3D GAME-LIKE VIRTUAL ENVIRONMENT FOR CHEMISTRY LEARNING

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In this paper, we present the concept, implementation and experimentation of a 3D MMO educational game designed for interactively learning chemistry. The game is integrated into the OpenSim framework to implement immersive, real time and multiuser "learning by playing" techniques that have proved to be among the most powerful learning strategies in learning science. Experimenting the game with high school students proved that virtual gaming can be a practical and effective educational tool. Results suggest that it is more powerful to support chemistry learning with virtual game technology than with the traditional learning methods.

Keywords: virtual learning environments, assisted learning, immersive learning, chemistry learning, chemistry game

1. Introduction

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 [1]. The improvement in the accuracy of audio-visual elements included in a virtual environment enables a high level of fidelity in reality simulation [2].

A 3D MMO (Massively Multiplayer Online) 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 [3].

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Such an environment provides facilities for interactive learning and allows students to access it anytime and from their favourite place. The student has to solve tasks for reaching a specific goal, moving from one level of difficulty to another, like in an MMO game. In this environment, students can manifest their own personalities and abilities, can work in groups to reach specific goals and win competitions [4]. World of Warcraft for example, is used by some economic colleges to train students in economic concepts such as buying, selling or bartering [5].

Metaverses are immersive 3D environments where people can interact through characters called avatars, controlled by real people using different interactive devices and techniques [6]. 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 computational goals to achieve, so users can define their own goals. Second Life [7] is among the most famous metaverse environments; it was used for building business applications, but also in schools, universities, hospitals and government [8].

In this paper, we present a game designed for interactively learning chemistry. The game is integrated in OpenSim [9] and exploits the 3D virtual reality environment provided by this platform to implement immersive, 'learn-by-play' techniques.

2. Related works

The study of Schaverien [10] 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. [11] 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 [12] 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 and teachers. The virtual 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 [13] identify 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 students' 3D view, creativity, competition, social interaction and critical-thinking. The game is designed as complementary to in-class teaching.

Virtual schools are learning centers that exist only in virtual environments. However, an experimental approaches teaching the Syrian language by combining language learning via Second Life and the real life. Electronic learning sources are rich with audio and visual media, having integrated a communication curriculum based on task performance [8]. Similarly, it emerged the idea of the teaching

English in the same way. Adding Second Life to audio features allows its members to speak with each other directly, enabling teachers to provide more interactive lessons by playing in Second Life [14].

During the application of all the studies mentioned above, there were lots of observations and challenges such as:

- Difficulty of delivering and interpreting methodology requirements into technology.
- The collaborative aspect in designing the project provides benefits, but also challenges [15].

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 [16].

3. Game Design 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 ninth 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 [17].

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 choose 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; runs on Windows, Unix/Linux and Mac Operating Systems; most important, allows access to 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.

4. Our Game

4.1. 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.

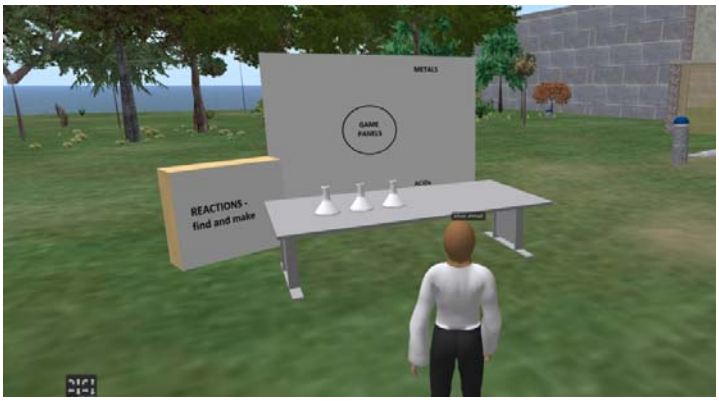

Fig. 1. Student main panel

The main goals for the game are “chemical reactions”. The reaction quests are provided from the main panel in the center of the virtual environment (Fig. 1). To solve them, the students must search 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 (Fig. 2).

Fig. 2. Student front puzzles to arrange some elements

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. Also, on higher levels, they will 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 (Fig. 3).

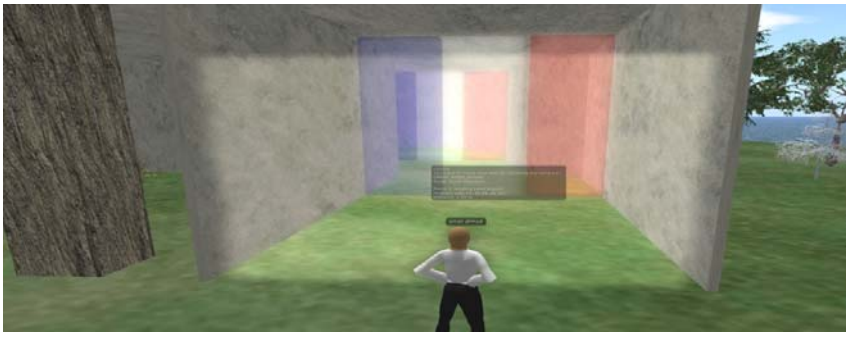

Fig. 3. Student in front of PH puzzle

4.2. 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 own avatar and make some customization to it.

