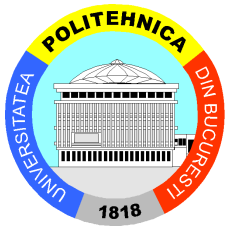

University POLITEHNICA of Bucharest
Doctoral School of Automatic Control and Computers

PhD THESIS

Teaching and learning in 3D multiuser virtual environments

"Predarea şi învăţarea în medii virtuale 3D multi utilizator"

Author: Eman Ahmad Shudayfat
PhD Coordinator: Prof. dr. ing. Florica Moldoveanu

BUCHAREST 2014

ACKNOWLEDGEMENTS

Foremost, I would like to express my sincere gratitude to my advisor Prof .Florica Moldoveanu for the continuous support of my PhD study and research, for her patience, motivation, enthusiasm, and immense knowledge. Her guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my PhD study.

I am particularly grateful for the assistance given by Alin Moldoveanu. I would like to offer my special thanks to Alexandru Grădinaru, Victor Asavei, and to my colleague in the Ph.D. Nasser Asfoure.

My deepest gratitude goes to my family. My mom, dad, brothers and sisters have always been close to me. Words cannot express how grateful I am to my mother and father for all of the sacrifices that you've made on my behalf. Your prayer for me was what sustained me thus far.

I would also like to thank all of my friends who supported me, and incited me to strive towards my goal.

Pride in my children who remained for a long time without me. Really express my deep gratitude to them, they are my life.

At the end I would like to express appreciation to my beloved Mohammad who spent long days waiting for me and was always support for me in every moment.

ABSTRACT CONTENTS

ABSTRACT FIGURES

ABSTRACT TABLES

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 labs 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 results of the analysis 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].

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.

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.

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 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 (VR Applications) and computerized laboratories on the achievement level in the knowledge of chemical concepts and phenomena 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 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: 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.

2.1. COMPUTER ASSISTED INSTRUCTION

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.

2.2. COMPUTERIZED LABORATORY

The objectives of computerized laboratory

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

1) The possibility 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.
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.
6) It increases the student's ability and confidence in dealing with the computer and the ability to analyze data by graphics and statistical tables for the results of experiments.

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.

Benefits and difficulties of using simulations in teaching and learning

The simulation 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.

There are many benefits of using simulation in education, there are also some flaws that, according to [Wieman, 2007], [Sharp, 2001] and [Allison, 2000] can be summarized as following:

- The simulation programs for education need a long time for planning and programming to become effective and efficient.
- These programs need a team of teachers, programmers, psychologists and experts of the curriculum and teaching methods.
- There is not enough amount of the necessary information about how to use them in education and training.
  There is a lack of financial resources for the needed laboratory equipment.
- There is a lack of adequately trained teachers on the educational uses of simulation.

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

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. 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].

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.

CHAPTER 3. VIRTUAL LABORATORY IN CHEMISTRY

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".

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.

Also, the virtual labs give the students an opportunity to self-evaluate their performance during experiments [Martinez, 2003].

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 at **Carnegie Mellon University**, USA. One advantage of this virtual chemistry lab is that it is designed for 14 different languages.

- **Virtual Chemistry Lab 2.0** is a free software that can be downloaded from Internet (http://www.softpedia.com/get/Others/Home-Education/Virtual Chemistry-Lab.shtml). It can be used in English and Spanish languages.
- The **LiveChem virtual laboratory** at **Oxford University** was developed to supplement their first year undergraduate teaching: http://www.chem.ox.ac.uk/vrchemistry/.
- 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 (http://farrer.csu.edu.au/chemistry/) is an accurate 3D model of the undergraduate chemistry teaching laboratory at Wagga Wagga campus.
- This **Virtual Labs** site (http://www.vlab.co.in/ba_labs_all.php?id=9) was developed in **India**, to allow remote-access to virtual labs in different disciplines of Science, among that Chemistry.

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, such as: [Kristensen, 2006], [Change, 2002], [Martinez, 2003], [Jensen, 2004], [Balmush, 2005], [Woodfield, 2005], [Al Radi, 2008], [Payne, 2005], [Shih, 2005] and others.

3.4. REAL LABORATORY VERSUS VIRTUAL LABORATORY

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.

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, 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.

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.

