of an object, the color, the texture, etc. One important feature that must be mentioned here is that each prim has an inventory where you can add items like scripts, textures, animations and even other prims. All the running scripts in the virtual environment must be contained within a prims inventory (see figure 7.15).

The Viewer has also the ability to upload and import external files like images (usually used as textures) or 3D models as meshes (see figure 7.15).

For the virtual environments used in this research we used primitives as well as imported 3D models. Also, there are some free OpenSim resource packs with common objects that can be used by importing. Each resource has a unique *key* identifier.

Modeling the virtual world environment is just creating or importing objects and placing them in the right position and at a right scale. We created objects, buildings, panels, signs etc. and organized them so it could be easy to use for users. This was only the first part in the environmental design work. The main, and the hardest part, was to create nice, fun and attractive interactions and functionality within the virtual world. In OpenSim we can do that by using a special designed scripting language called Linden Scripting Language (LSL).

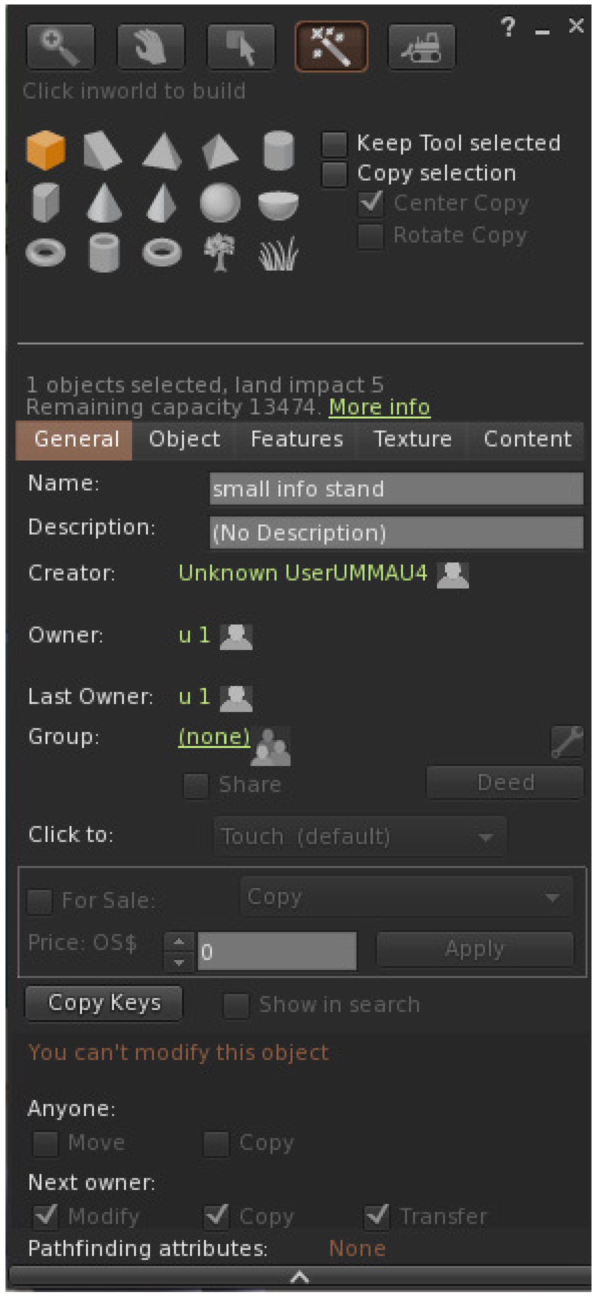


Figure 7. 15.Building tool.

7.4.3. Scripting

LSL is the scripting language developed by Linden Labs for Second Life and it is used in OpenSim. As a programming language, it is very similar with Java or C, commonly used programming languages these days, so it is pretty easy to get used to it. A script in OpenSim is a set of instructions and functions that can be placed inside the virtual environment to provide custom functionality and interaction. OpenSim viewers have a special editor for scripts with error reporting and a library with functions. One important note is that LSL scripts are interpreted and executed on the OpenSim server and not on the Viewers.

The unique feature of LSL is its ability to easily model real life behaviors using states. A window can be “open” or “closed”, a person can “sit” or “stand” etc. LSL is organized as a finite state machine. It has states with multiple events that can occur while the object is within one specific state and also functions and variables to describe how to react to those specific events. To be able to run, scripts must reside in a prims inventory. Multiple scripts may execute simultaneously inside one prims inventory or in separate prims.

Using scripts we can change most parameters and properties of an object and also interact and communicate with other objects, agents and even avatars. There are over 300 library functions available and the ability for users to define their own functions. With scripts we can make an object move, change color, size, shape or texture, talk, listens and so on.

In LSL a state is a section that is currently running, waiting for events to occur. Obviously, one script can have only one active state. Each script must have a default state, which must be defined first. This is the first state that the script enters when it is compiled, loaded or reset. Any other state must be defined using a unique state name, preceded by the keyword state.

```
 default
{
   // contents of the default state
}
 state playing
{
   // this is a state called "playing"
}
```

In LSL, a state must have at least one event to be able to run because the scripts are idle until they receive input or detect some changes in the environment. An event can be defined as a trigger for a specific action. For example, *touch start* event handler is triggered when an avatar touches the object in which the scripts reside. Events are executed in the trigger order, they don't interrupt each other and if multiple events occur they are queued FIFO (first in first out).

Unlike functions, events are only predefined so it is not possible to create new custom event handlers. A method to check whether or not something has occurred is by using the *timer* event.

```
default
{
   // begin
   touch start(integer num_detected)
   {
      // content of the event
   }
   // end
}
```

There is a large library of predefined functions which enables extended control over the environment objects. The user can define its own functions by combining the predefined one, thus making complex functionality.

To better understand how the scripts work in OpenSim lets us examine an actual script with two states and two touch event handlers.

```
default
{
   state entry ()
   {
llSay(0, "Script running");
llSetColor (<0, 0,0>, ALL_SIDES);
   }
   touch start(integer num_detected)
   {
state on;
   }
}

state on
{
   state_entry()
   {
llSay(0, "New state");
llSetColor (<1, 0, 0>, ALL_SIDES);
   }
   touch_start(integer num_detected)
   {
state default;
```

```
    }
}
```

A simplification for this script in natural language would be:

```
default
{
//set colour black and, if touched, enter the on state
}
state on
{
//set colour red and, if touched, enter the default state
}
```

We can observe that the default state is the first one, and the other state is preceded by the keyword *state*.

First, in the default state we have the *state entry* event handler, which gets triggered each time a state is entered. The first line in this event has a function *llSay* that makes the object speak "Script running" on channel 0. This channel is the public chat, so all the avatars in the proximity will see this message in their chat box. The next function *llSetColor* is pretty self-explanatory because it sets the prim colour to black using RGB (0, 0, 0) on *ALL_SIDES*.