The user (student) can navigate freely and interact 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.

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 they succeed, they move to the second level of this part and so on until they reach 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. Fig. 2 shows the avatar in front of such puzzle. As the student moves to higher levels of this part, the number of elements to be arranged gradually increases (Fig. 4). The last and most difficult level includes ten chemical elements to look for in our virtual environment in a manner that ensures the student will arrange them by chemical reactivity from low to high (Fig. 5). 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 it: 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 can continue playing and learning, going on to the second level.

Level II: the number of gates is increased: weak acidic, strong 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 the different colors: red, orange, blue, and violet, and choosing the appropriate color for each reaction. The gate will open in the case of correct answers, 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 chemicals.

Fig. 4. A student choosing chemical elements

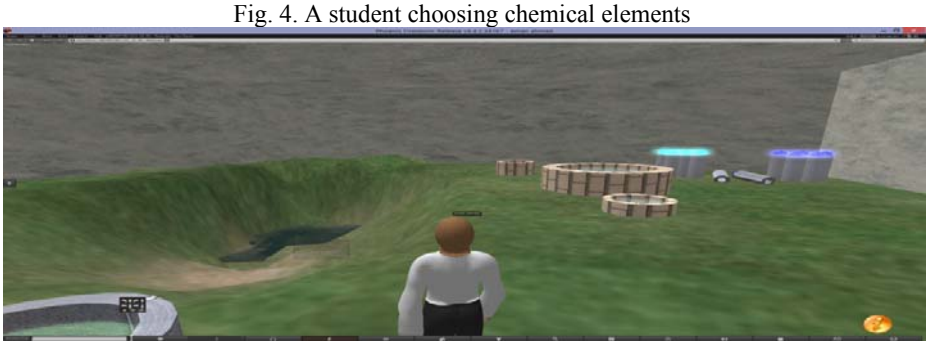

Fig. 5. A student choosing chemical reactivity for elements

4.3. General Features

Immersive learning environment: the use of the 3D environment provided by the OpenSim framework allows immersive learning, i.e. in the game; the context in which the user is immersed and in which he navigates, corresponds to the learning context by flying between different puzzles in the chemistry game, containing fundamental concepts in this subject; such an immersive learning environment promotes development of deep, conceptual knowledge of a particular subject by allowing players to experience the virtual world through sight, sound, participation and imagination, in a non-linear fashion.

Massive multiuser online: through the OpenSim framework, even hundreds of users can access the same virtual environment at the same time, interacting through their avatars and the various 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.

In our game players can remain in touch with each other through communication tools, and therefore players can cooperate using the skills of the game. Each player must complete the skills of the full game, communicate with each other and assist one another so as to benefit from the experiences they went

through during the play. Our game is meant to be played in a cooperative manner, not a competitive one.

The teacher here has the role of the observer. Many discussions have taken place when students are playing at the same time and so the teacher intervenes by helping the students to have useful discussions and ask them some questions by text chatting or voice (VOIP). Additionally, he takes notes about how students work in the game and it is quite important to constantly evaluate the performance of those students.

5. Experiments and Results

Our project 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.

During in the fall 2013 semester, we introduced the virtual game in a school from Jordan. We selected 20 students in the ninth 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.

We put students in groups, who then started playing together. The first survey asked the students' opinions about the game. 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 image?

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 Fig. 6:

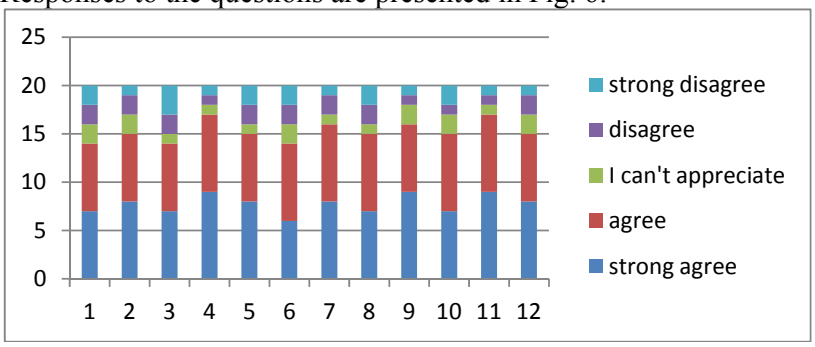

Fig. 6. Results of questions: x-axis = the questions' id, y-axis = number of students' answers

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.

The problems during the game play are that many students found it difficult to download and install OpenSim. Similarly the students who do not play often or at all computer games, found it difficult to interact with the virtual environment through flight or walking. If more students attempt to speak at the same time there are noise problems. A solution to that could be that the student who wishes to speak with the microphone should first announce his intention first through their avatar.