4.2. OPEN SIMULATOR

4.2.1. Presentation of OpenSim

Open Simulator (http://www.opensimulator.org) is an 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 [2].

Open Simulator can be run on Windows and on UNIX, since it is written in C#.

4.2.2. The components of the Open Simulator

To access the server provided by Linden Labs you need a client. The typical interface of OpenSim in the client software contains 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.

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), Grid (multi-server), Hyper Grid.

Main features of the server: management of primitives, users, worlds, others.

CAPTER 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, 2014-11], 5.4 [Shudayfat, 2014-13].

5.1. A 3D VIRTUAL CLASSROOM FOR TEACHING CHEMISTRY

For the creation of our virtual environment, we selected the EON Creator software. 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. 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 figures 5. 1 and 5. 2).

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) is http://www.eonreality.com/eon-coliseum/.

By clicking on a 3D object (like the 3D representation of a molecule) the student can obtain information, choosing between many visualization options: text , sound, still pictures, motion pictures (video), Graphics, animations , hyper Links.

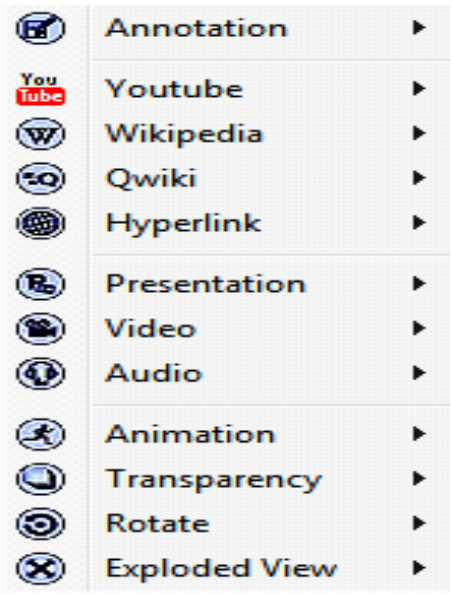

Figure 5. 1. Interactive Authoring Configuration Tool.

Figure 5. 2.Interactive Runtime Tool.

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.

Our conclusion from the first experiment with this application was that VR is a significantly compelling creative environment in which to teach and learn. 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 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.

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.

5.2.1. Application description

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. 3).

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. 4).

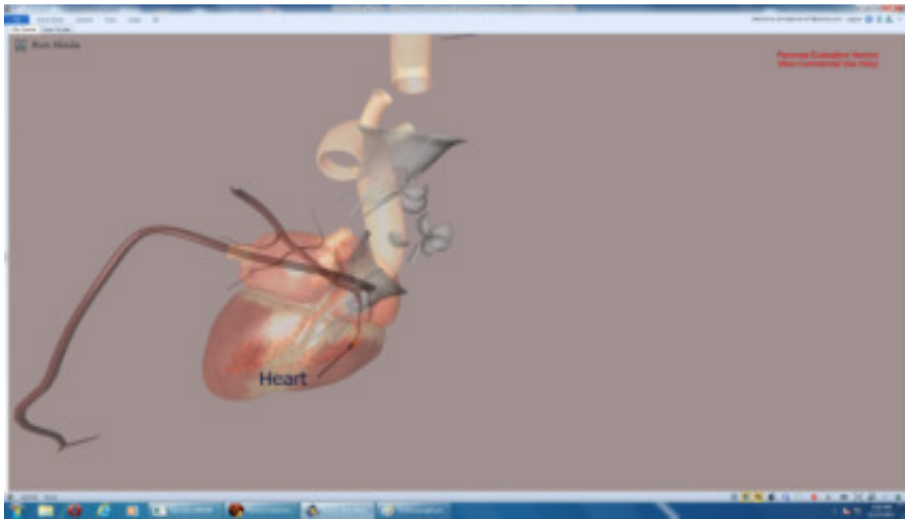

Figure 5.3. Heart section.