At this moment the script is idle, waiting for event triggers. When an avatar touches the object it will trigger the *touch start* event. Now the *state* command changes immediately the state of the object to the new state called *on*. This new state is very similar to the first one, the only differences being the colour of the prim - red (1, 0, 0) - and the message in the chat - "New state". When touched in this state the script will go back into the default mode, creating a loop flow:

1. Default state - running state_entry event
2. On touch enters the new state *on*
3. On state - running state_entry event
4. On touch enters the *default* state - we are back to 1.

This was a simple and common used script in OpenSim that handles an on/off functionality. We can always make more complex scripts to suit our needs.

7.4.4. Animation

With LSL scripts we can animate objects one time or in a continuous loop. We can achieve this using regular transform functions (rotate, translate, scale):

```
llSetPos(<0,0,1>); //translate position
llSetRot(llEuler2Rot( <45 * DEG_TO_RAD, 0, 0> )); //rotate
llSetScale(<0.1, 0.1, 0.1>); //scale
```

Or using a special function to create keyframes motion:

```
llSetKeyframedMotion(
   [<0.0, 0.0, 20.0>,  5, <0.0, 0.0, -20.0>,  5], //keyframes list
   [KFM_DATA, KFM_TRANSLATION, KFM_MODE, KFM_LOOP] //motion params
);
```

The script above creates a key framed animation by translating (*KFM_TRANSLATION*) the prim from <*0, 0, 20*> to <*0, 0,-20*> in a continuous (*KFM_LOOP*) mode (*KFM_MODE*). Each key frame has duration and is interpreted relative to the previous transform of the object. For example, considering the following list of key frames [<0,5,0>, 5, <0,0,0>, 3, <0,-5,0>, 7], would cause the prim to move up 5 meters over the course of 5 seconds, then remain at the same location for another 3 seconds and then move back 5 meters over the course of 7 seconds.

7.4.5. Colours, textures and media textures

Using scripts you can easily change an object colour, transparency or texture. The texture can be applied to a specific side or to all sides and can be referenced in two ways: it can be the name of a texture in the object's inventory or it can be the unique *key* of the texture.

```
// applies the texture named "grass" from the prim's inventory
llSetTexture("grass", ALL_SIDES);

// applies the texture with the specified key only on side 0
llSetTexture("5748decc-f629-461c-9a36-a35a221fe21f", 0);
```

There are also defined some constants with common used textures such as *TEXTURE_BLANK*, *TEXTURE_DEFAULT* etc.

Textures are very important in OpenSim because it is the only way to display and represent information like text or images in the virtual environment. A very useful type of texture is the *media* texture. This kind of textures can be applied to a single face and allow the simulator to display dynamic web content. Basically you can transform a prim's face into an internet browser that can render web pages, text, videos and many more. It is a very useful feature. To set media textures we must use a specific function.

```
llSetPrimMediaParams(0,  // Side to display the media on
   [PRIM_MEDIA_AUTO_PLAY, TRUE,                    // Flag to show the page immediately
    PRIM_MEDIA_CURRENT_URL,"http://google.com",    // The currently showing url
    PRIM_MEDIA_HOME_URL,"http://google.com",       // The url if users hit 'home'
    PRIM_MEDIA_HEIGHT_PIXELS,512,                  // Height and width
    PRIM_MEDIA_WIDTH_PIXELS,512]);
```

An interesting trick is to use this media textures to directly display text into the virtual environment using a *data* type instead of a classic http address.

```
html = "data:text/html," + llEscapeURL("<h1>Title</h1><p>Plain text</p>");
```

```
llSetPrimMediaParams(0,
   [PRIM_MEDIA_AUTO_PLAY, TRUE,
    PRIM_MEDIA_CURRENT_URL, html,
    PRIM_MEDIA_HOME_URL, html,
    PRIM_MEDIA_HEIGHT_PIXELS,512,
    PRIM_MEDIA_WIDTH_PIXELS,512]);
```

Notice that the text can still be HTML (Hypertext Markup Language) rich formatted like in any other web pages or resources.

7.4.6. Object instantiation

Using scripts in LSL you cannot create a prim. You can only use an existing object and *rez* it into the virtual environment. Furthermore, you can only instantiate an inventory object with a specified position, velocity, rotation and a start parameter.

```
llRezObject("Object",  <0.0,0.0,1.0>, <0.0,0.0,0.0>, <0.0,0.0,0.0,1.0>, 0);
```

The start parameter is very important. Each object that is rezzed can be uniquely identified by using the start parameter because this is the parameter of the *on_rez* event, triggered in the new instantiated object.

```
default
{
   on_rez(integer start_param)
   {
      llSay(0,"I am object no "+ start_param);
   }
}
```

7.4.7. Avatar control

Creating direct interaction with the user or controlling the user avatar is quite restricted in OpenSim. We have only a few options and predefined LSL functions for creating basic dialogs, teleporting and for avatar detection. Also, we can interact with the user using chat messages.

Using the *llDialog* function we can display to the user a dialog in the upper right corner of the screen. The dialog can display a message and choice buttons, as well as an ignore button. We can use this dialog to create menu systems. There are lots of limitations: we cannot control the size, the colour or the position of the dialog box. Also, there are restrictions for message length and buttons limits.

Another way to control the avatar is to instantly teleport it to a specific location using scripts. We can use a stored landmark or a coordinate's position for the teleport destination (<13.0, 38.0, 23.5>). We also have the possibility to set the avatar to look at a specific point after the teleport (look_at <0,0, 0>) .

```
llTeleportAgent(avatarkey, "", <13.0, 38.0, 23.5>, <0,0, 0>);
```

A useful function regarding the interaction with avatars is the *llSensor* function that performs a scan within a specific range and arc to detect avatar presence. There is also a recursive version of the function *llSensorRepeat* that repeats once at a specific time. The sensor events are caught by *sensor* and *no_sensor* events handlers: *sensor* is triggered when the sensor function scan detects something and *no_sensor* otherwise. A simple example that displays the detected agent's name:

```
default
{
   touch_start(integer total_number)
   {
      llSensor("", NULL_KEY, AGENT, 30.0, PI);
   }

 sensor( integer detected )
   {
      while(detected--)
      {
         llOwnerSay(llDetectedName(detected));
      }
```

```
    }
}
```

7.4.8. Communications

Combining functions and events to allow scripts to communicate with other scripts, with users and with any external sources is the most important and the most used functionality in LSL.

Communication between objects is possible for a specific chat channel, using a function like *llSay* or *llRegionSay* to send a message and a specific event handler *llListen* that is listening to that specified channel. Furthermore, you can restrict the listening handler with filters for name or id of an object or avatar and also with a specific message so the handler is triggered only when a message that meets the specified criteria is heard.

```
integer llListen(integer channel, string name, key id, string msg)
```

A common example of using object to object communication is a simple remote controller script: that means one object gives a command and other objects that are listening to that channel will execute the command.