6. Conclusions

In this paper, we have presented our work on VR-enhanced chemistry education using a gaming approach to improve the learning process. Students can repeatedly play the game in a risk-free manner [18]. The program is fun, interesting and motivates them to learn chemistry, while also stimulating

cooperation and encouraging to learn from and adapt to each other's tactics and play styles [19]; these attributes are of particular importance when teaching the "Internet - generation" students.

Our game was developed using he 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 game is the sense of presence or "being there" when the student interacts with the learning system based the virtual game.

Overall, the results suggest that it is more powerful to support chemistry learning with virtual game technology than with traditional learning methods, consistent with previous results of using virtual game playing in learning a particular subject. 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 [10], which allows for discovery and self-paced learning. More non-linear and student-centered approaches of instruction become thus possible. Additionally, studies found that when using immersive environments, students show more improvement than when learning with other educational software [14].

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

One of our future research directions is to conduct studies on the positive emotions experienced in virtual game based learning.

We will also add more game features and rich interactions regarding hands on experiments. The immersion rate will be studied for these interactive experiments. Experiments will have realistic effects and mixing two or more chemical elements should produce live realistic results. Also, there will be quests that require some solution effects, like explosions, and students are asked to find elements and make the solutions with the required properties.

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REFERENCES

[1] *M. Macedonia*, "Generation 3D: Living in Virtual Worlds," Computer, **vol. 40**, no. 10, 2007, pp. 99-101.

[2] *B.L. Stewart., S. Ezell, D. DeMartino, R. Rifai, B. Gatterson,* Virtual Technology and Education A Collaborative Pilot Case, in The Quarterly Review of Distance Education, **vol. 7**, no. 4, 2006, pp. 377-385.

[3] *K. Jin Shim* ,An Exploratory Study of Player Performance, Motivation, and Enjoyment in Massively Multiplayer Online Role-Playing Games, Privacy, security, risk and trust (passat), 2011 IEEE third international conference on social computing, Boston, MA, 2011, pp.135 – 140.

[4] *L.L. Crumpton, E.L. Harden,* Using virtual reality as a tool to enhance classroom Instruction, in Computers & Industrial Engineering, **vol. 1-2**, 1997, pp. 217-220.

[5] *A. M. Al-Karam, N.*V. *Al-Ali, A. Ezzat*, Education development through utilization of technology, UNESCO Regional Office for Education in the Arab States, 2001, pp. 49-63.

[6] *T.Y. Chuang*, Effect of Computer-Based Video Games on Children: An Experimental Study, Digital Game IEEE, Jhongli, 2007, pp. 114 - 118

[7] Second Life, http://secondlife.com/

[8] *K.J. Shim*, J. Srivastava,Team Performance Prediction in Massively Multiplayer Online Role-Playing Games (MMORPGs), Proceedings of the IEEE Social Computing (SocialCom-10). Minneapolis, Minnesota, USA, 2010.

[9] Open Simulator, http://opensimulator.org

[10] *L. Schaverien,* Teacher Education in Generating Virtual Classroom: A Web-Delivered Context for Developing Learning Theories, J. of Bibliographic Research, **vol. 20**, 2001, pp. 5.

[11] *T.L. Murry,* Exploring the Psychological Terrain of the Virtual Classroom: The nature of Relationship and Power in online Teaching and Learning, 2005.

[12] *P. Khalili, M. Pete,* An in Depth Look At How Learning In A Virtual Classroom Impacts On the Curriculum, Technikon Natal, South Africa, 2000.

[13] *L. Stefan, F. Moldoveanu*, Game-based Learning with Augmented Reality – From Technology's Affordances to Game Design and Educational Scenarios, Proceedings of 9th International Scientific Conference eLearning and Software for Education (eLSE 2013), Bucuresti 2013, **vol. 2**, pp. 105-114.

[14] *M. Virvou et al.*, Combining software games with education: Evaluation of its educational effectiveness, Educational Technology & Society, **vol**. **8**, 2005, pp. 54-65.

[15] *R. Van Eck*, presentation at the 2006 ELI Annual Meeting, San Diego, California, 2006.

[16] *A. Moldoveanu, F. Moldoveanu, V. Asavei*, Méga Musée Virtuel, CIFA 2008 Proceedings - IEEE Conference Internationale Francophone d`Automatique, Bucarest, Roumanie, 2008.

[17] *A. Moldoveanu, F. Moldoveanu, V. Asavei, A. Morar, A. Egner*, From HTML to 3DMMO - a Roadmap Full of Challenges, in Proceedings of CSCS 18 - The 18th International Conference On Control Systems And Computer Science, Bucharest, 2011, pp. 620-627.

[18] *A. Steed, R. Schroeder, A.S. Axelsson, A. Nilsson, I. Heldal, J. Wideström, Å. Abelin,* Solving a 3D Cube Puzzle in a Collaborative Virtual Environment: As Good as Really Being There Together, SIGGRAPH, 2001.

[19] *D. Oblinger,* Simulations, games, and learning, Educause Learning Initiative, 2006.