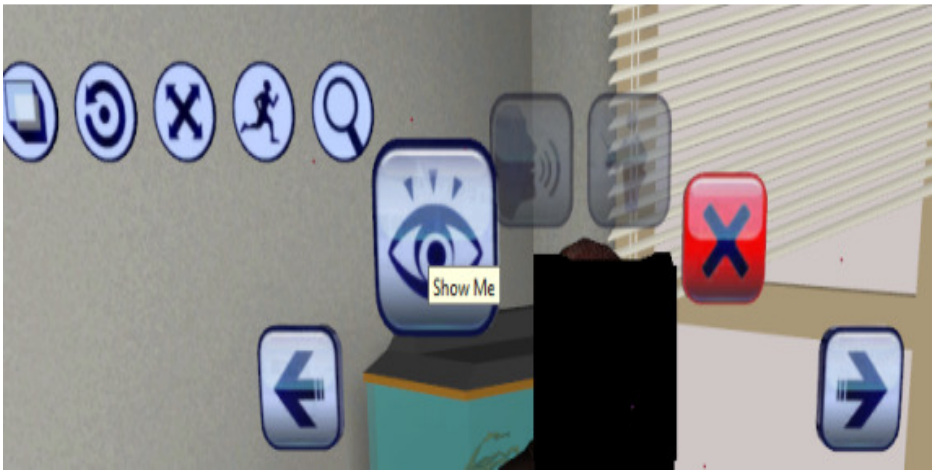

Figure 5.4. Visualization options.

The bone cell lesson

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.

5.2.2. Implementation

The application was created using EON Creator and published on the EON Experience portal [http://www2.eonexperience.com/eon-models/details.aspx?cid=4574].

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 (see figure 5.5).

Figure 5. 5. Biology virtual class.

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.
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

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.

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, 2008].

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 lying between different puzzles of the chemistry game that contain fundamental concepts.

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.

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 and customize their avatars.

Students navigate freely and interact with the virtual world by touching, moving or even flying. Apart from free exploration, they must solve quests and puzzles to access special area or objects, to finish each level and eventually win the game.

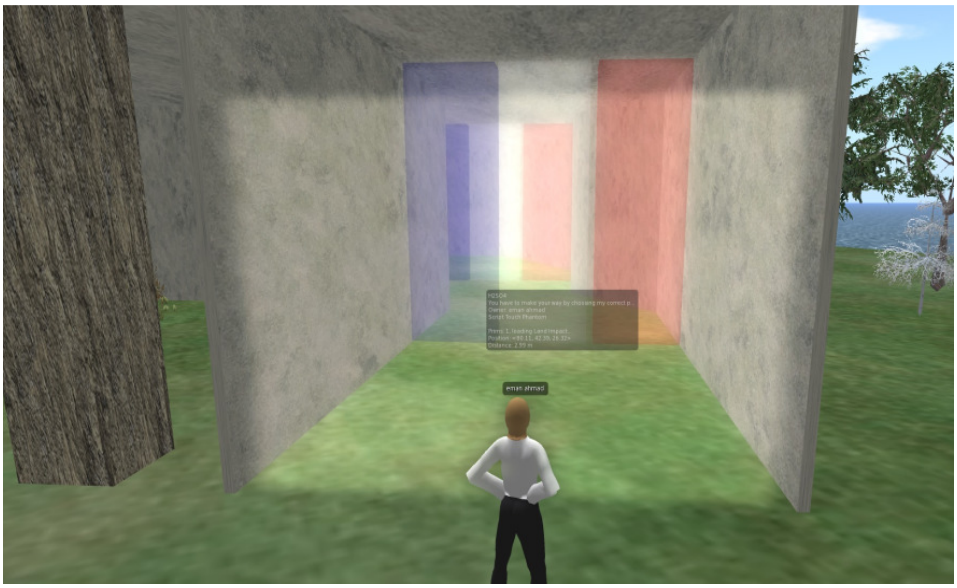

Figure 5.6. Student in front of the PH puzzle.

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 level, after finding the chemical elements, the student chooses them by their reactivity. If the student chooses correctly, a message tells him. As the student moves to higher levels of this part, the number of elements to be arranged gradually increases. 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. 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 (see figure 5.6).

5.3.4. Experiments and Results

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 more times); 17 students found the game challenging because the game requires they should know a lot more information in chemistry.

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.

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

5.3.5. Conclusions

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.

We implemented the virtual laboratory using OpenSim. 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. 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 favour 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 5.7).