We have to mention, though, that using too many instances of llListen handler can cause lag and can visible affect the sim performance.

7.5. EVALUATION

Students will benefit from using our Serious Game due to many features that have emerged from our goals:

- **Information.** The game offers information sources by access to a lot of educational resources and provides data from the web: images and information about the elements, visualization of different views and details of the elements like atoms, difficult to be viewed in reality due to their size or to accessibility issues (i.e. small size), from sources of information included in the game or by video on YouTube.
- **Communication, cooperation, competition and socialization.**
  These objectives are achieved by many mini-games, like the virtual tour around electronic configurations. Students compete here to answer questions about the distribution of the

electrons in the atoms of the elements. Communication and collaboration take place through voice and chat between players which are simultaneously online with the game. Through discussions and cooperation among students in our game, they get useful information. Also, the communication and collaboration are the main means of socialization. (see figure 7.16).

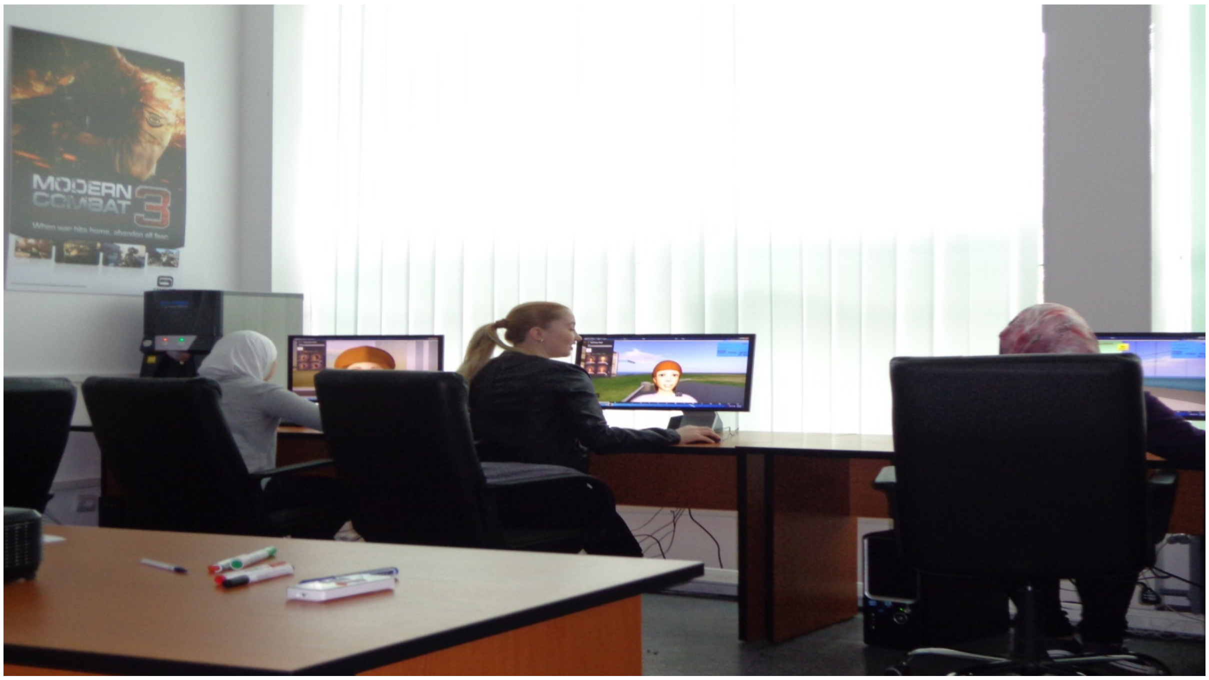


Figure 7. 16.Communication and collaboration between students in our experiment

The students gain greater information about the chemistry science phenomena through the process of competing to answer questions.

The added value of our work is that it is the most comprehensive game on the periodic table study, but does not focus solely on the periodic table. It incites towards a thorough analysis of the components of organic chemicals. The interaction within this game and the rivalry with a number of users at the same time helps in understanding the characteristics of the chemical elements.

Many of the previous studies examined the effect of Serious Games in learning chemistry, but our study tended to allocate a part of the science of chemistry, the Periodic Table and partial elements of it - organic elements. Our work focuses on a comprehensive and intense study about organic elements in the periodic table, so the focus about all the general information about organic chemistry elements, so that there will be focus and more specialized in my work that part of the periodic table. The goal of the student is to focus more on these important elements, and not be distracted about other areas when gathering this information. We want to create a virtual world to represent the organic elements.

A Serious Game (that uses MMO technology to offer extensibility so future improvements could be easily made) for e-Learning would have some of the following functionalities: school contests between different classes; multiple classes studying at the same time; open world where anyone can study chemistry, and virtual learning between many schools to allow procedure contests between schools.

During the evaluation of our game we investigated a number of objectives. The following table 7.1 summarizes how the game performs various objectives that we have set.

Table 7. 1.Objectives covered by the game.

Objective	How is the objective covered by the game
Information	Information is offered in many ways. Through the interaction with the periodic table or chemical elements the student can see the pictures of the chemical elements which cannot be seen in the real world, because they are very small or cannot be found in a real laboratory. They have access to video clips from YouTube and many other websites. (See figure 7.17).
Communication	The game allows many ways of communication between players, like chatting or voice dialogue with a microphone. For example, they discuss about information from a website with the teacher or between them. Keeping communication between our students is very important because some games cause isolation.
Competition	The multi user's online (MMO) feature of our game allows students to compete with each other. Students are faced with questions which they have to answer, with previous knowledge acquired from previous stages played in the game. These answers are compared to the answers of other students, in a competitive way, to get grades. If a student has committed an error during the game, he must wait for a few minutes before continuing the game. Competition among students helps them to obtain information on the chemical elements, and this is the goal of our game (see figure 7.18).
Cooperation	Students cooperate in many ways in our game. For example, they cooperate discussing between them and with the teacher, at the first floor of the virtual building, about information from the internet, and how to make use of it. Cooperation is supported by a voice dialogue. Players present in the game are in different locations in real-life, but online they are in the same place at the same time (see figure 7.19).
Socialization	The massive multiplayer interaction between students in the game encourages socialization. Through communication and cooperation during the game, they get to

	know each other. Here we achieve the goal as educators to maintain social relationships for our students (see figure 7.20).
Customize an Avatar's	Each student chooses an Avatar, he/she can customize it, and this Avatar represents the student in the game, and they all compete together with their Avatars (see figure 7.21).

Figure 7.17 .Student watches clip video from YouTube

Figure 7.18 .Competition between student

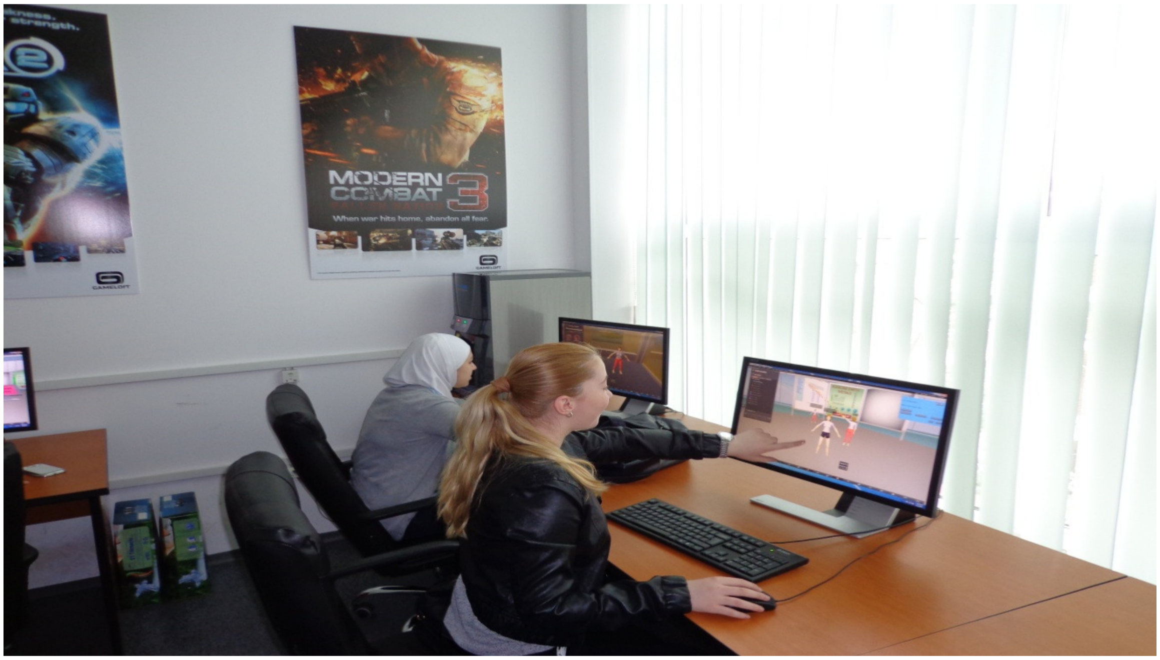


Figure 7. 19.Cooperation between students by chat.

Figure 7. 20.Social relationships between students in our experiment.

Figure 7. 21.Here student customize her avatar.

After implementing a first prototype of our game we had a preliminary assessment of it with only two participants. We had observations regarding the student's movement between the objects in the game. They find that this is difficult and because of this they waste time. So, we have modified the prototype and included the teleport as another model of movement in the game.

We have experimented the current prototype with several students from the tenth grade. After the students finished the game, we had questions prepared for them to get feedback about the game: the experience and the overall learning process compared to the traditional learning. These are the questions:

1) Competing in the game distracted my attention on taking the information.
2) I competed seriously in the Serious Game.
3) Serious Games allow for personalized learning.
4) It was easy to control the avatar.
5) Serious Games are not easy to interact with.
6) Learning through competition using games is better than individual learning.
7) I prefer chemistry lessons to Serious Games.

8) Chemistry is learnt better through Serious Game.
9) Learning through Serious Games helped me to assimilate information about chemistry.
10) The use of a virtual game for a long time made me feel bored.
11) Learning chemistry during the games took me less time than learning in other ways.
12) A game strengthens my relationship with my colleagues.

We created a chart to summarize the feedback from students (see figure 7.22).

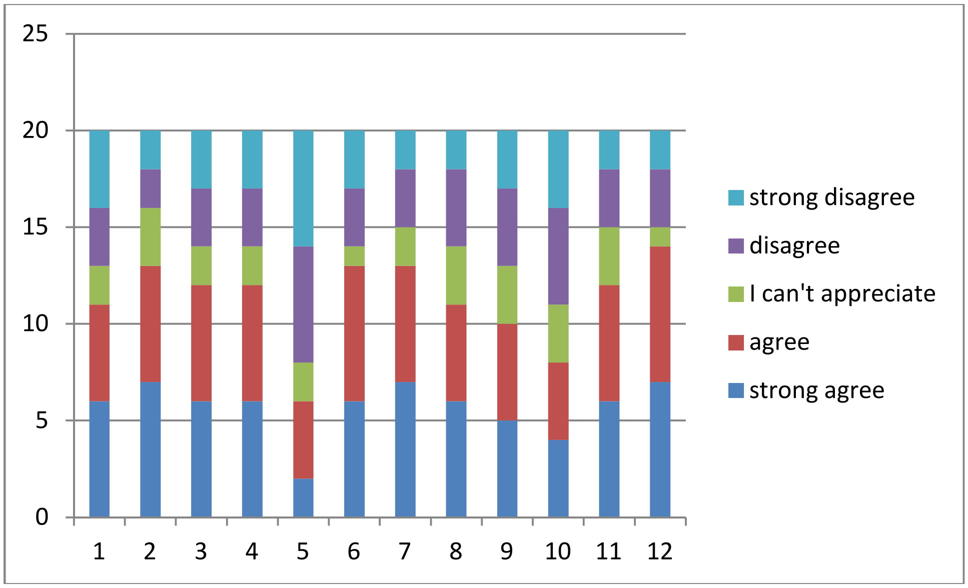


Figure 7. 22.Feedback chart.

To sum up, by exploring the feedbacks from the students who played our Serious Game, we got positive reviews from students about the Serious Game and its role in learning chemistry. Features provided by the Serious Games such as fun and immersion in a virtual world attract students strongly, and particularly as it is a new environment for the target group of our experiment. Other feedbacks from the student activities in the game include the students' personality which reflects as they choose their avatar.

All of these results motivate us to suggest the style of Serious Game in learning chemistry. Communication and interaction among students to learn about best styles to achieve the educational goals is sought by teachers. The most important advantage of serious games is that they allow students to study and play and interact with others without shame.

A disadvantage of using a Serious Game running in a virtual environment is given by the fact that the individual schedules of the students may present a problem in allowing the simultaneous presence of all the users in the virtual space. Here the teacher will select the most appropriate times for the groups of students to access the virtual space. (See figure 7.23).