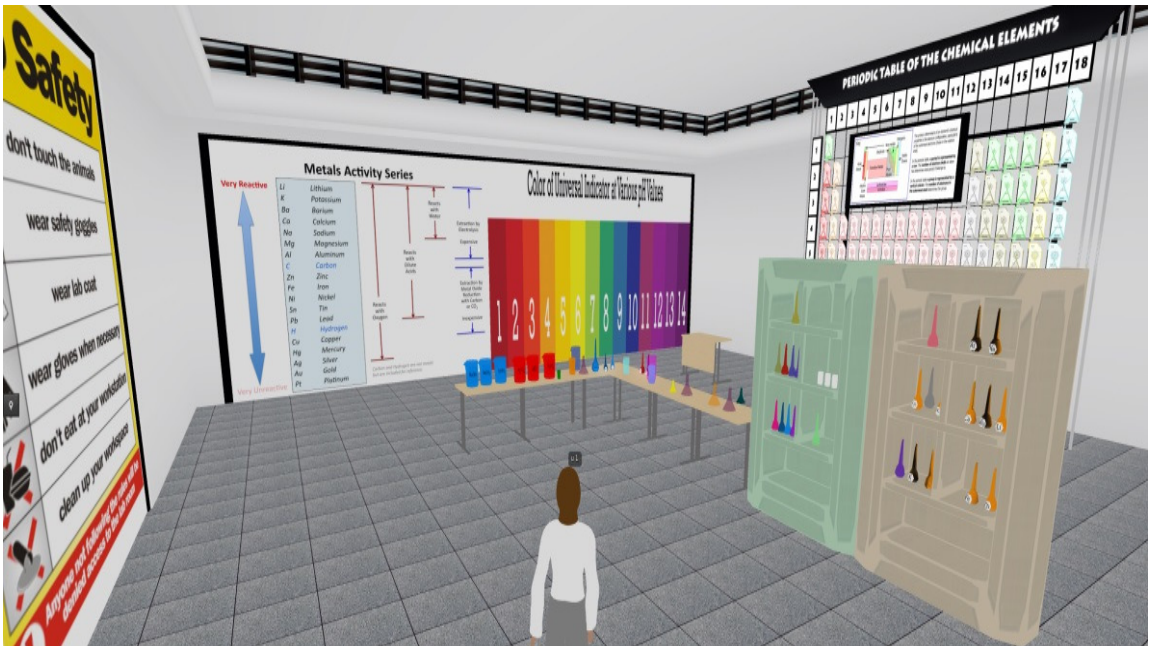

Figure 5.7. Our virtual chemistry lab.

5.4.3. Activities in Virtual Laboratory

1. The reaction of metallic elements

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).

2. The Periodic Table

The student reaches the Periodic Table 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.

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. 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.

5.4.4. Evaluation

From the student's answers our questionnaire 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.
- 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.
- 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.

5.4.5. Conclusions

- 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

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.

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.

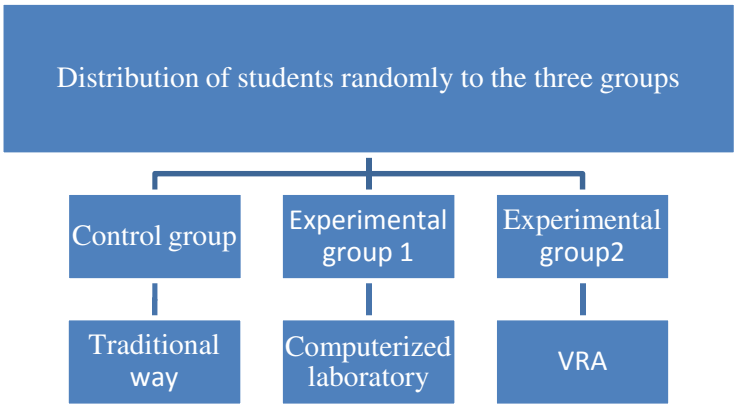

Figure 6. 1. The methodology used in the experimental research.

6.2. THE TARGET GROUP OF THE RESEARCH

The target group consisted of students of the tenth grade in a public school of Almafraq 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.

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	

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.

6.3. 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.

6.4. STATISTICAL ANALYSIS OF RESULTS

The main purpose of the statistical analysis was 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) [4] 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 analysis was done using the grades in the achievement test for all students in the three groups and the answers to: the "trend toward chemistry" questionnaire, the "Students' views on the use of computerized laboratories in teaching chemistry" questionnaire and the "Students' views on the use of Virtual Reality Applications in teaching chemistry" questionnaire. All questions were with answers on a Likert scale.