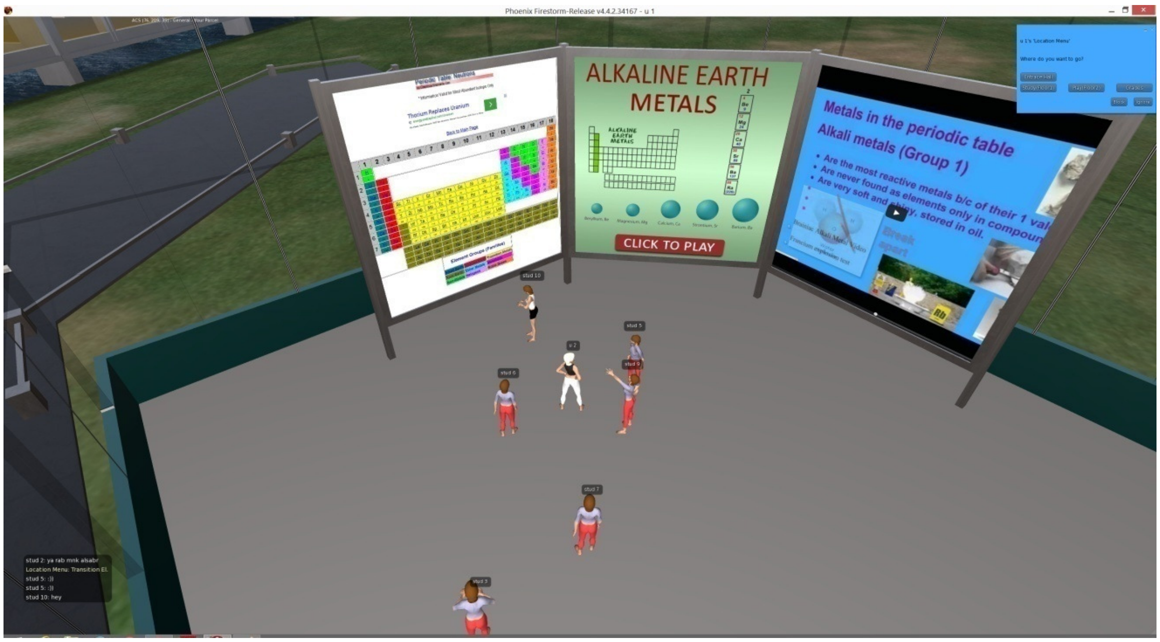


Figure 7. 23.Students come to the Serious Game in the same time.

On the negative side, some problems have been identified in the design of the game. The game should be more balanced between fun and learning, because our game had a lot more information games than fun games.

There were some negative opinions about the mini-games, because they are focused on the education side more than the entertainment, and this deficiency in the design of our game needs to be adjusted. Not taking the game seriously was also one of the negative reactions from students towards the mini-games.

The most important observations of students about our game was that the male students, did not see the game as attractive as some “pleasant” games that contain types of fighting and battlefields, and so their views differed significantly from the ones of the female students.

Students preferred to communicate with each other through chat more than voice communication. Some of the students commented on technical problems, for example, some delays in transmission that don't allow smooth verbal communication. Other technical problems include the echoing when students used the microphone to communicate with each other. There were also personal opinions about using voice chat, as one student commented, "I don't like using the microphone. I'm more comfortable with (text) chatting".

Another problem in 3D Serious Game which runs in a virtual environment is that sometimes the loading process of the assets (textures, models) could take a long time. The solution is that there should be a strong Internet connection with low bandwidth latency.

Chapter 8. Conclusions

8.1. ORIGINAL CONTRIBUTIONS

The main aim of this thesis was to investigate the effectiveness of using Virtual Reality applications in the process of teaching and learning of Chemistry in high schools. The study included also the use of computerized laboratories and was made comparatively with the traditional way of studying Chemistry, that is, by teaching in a classroom and making experiences in a real laboratory.

Starting from the difficulties with real Chemistry laboratories and based on the young people enthusiasm for using computers, especially 3D games and collaborative virtual environments, we decided to create some computer programs dedicated to teaching and learning Chemistry. As a result, we developed 5 original applications, all of them based on 3D virtual environments. Two of them are of type “virtual classroom”, one is a”virtual laboratory” and two of them are games. These applications were used in a study realized by the author of the thesis, regarding the effectiveness of using Virtual Reality in education, particularly in Chemistry study. This study is also an original contribution of the thesis. All these contributions were described in different publications, as specified at the end of this chapter.

The main contributions of the thesis are summarized below.

Chapter 5 presents four original software applications:

1. “A 3D Virtual Classroom for Teaching Chemistry”. Students and teacher can meet in a friendly, 3D environment, rich in learning resources. Students can interact with different 3D objects from the environment by means of avatars, to obtain meaningful information about the elements of the Periodic Table. Besides the main aim of the application, that of knowledge acquiring, collaboration between participants in the virtual space is another gain, with the effect of socialization.

2. "A virtual 3D Classroom for Teaching Biology" application helps students to see and analyze, in a three-dimensional space, the invisible parts of the human body: heart, its internal structure and different heart sections, bone cells, neuron cell and its nucleus. The experiment with a group of 20 students proved the positive effect of the lesson on knowledge acquiring and students motivation for studying Biology.

3. "A 3D Game for Learning Chemistry in a Virtual Environment" offers the students a means to enrich their knowledge about the world of chemistry in a pleasant and enjoyable way. The game contains an immersive learning environment, has Massive Multiuser Online features as well as many means of synchronous communication between participants. The game consists of three parts that cover important chemical topics, each part having more difficulty levels. Using his avatar, the student navigates freely and interacts with the virtual world by touching, moving or flying. Apart from free exploration, he must solve quests and puzzles to access special area or objects, to finish each level and eventually win the game.

4. "A 3D MMO Virtual Chemistry Laboratory" was conceived to allow students to make chemical experiments like in a real laboratory, but without any danger, and help them to understand the components' properties and how they react. The virtual chemistry lab looks like and has the same layout as a real lab, with all the shelves filled with chemicals and reagents. The role of a teacher in the Virtual Laboratory is almost the same as it is in the traditional laboratory; starting with describing the main purpose of the lesson, ending with question - answer session. The virtual environment offers support with many information resources such as videos, documents, pictures and others. Students execute different activities, interacting with the 3D objects from the lab by means of their avatars. The virtual laboratory encourages the social interaction and collaboration between students.

Chapter 6 presents the study realized by the author of the thesis regarding the efficiency of using VR applications and computerized laboratories in teaching and learning, compared to the traditional method. The study is based on experiments conducted by the thesis' author with three groups of students: the control group and two experimental groups (one group used a computerized lab and the other the VR applications described in chapter 5). The aim of the study was to make a comparison between the three groups from two points of view: knowledge achievement and the development of student's trends toward Chemistry. Also, the impact of using VR in teaching and learning. The students' grades on the chemical subject knowledge and also their responses to more questionnaires were statistically analyzed using "One way ANOVA" method, by means of the SPSS software, and the results of this analysis have been discussed.