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 and 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. SERIOUS GAMES - 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 features:

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.

Potential benefits of using games in education:

- develop student's confidence and increase his intellectual capacity;
- improve self-monitoring;
- develop different skills, such as critical thinking skills and strategic analytical skills;
- help to identify and resolve problems;
- help to make decisions;
- improve memory;

- increase social skills such as cooperation, negotiation and acquaintance [Enochsson, 2004].

7.2. OUR SERIOUS GAME

In this section we describe an original game, developed by the thesis' author and published in [Shudayfat, 2012-12].

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. Another objective 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 Chemistry game provides several activities to encourage active learning experiences, through challenge and competition among students, stimulating students' curiosity, imagination and social fun.

7.3. 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.

7.4. 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. Some games are simple single-selection games where the users have to click and select the correct answer from a set of multiple options, others, more complex, but still simple game are match-pairs, where the user has to match image-pairs from two columns. The games have more

difficulty levels, some grading and competition features. The teacher can record and monitor all the results, the total points and the final level for each student.

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.
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.

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

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".

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. The game has all features of a serious 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 GRDINARU, "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 GRDINARU, "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.

5. Eman Ahmad SHUDAYFAT, Florica MOLDOVEANU, Alin MOLDOVEANU, Alexandru GRDINARU, "3D game-like virtual environment for chemistry learning",Scientific Bulletin of UPB, Series C, vol 76, iss. 3 (to appear).
6. Maria-Iuliana Dascalu, Alin Moldoveanu, Eman Ahmad Shudayfat, "Mixed Reality to Support New Learning Paradigms", sent to ICSTCC 2014, Sinaia, October 2014.

REFERENCES

[1] A.Al Radi, 2008, "The Impact of using Virtual labs on High School Students Results (Natural Science) Chemistry", Al Qusseim education sector, master thesis Education faculty, King Saud University, Al Riyadh.

[2] A.Basawapatna, A. Koh, K. H. Repenning, 2010, "Using Scalable Game Design To Teach Computer Science From Middle School to Graduate School", ITiCSE '10: Annual Conference on Innovation and Technology in Computer Science Education, Ankara, Turkey.

[3] B.Dalagrano, J. Lee, 2010, "What are the learning affordances of 3-D virtual environments", British Journal of Educational Technology, 41 (1), pp 10-32.

[4] B.Woodfield,M. Andrus, T. Anderson, J. Miller, B. Simmons, G. Weddoups, M.; Moore, 2005, " The virtual chemlab project: A realistic and sophisticated simulation of organic synthesis and organic qualitative analysis". Journal of Chemical Education, 82, 11, 1728-1735.

[5] Balmush, R. Dumbravianu.2005, Virtual laboratory in optics". Third International Conference on Multimedia and Information & Communication Technologies in Education June 7-10th, 2005.

[6] C.Abt, 1970, "Serious Games". New York: The Viking Press.

[7] C.E. Wieman, K.K. Perkins, and W.K. Adams, 2007, "Interactive simulations for teaching physics: what works, what doesn't, and why", American Journal of Physics, vol 76 (4&5), pp. 393-399.

[8] C.Y.Change, 2002, "Dose Computer-Assisted Instruction + Problem Solving = Improved Science Outcomes Apioneer Study". Journal of Education Research, 95, (3), pp 143-150.

[9] D .Gaba.1997, "Simulators in Anesthesiology". Advances in Anesthesia 1997, pp. 14.

[10] E. Shudayfat, F. Moldoveanu, A. Moldoveanu, A. Grdinaru, 2013, "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.

[11] E. Shudayfat, F. Moldoveanu, A. Moldoveanu, A. Grdinaru, 2014, "3D game-like virtual environment for chemistry learning", Scientific Bulletin of UPB, Series C, vol 76, iss. 3 (to appear).

[12] E. Shudayfat, F. Moldoveanu, A. Moldoveanu, A. Grdinaru, 2014, "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.

[13] E. Shudayfat, F. Moldoveanu, A. Moldoveanu, A. Grdinaru, 2014, "Prototyping a 3D MMO Virtual Environment for Chemistry Learning", The 10th International Scientific Conference eLearning and Software for Education, Bucharest, April 25-26.