Chapter 7 makes an analysis of the Serious Games features, advantages and possible disadvantages of their use in education. Also, the chapter presents an original Serious Game dedicated to Chemistry learning. The game runs in an immersive virtual world, which is visually rich and allows students to interact with various 3D objects. The game achieves its MMO goal by allowing a great number of users to interact at the same time. The interactions include competition, cooperation, information sharing and social networking between users. The students can navigate freely in the virtual environment by moving, teleporting or even flying, by means of their avatars, chosen and personalized by them at the beginning of the game. The game contains many mini serious games of various difficulties.

8.2. RECOMMENDATIONS AND SUGGESTIONS

In light of the research results, we can make the following recommendations:

1) The adoption of the use of computers in the teaching of science, whether through computerized laboratories or by using VRA.
2) The specialized educational computer programs that rely on computer simulations need the participation of specialists in curriculum and teaching methods, science courses, and software development that rely on VR.
3) The development of the curriculum in its broadest sense, taking into consideration the time of practical experiment during the design of the curriculum.
4) To identify the experiments that can employ VR and computerized laboratory compared to the traditional way, so that the teacher can realize the experiments that can be performed by using computerized laboratories or VRA.
5) To train teachers to use modern technologies in the teaching of Chemistry, including the use of computerized laboratories and VRA.

Suggestions:

1) Similar studies should be conducted for other sciences such as physics and biology, with an increasing of the allotted time for the implementation of the experiment, to be at least a full scholastic semester.
2) Further studies should be designed to investigate the effect of VR on other skills such as thinking skills, on different education levels.
3) Some studies should be designed to investigate the effect of integration between the practical work and the use of computer technologies such as computerized laboratory and VRA.

8.3. FUTURE WORK

In the future I want to continue creating serious games to help students understanding sciences. I will focus my work on natural sciences that are studied in Jordan by students of six and seven grades because in this stage students start to learn important scientific phenomena. I think students find difficult to understand these phenomena, but learning by game, through 3D simulations and Virtual Reality can help them a lot. Teaching in the traditional way will help me to discover where students find problems in learning natural sciences.

PUBLICATIONS CONNECTED TO THIS THESIS

1. Eman Ahmad SHUDAYFAT, Florica MOLDOVEANU, Alin MOLDOVEANU. “A 3D Virtual Learning Environment for Teaching Chemistry in High School”, Annals of DAAAM for 2012 & Proceedings of the 23rd International DAAAM Symposium, ISBN 978-3-901509-91-9, ISSN 2304-1382, pp 0423 - 0428, Editor B[ranko] Katalinic, Published by DAAAM International, Vienna, Austria 2012.pp. 0423-0428.
2. Eman Ahmad SHUDAYFAT, Florica MOLDOVEANU, Alin MOLDOVEANU,Alexandru GRADINARU, “virtual reality-based biology learning module” The 9th International Scientific Conference eLearning and Software for Education Bucharest, April 25-26, 2013 10.12753/2066-026X-13-209, pp.612-626.
3. Eman Ahmad SHUDAYFAT, Alin MOLDOVEANU, Alexandru GRADINARU, “Learning The Bases Of Chemistry In A Content Rich, Game Based 3D MMO Virtual Environment”, The 10th International Scientific Conference eLearning and Software for Education Bucharest, April 25-26, 2014 .
4. Eman Ahmad SHUDAYFAT, Florica MOLDOVEANU, “Prototyping a 3D MMO Virtual Environment for Chemistry Learning”, The 10th International Scientific Conference eLearning and software for Education Bucharest, April 25-26, 2014.
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6. Maria-Iuliana Dascalu, Alin Moldoveanu, Eman Ahmad Shudayfat, “Mixed Reality to Support New Learning Paradigms”, sent to ICSTCC 2014, Sinaia, October 2014.

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Annex 1. The students' grades in the achievement test

Nb.	Student name	Group	Grades to achievement test
1.	Manal Mustafa	Control group	9
2.	Amal ahmad	Control group	21
3.	Hanan Salem	Control group	15
4	Areej Hassan	Control group	16
5	Fida Mdallah	Control group	9
6	Razan Mowaffak	Control group	8
7	Maram Abdul Rahman	Control group	19
8	Hanan Mahmoud	Control group	23
9	Abeer Abdulrahman	Control group	15
10	Hanadi Hassan	Control group	8
11	Iman Walid	Control group	20
12	Maram Ateha	Control group	13
13	Lara Nazal	Control group	9
14	Manal Yusuf	Control group	9
15	Razan Mowaffak	Control group	7
16	Diana Ibrahim	Control group	21
17	Laila Nabhan	Control group	11
18	Tamara Ghalib	The first experimental group	15
19	Hadeel Jamal	The first experimental group	9
20	State Riad	The first experimental group	7
21	Reem Mahmoud	The first experimental group	10
22	Maram Abdullatif	The first experimental group	9
23	Souad Mohamed	The first experimental group	13
24	Nora Mohammed	The first experimental group	22
25	Breezes Abdullah	The first experimental group	23
26	Miss Ibrahim	The first experimental group	11
27	Hanadi Ibrahim	The first experimental group	9
28	Farah Abdul Razak	The first experimental group	11
29	Suhair Joseph	The first experimental group	11
30	Ahlm Mohammed	The first experimental group	17
31	Areej Abdullah	The first experimental group	21
32	Sahar Khmed	The first experimental group	22
33	Lena Radwan	The first experimental group	13
34	Maha Ayman	The first experimental group	25
35	Nasreen Anwar	The Second experimental group	19
36	Tasneem Ahmed	The Second experimental group	11
37	Alaa Ali	The Second experimental group	9
38	Ibtisam Isa	The Second experimental group	17

39	Ataef Farraj	The Second experimental group	25
40	Abeer Smadi	The Second experimental group	18
41	Fatima Hussein	The Second experimental group	17
42	Noha husban	The Second experimental group	12
43	Aiaat Atallah	The Second experimental group	12
44	Rowan Fathi	The Second experimental group	14
45	Mona Zaki	The Second experimental group	15
46	Elham Shaheen	The Second experimental group	11
47	Asma Hamza	The Second experimental group	17
48	Rwanda Ahmed	The Second experimental group	10
49	Alaa Aaad	The Second experimental group	11
50	Noha Mohammed	The Second experimental group	11
51	Tasneem Hassan	The Second experimental group	9