[14] E. Shudayfat, F. Moldoveanu, A. Moldoveanu,2012,"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.

[15] F.Alshaya. 2005, "The reality of the use of computerized science laboratories at the secondary level and trends of science teachers and students towards it". Journal of King Saud University. Saudi Arabia.

[16] F.Moldoveanu, A. Moldoveanu, V. Asavei,2008, "Méga Musée Virtuel", CIFA 2008 Proceedings - IEEE Conference Internationale Francophone d`Automatique, Bucarest, Roumanie.
[17] G.Dafoulas, N. Saleeb, M. Loomes, 2012, "The impact of 3D virtual environments on communication patterns". Information Technology Based Education, 2012 International Conference on Istanbul, pp 1 – 5.
[18] H.Zaytoon,2005, "A New Vision Teaching- E- learning- Concept", Issues, Application, Evaluation-, Dar Assoltia for Publishing and Distribution, Al Riyadh, Saudi Arab Kingdom.
[19] J.E. Sharp, 2001, "Teaching teamwork communication with Kolb learning style theory", Proceedings of the 31st ASEE/IEEE Frontiers in Education Conference, Reno NV, Oct.
[20] J.Kristensen, 2006, "Simulation of laboratory assignments to support students' learning of introductory inorganic chemistry". Chemistry Education Research and Practice, 7(4), 266-279.
[21] J.Martinez, P. Pedrajas, A. Polo, J. Bellido, M.S, 2003, "Learning in chemistry with virtual laboratories". Journal of Chemical Education, pp 80.
[22] K. Smetana, L.Randy, 2012, "computer simulations to Support Science Instruction and Learning: A critical review of the literature",International Journal of Science Education Volume 34, Issue 9,
[23] L. Schaverien, 2001, "Teacher Education in Generating Virtual Classroom: A Web Delivered Context for Developing Learning Theories", J. of Bibliographic Research, vol. 20, pp. 5.
[24] L.Allison, L. F. Hodges,2000, "Virtual Reality for Education", VRST 2000, Seoul, Korea, ACM, pp 160-165
[25] M. Virvou et al, 2005, "Combining software games with education: Evaluation of its educational effectiveness", Educational Technology & Society, vol. 8, pp 54-65.
[26] M.Al – Harthy, 2010, "The teaching of science in a manner to solve the problems of theory and practice". Riyadh.
[27] M.Alfar, 2011, "Computer Educations emitters' philosophy and reasons for the application".
[28] M.Murphy, S. Redding, J. Twyman, 2013, "Games in Learning, Design, and motivation", Philadelphia, pp 149.
[29] N. Jensen, G. Voigt, W. Nejd, S, 2004, "Development of a Virtual Laboratory System for Science Education Interactive Multimedia Electronic Journal of Computer-Enhanced Learning.
[30] P.Garrison, 1985, "Simulators Yesterday, Today, and tomorrow. In Flying Without Wings: A Flight Simulation Manual", Blue Ridge Summit, PA: TabBooks Inc. pp 1-30.
[31] R.E. Clark, 2007, "learning from serious games Arguments", Evidence, and Research Suggestions. Educational Technology, pp 56-59.
[32] R.Payne, 2005, "Classroom: For the Next Century, Computer & Internet Communication", Cresskill, NJ: Hampton Press, pp 82.
[33] R.Swyer, 1998, "Teacher and student attitudes toward microcomputer based laboratories (MBLs) in the province of Newfoundland and Labrador", Published master thesis. Memorial university of Newfoundland: Canada.
[34] S.Alhudhaifi, "2005, Modalities and methods of science education at the secondary level in the Kingdom of Saudi Arabia and the United States", King Saud University Journal.
[35] T. Drury.2001, Generating a Three-Dimensional Campus Model. MIT Laboratory for Computer Science. AUP Report.
[36] W.p. Liao, 2009, "Applications of Computer Technology on Modern Chemistry Teaching and Research", First International Workshop on Education Technology and Computer Science, vol. 1, pp 534-536.
[37] Y. Fan, 2009, "Integrate college English teaching reform by means of information technology", Jiangsu Foreign Language Teaching Research, pp 2-5.

WEBSITES

[1] http://www.eonreality.com/eon-creator
[2] http://opensimulator.org/wiki/Main_Page