Annex 2. Answers to the questionnaires

Annex 2.a

Answers to the "trend toward chemistry" questionnaire in the control group

PN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17
Q1	5	4	1	5	4	3	5	2	1	5	4	5	5	4	5	5	1
Q2	4	4	2	5	4	2	5	4	3	5	2	5	4	4	5	4	4
Q3	4	3	5	2	4	5	3	1	5	4	5	3	5	4	4	4	4
Q4	2	4	1	1	2	4	1	2	4	3	2	3	2	1	2	2	1
Q5	3	4	5	2	4	5	4	5	4	5	2	4	1	4	2	4	4
Q6	4	5	2	4	5	2	4	2	4	3	5	4	3	4	4	4	2
Q7	3	4	4	5	3	2	4	5	4	4	4	2	4	1	4	4	4
Q8	4	4	2	4	4	2	4	3	4	4	4	4	4	4	4	2	3
Q9	1	5	2	2	4	2	5	4	2	4	2	3	1	2	2	2	2
Q10	3	2	2	5	2	4	1	1	1	5	1	4	5	2	4	2	2
Q11	4	2	2	5	1	3	5	4	3	4	2	5	4	2	4	3	3
Q12	1	1	5	1	5	1	5	3	5	4	2	3	4	2	3	1	1
Q13	2	2	4	2	4	3	4	5	2	2	5	1	4	2	2	2	2
Q14	3	4	2	4	3	5	2	3	5	4	5	2	2	1	2	1	1
Q15	4	1	2	4	5	2	4	2	3	4	2	3	4	1	4	2	2
Q16	2	2	1	5	3	2	5	4	2	5	2	2	5	2	4	1	4
Q17	4	4	2	4	2	2	5	3	4	2	5	2	2	1	1	2	5
Q18	4	4	4	2	4	2	2	5	3	2	2	5	2	2	1	5	1
Q19	3	3	4	2	5	1	1	4	5		4	2	4	1	1	3	3
Q20	4	1	2	2	2	1	1	1	4	5	2	1	4	2	2	4	5
Q21	2	4	2	5	2	5	2	2	5	4	4	5	4	1	4	4	5
Q22	4	1	4	3	2	3	5	4	5	2	5	2	5	4	5	1	5
Q23	3	3	5	5	4	5	3	4	5	4	5	3	4	5	2	1	1
Q24	4	4	2	4	4	5	4	2	4	2	5	4	5	2	5	2	5
Q25	3	2	5	2	4	5	5	5	4	3	5	4	5	3	5	2	3
Q26	2	4	2	1	1	4	2	3	1	3	2	2	1	1	1	1	1
Q27	5	4	4	5	3	5	2	5	4	5	3	5	4	5	4	5	2
Q28	2	1	1	2	1	2	1	2	1	2	3	1	1	1	3	1	4

Annex 2.b

Answers to the "trend toward chemistry" questionnaire in computerized laboratory group

PN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17
Q1	5	4	5	5	4	5	4	5	4	5	5	5	4	4	3	3	5
Q2	4	5	5	5	4	5	5	5	5	5	4	5	3	4	4	4	1
Q3	4	5	5	4	5	5	5	4	5	2	4	5	4	5	5	2	4
Q4	5	5	4	4	5	4	5	4	3	5	3	5	2	5	1	5	4
Q5	3	5	4	5	4	5	3	5	4	5	4	3	4	4	2	5	3
Q6	3	2	5	1	5	2	1	4	2	1	2	1	2	1	2	1	1
Q7	4	3	4	4	3	4	5	3	3	5	3	4	5	2	1	4	5
Q8	1	1	4	3	5	1	5	2	1	2	2	2	2	1	1	1	2
Q9	4	3	2	1	4	2	1	4	1	3	1	2	1	2	1	1	3
Q10	3	1	5	4	2	1	1	3	4	2	2	1	1	2	2	2	1
Q11	5	4	3	2	1	2	4	1	2	1	3	2	2	2	2	3	1
Q12	4	3	1	1	4	3	3	1	1	4	1	3	1	3	1	1	5
Q13	2	2	1	3	2	4	1	2	5	2	1	2	1	1	1	5	5
Q14	5	3	5	3	4	5	3	5	3	2	3	3	4	1	4	1	4
Q15	2	3	1	1	3	4	1	4	2	4	1	4	1	4	1	1	5
Q16	4	5	3	5	4	5	4	5	4	5	4	2	1	1	2	1	5
Q17	4	3	4	3	4	4	1	2	5	4	4	4	4	2	3	5	2
Q18	5	1	5	1	4	2	5	1	4	3	4	2	1	2	4	2	4
Q19	3	2	4	1	4	5	2	2	5	2	5	5	1	1	1	1	2
Q20	5	1	3	4	3	4	3	4	1	4	3	3	4	1	4	1	2
Q21	3	3	4	4	2	3	3	1	5	1	3	5	1	4	1	1	5
Q22	3	3	3	3	4	1	2	4	2	4	5	4	3	3	5	3	3
Q23	5	5	4	1	2	5	2	3	1	5	4	3	4	3	2	3	2
Q24	3	4	3	5	4	5	2	2	5	2	5	2	4	2	2	1	5
Q25	4	5	2	4	3	4	1	4	3	5	2	1	1	1	1	1	1
Q26	3	2	4	1	5	1	2	4	1	4	3	1	3	1	1	3	1
Q27	5	4	2	3	2	4	3	4	2	2	3	4	2	2	2	2	1
Q28	4	1	4	2	5	3	1	3	1	3	2	2	1	2	1	1	2

Annex 2.c

Answers to the "trend toward chemistry" questionnaire in VRA group

PN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S14	S13	S12	S11	S16	S17
Q1	4	1	4	4	1	1	4	1	4	1	4	4	4	4	4	4	3
Q2	3	1	1	4	3	1	1	3	2		2	2	1	1	1	1	2
Q3	1	1	4	1	2	1	4	4	1	4	1	1	4	1	4	4	3
Q4	4	1	4	3	1	4	1	4	1	1	4	1	2	1	1	2	1
Q5	2	2	2	1	3	2	2	3	2	4	1	1	1	1	4	1	1
Q6	4	2	2	4	2	4	1	4	1	4	3	1	2	1	2	2	1
Q7	2	1	1	2	1	3	2	2	3	1	4	1	2	2	4	2	1
Q8	1	4	3	4	1	2	4	3	4	1	4	2	3	4	1	4	4
Q9	3	2	4	3	4	1	2	4	3	4	1	4	1	1	2	1	2
Q10	2	1	2	1	4	1	3	1	1	1	1	1	2	1	2	1	1
Q11	4	3	4	1	4	2	1	4	4	2	4	2	1	4	2	2	4
Q12	1	4	1	1	2	4	2	4	1	4	2	4	2	4	2	4	3
Q13	4	3	2	4	2	1	4	3	4	2	4	1	4	2	2	2	1
Q14	4	1	3	4	4	1	1	1	4	3	1	4	3	4	3	2	1
Q15	1	4	2	1	2	4	1	1	1	1	1	2	4	3	2	2	3
Q16	1	1	3	1	4	3	1	4	1	1	3	2	3	1	3	3	1
Q17	4	1	2	4	1	2	4	3	1	4	1	4	1	1	4	1	1
Q18	1	1	3	1	4	2	1	1	2	4	1	1	2	4	1	2	4
Q19	4	2	4	2	1	3	4	2	3	4	2	3	1	2	4	2	2
Q20	2	4	2	1	2	4	1	2	1	2	1	1	4	3	1	3	2
Q21	3	1	1	2	1	3	4	2	1	4	3	1	1	2	1	2	1
Q22	1	3	4	1	2	4	2	4	1	4	2	1	4	2	4	2	4
Q23	1	2	2	4	1	2	1	2	1	4	1	2	1	3	2	1	4
Q24	4	2	1	1	2	1	1	4	2	1	2	4	2	1	3	1	2
Q25	3	4	2	1	2	4	3	2	4	1	3	2	1	1	2	1	3
Q26	4	2	3	2	1	3	2	1	2	3	2	1	1	2	1	1	1
Q27	1	4	3	1	4	1	3	4	1	1	1	3	1	4	4	3	4
Q28	3	2	4	1	2	1	3	1	2	1	2	1	2	1	1	1	2

Annex 2.e

Answers to the "Students' views on the use of computerized laboratories in teaching chemistry" questionnaire

PN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17
Q1	5	4	5	5	4	3	5	1	5	5	5	3	5	5	5	5	5
Q2	5	4	5	3	5	4	5	4	4	3	5	5	1	5	5	5	5
Q3	4	5	4	5	4	5	4	5	4	4	3	5	4	5	4	4	4
Q4	5	4	5	4	5	4	5	4	5	3	5	4	5	2	4	4	4
Q5	4	5	4	5	4	5	5	4	5	4	4	4	4	1	4	1	4
Q6	4	5	4	5	4	1	5	4	5	4	1	5	4	5	4	4	4
Q7	5	4	3	5	4	5	4	3	5	4	4	5	4	2	4	2	4
Q8	4	5	3	1	5	4	3	2	5	4	3	5	4	5	4	3	4
Q9	4	3	3	5	4	4	5	4	3	5	4	5	4	1	4	4	4
Q10	5	4	5	4	4	5	3	5	4	3	5	4	5	2	4	2	2
Q11	4	3	3	4	4	3	5	4	3	4	5	4	5	4	4	3	4
Q12	2	2	5	4	4	5	4	5	3	4	4	3	4	4	4	4	4
Q13	5	4	5	5	3	5	5	3	5	5	3	3	5	2	2	4	1
Q14	4	3	5	4	5	4	3	5	4	5	4	5	2	5	2	1	2
Q15	3	4	4	4	3	5	3	4	3	5	4	3	4	3	4	2	5
Q16	4	3	4	5	3	2	5	4	2	5	4	2	4	4	3	4	4
Q17	4	2	4	2	5	3	4	5	3	4	3	4	5	4	3	4	3
Q18	5	4	4	5	3	5	4	3	5	4	3	5	4	3	2	1	2
Q19	3	2	3	2	1	5	4	2	5	1	4	3	2	2	3	1	2
Q20	4	5	4	2	4	5	3	4	4	4	2	4	4	3	4	1	1
Q21	4	1	4	2	4	5	1	4	3	4	4	4	3	4	3	4	4
Q22	3	4	3	4	2	2	4	2	4	5	4	4	2	5	4	4	2
Q23	5	3	4	2	3	4	2	4	5	4	4	3	3	4	3	1	3
Q24	4	2	3	4	2	3	5	2	3	2	3	3	2	4	2	3	1
Q25	4	3	4	3	5	4	4	5	4	4	4	4	5	4	4	4	5

Annex 2.f

Answers to the "Students' views on the use of Virtual Reality Applications in learning chemistry" questionnaire

PN	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17
Q1	5	5	4	5	5	4	5	5	5	4	5	5	4	5	4	5	4
Q2	4	4	5	2	5	4	5	4	5	5	4	5	5	4	5	3	5
Q3	5	4	5	4	5	4	5	4	5	5	4	5	1	5	5	1	4
Q4	4	2	4	4	5	1	5	4	5	5	4	5	4	4	5	4	2
Q5	2	4	3	5	4	5	4	5	4	5	4	5	4	2	4	2	4
Q6	5	4	2	4	5	4	4	5	5	4	1	4	4	4	3	4	4
Q7	4	3	2	2	5	4	3	4	5	5	3	5	5	4	5	2	5
Q8	3	4	4	5	4	5	4	5	5	4	4	3	2	3	4	2	3
Q9	5	4	2	3	5	4	4	5	4	1	4	4	3	4	4	4	4
Q10	4	1	1	4	2	2	3	4	2	1	4	3	1	2	1	2	3
Q11	5	5	2	5	4	2	5	2	4	2	5	4	3	2	3	1	5
Q12	4	4	2	2	5	4	2	4	4	2	4	4	3	4	4	3	1
Q13	5	1	4	4	5	1	4	5	5	4	1	4	4	1	2	4	3
Q14	1	2	3	5	3	3	3	5	4	3	4	4	3	2	3	4	4
Q15	4	2	4	3	5	4	5	3	4	2	1	5	4	4	2	1	2
Q16	5	2	3	5	4	2	4	3	4	2	4	4	3	4	3	2	1
Q17	4	2	3	2	4	4	1	4	1	5	5	2	2	5	2	2	5
Q18	2	4	1	1	5	2	2	4	3	4	3	4	3	4	1	3	4
Q19	5	2	4	1	5	1	5	4	3	2	4	2	5	1	3	1	2
Q20	1	2	5	4	1	5	4	1	4	4	1	4	3	2	3	2	3
Q21	4	3	2	3	2	3	5	2	4	3	4	3	1	2	2	3	1
Q22	2	2	4	2	5	1	2	1	3	5	1	1	3	1	3	1	4

CONFIRMATION OF EXPERIMENT

المملكة الأردنية الهاشمية
وزارة التربية والتعليم

By the name of allah

Ministry of Education

Dirctorate of Education of ALmafraq

ALManshia Secondry Comprehnsive School for Girls

To Whom It May Concern:

CONFIRMATION

This is to confirm that Mrs. Eman Ahmad Salem Shudayfat has conducted an experiment in our school from Almafraq city, Jordan, in the framework of her doctoral studies, during the period 01.04. 2013 – 01.06.2013, four hours per week.

The experiment involved 51 students from the tenth grade which were divided in three groups. All the students learned the same subjects in that period, but in different ways: the first group studied in the traditional laboratory; the second group in the computerized laboratory – where each computer has a PH device connected to it; the third group has used a Virtual Reality software application for learning chemistry which was developed by Mrs. Eman Ahmad Salem Shudayfat.

Date: 6l4l2014

School Director/Manager

Name:Zohoor kahlaf al hamdan

Signature: