Putting Theory into Practice with Technology in Chemistry Education

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Abstract. In recent years the field of alternative haptic interface is expanding and improvements are being made by developing, testing and refining devices along with software to give users the possibility of inter- acting with three dimensional virtual objects in an intuitive way. Such technology can play a significant role in education, especially as complements of MOOCs delivery. This paper presents a description of an educational haptic system for chemistry experiment simulations and molecular visualization that can complement a virtual delivery system by providing hands-on experiences. It also describes some didactic scenarios and discusses current results and future works.

Keywords: Haptics, haptic interface, technology enhanced learning, chemistry education, e-learning, simulation, molecular visualization.

1 Introduction

In recent years, the evolution of technology has influenced education in several ways. Various tools and methods based on visual interaction technologies have been introduced that help students to acquire knowledge through simulation. It has been realized that virtual visualization could solve the difficulty in under- standing certain aspects of the real world and help learners to fully grasp the idea behind scientific rules and laws or other subjects rather than just having theoretical knowledge [1].

There is a general consensus on two different approaches to learning. One is passive learning, in which students are asked to sit and understand the theories through visual and auditory cues. This way of learning can be boring for the students and diverts their attention after some time. On the other hand, active learning is a means of learning in which the students are directly involved. They have control over learning, they explore a concept, and they expand their energies to make decisions. This method of learning is recognized to develop the interest of the students and motivates them to explore and learn more [2].

A recent research has found that the use of acoustic and visual presentation techniques works exceptionally well in educational domains. In 1996, [3] shows that displays for educational purposes are primarily vision based even in the field of virtual reality and up until now, the elected methodology in education is based on a passive approach of learning. More recently, newer methods of teaching delivery exists, such as MOOCs and online virtual labs, which allows thousands of students to access lectures and lessons from everywhere in the world. However, a perceived missing element of such methodology is the fact that students have difficulties in actively engage in the training, as often there is no means for the students to actually be active in the learning process. Indeed, many available MOOCs today are based on lectures and visual contents [4]. For example, imagine a task assigned to a student, in which the student will learn a method to replace a devices component. Without getting the real touch and feel of that object under simulation, this task can be meaningless.

In contrast, teaching practices based on haptic technologies within an overall MOOC ecosystem can encourage active participation of students and can provide a better understanding by means of direct interactions with the course material as it exists in the real world [5]. Haptic technologies and modern visualization systems can provide active elements in the training process that may greatly help to complement the current delivery methodology.

Haptic technology is already applied in various fields, like surgical simulation, medical training and scientific visualization [6]. The use of haptic technology in education has been a revolution to the learning experience. The learning experience that is gained through the use of haptic technology produces interesting results and motivates students [7]. Moreover, haptic technology has come up with a great value addition for students with visual impairment [7].

Within this field, haptic-based chemistry systems are regarded as a new topic and most of the current interactive tools and systems based on haptic feedback are suggested to be used by postgraduate chemistry studies and professionals. In addition, they are not combined with molecule virtualization system and virtual labs. Therefore, the research on using haptic devices in education, specifically in the chemistry field, is becoming very important. An overview of examples of haptic based labs and visualization systems in chemistry education and their evaluations is provided in [8].

Based on our research in using haptic technology in education, we developed a prototype of a haptic system that combines the possibility of replicate chemistry experiments in simulation with 3D molecular visualization. This sys- tem could be applied both in research and e-learning.

2 Materials and methods

We are developing an educational haptic system for chemistry experiment simulations and molecular visualization. The system uses an easily available haptic device, which is the Leap Motion controller, with 3D graphical user interface.

The potential of the Leap Motion controller is huge and it is expected to be used in education and simulation environments to simplify learning issues. The Leap Motion controller can recognize the position and the rotation for left and right hand models with ten fingers composed of bone-segments. The Leap Motion was designed to perform tasks such as exploring 3D objects with high accuracy using gestures which makes it possible to be used for interacting with the operating system. These features can be used to design many useful education applications [9].

The Leap Motion may help students in their learning process. By virtually touching and exploring objects, students can deal with the conceptual barriers in chemistry science. The use of haptic technology in education actively involves and engages students by having an interaction with the courses material such as beakers, flasks and chemical compounds. This interaction makes them understand better and enhances their ability to learn and grasp the concept, thus making the use of haptic technology beneficial for students in education [10].

The basic barrier and obstacle that students may face in the study of chemistry is connecting between what they can see in a lab (macroscopic level) and what they cannot directly see (microscopic level). The system described in this paper combines the two contrasting views which are the macroscopic view at a chemical lab and the microscopic view at a molecular level.

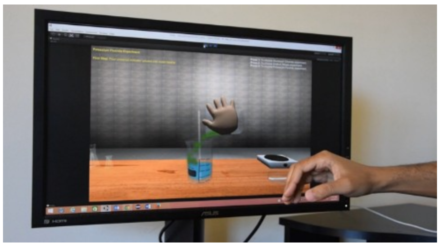
The scenario-based learning methods provide users with a feeling that they are in a chemistry lab. As a result, users can use their fingers and hands to move and rotate objects and apply experiments scenarios similar to what is done in a real lab. In addition, this system visualizes the characteristics of atoms, molecules, electrons and the forces produced by the chemical bonds, which will translate into physico-chemical terms. It can help users to form and create complex molecular structures in virtual reality and understand the binding affinity of macromolecular interactions [11].

3 Preliminary Result

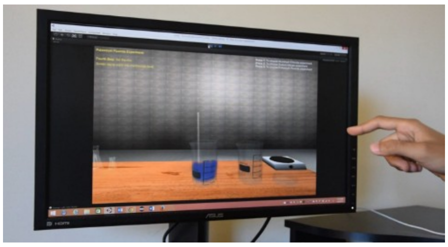
A student using the haptic device system with its PC is shown in Fig. 1. Our system introduces two chemical experiments that can be used in chemistry with secondary school students, who can have benefit by practicing the experiments techniques and steps in a virtual lab environment before applying them in a real lab. The students can also benefit from the system to understand the chemical changes and chemical bonds which cannot be seen by the naked eye. In each experiment, a student can interact with the haptic device and complete the experiment steps as in a real lab, what they called in chemistry macroscopic level. At the macroscopic level, a user can use physical movements to move and rotate glassware and chemical substances to act and perform experiments steps as in a real lab. Then, the user can zoom into the chemical compounds and see and interact with virtual representations of molecules and chemical bonds, what is called in chemistry, the microscopic level. At the microscopic level, the system shows the interaction between molecules due to the electric field around them and its features and allows the user to interact with atoms and molecules using haptic technology. At the microscopic level, the user can use gestures to rotate the 3D molecular models of the chemical compounds and explore the 3D structure. The following subsection describes an experiment that can be executed with the system.

3.1 Salt Hydrolysis Experiment

The objective of this lab is to study the change of three different types of salts when they are added to water, chemically called Salt Hydrolysis. Our system allows the user to select one of three different types of salts - ammonium chloride salt, sodium nitrate salt or potassium fluoride salt. Each one of these salts gives a different result when they are added to water. At the macroscopic level of the system, the user completes the experiment steps using the haptic device and then the change can be observed in the mixture's appearance as in a real lab. The chemical explanation of this change can then be discovered by moving to the microscopic level which can help deliver a better understanding of this chemical reaction.



(a)



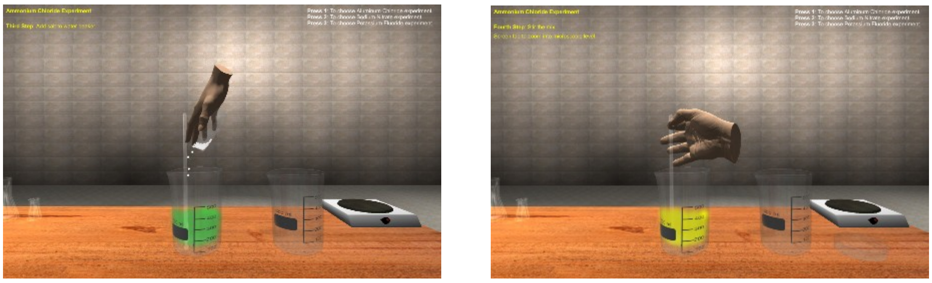
(b)

Fig. 1: A student using the haptic system (a) The student pouring the universal indicator solution into the water beaker; (b) The student tapping the screen remotely using the Leap Motion to move to the microscopic level.

Ammonium Chloride Salt. At the macroscopic level, when the universal indicator solution is added to the water beaker and the mixture is stirred through interaction with the haptic device, the color of water changes to green. Then, ammonium chloride salt (NH4Cl) is added to the water beaker, as shown in Fig. 2 (a). As in Fig. 2 (b), the color of the mixture turns to yellow when it is mixed using a glass rod, which means, chemically, an acid is formed [11]. At the microscopic level, ammonium chloride dissociates in water into ions. These ions react to produce ammonium hydroxide (NH4OH) and hydrochloride acid (HCl). In this case, the net result is a relative excess of hydrogen ions, giving an acid solution which causes changing the solutions color to yellow [11].

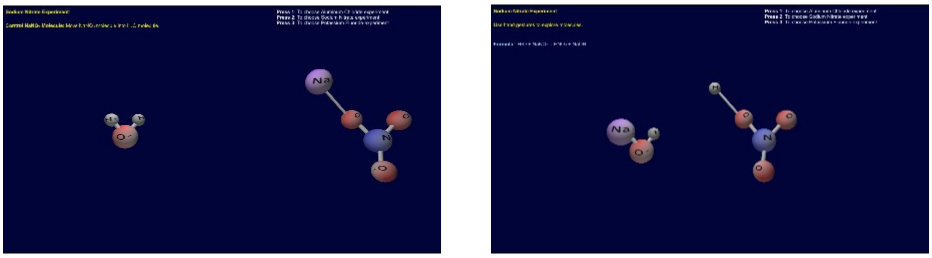
Sodium Nitrate Salt. As in the macroscopic level of the previous lab, the universal indicator solution is mixed with the water. However, when sodium nitrate salt (NaNO3) is added to the water beaker and mixed using the Leap Motion controller, the color of the mixture does not change because a neutral solution is formed. At the microscopic level, 3D visualization of the water molecule and the sodium nitrate molecule is shown as in Fig. 3 (a). When the user adds the water molecule to the sodium nitrate molecule, the sodium ion reacts with the hydroxide ion to produce sodium hydroxide (NaOH), which is a strong base, whereas the nitrate ion reacts with hydrogen ion to produce nitric acid (HNO3), which is a strong acid [11]. In this case, the net result is a neutral solution which keeps the color of the solution constant, as shown in Fig. 3 (b).

Potassium Fluoride Salt. Potassium fluoride salt (KF) is added to the water beaker which has been already mixed with the universal indicator solution. The color changes to blue, which means that chemically a base is formed. Then, the user taps the screen remotely to explore the result compound and goes from the macroscopic level to the microscopic level. At the microscopic level, 3D representations of water and potassium fluoride molecules are displayed. When the user uses the haptic system to add the water molecule to the potassium fluoride molecule, ions react and produce potassium hydroxide (KOH) and hydrofluoric acid (HF). In this case, the net result is giving a basic solution which causes changing the solutions color to blue [11].



(a) (b)

Fig. 2: The macroscopic level of the ammonium chloride salt experiment (a) Ammonium chloride salt is added to the water beaker; (b) The color of the mixture is changed to yellow.



(a) (b)

Fig. 3: 3D visualization of water and sodium nitrate molecules before the chemical reaction; (b) The final molecules after the chemical reaction

4 Conclusions and Future Work

This paper introduces a molecule virtualization system and virtual labs along with the haptic interface implemented within it. In reference to the above examples, our educational system combines two approaches to the study. Thus, students will be able to apply lab phases in a virtual lab environment and molecular structures by only downloading the system and plugging in the Leap Motion controller. The virtual reality along with haptic technology allows a user to visualize and compute complex data in simulated environments.

We believe that this kind of application have the potential to complement traditional e-learning delivery, particularly in conjunction with organized teaching structures such as MOOCs. The MOOC educational format has the possibility to reach several people in every part of the world, however, in many cases it is difficult to properly engage followers in hands-on learning activities. With the help of interactive systems, students might complement theoretical knowledge with practical ability. This is especially important for disciplines like chemistry, discussed here as an example, in which theory and practice are deeply entangled. Moreover, besides the facilitation of concepts acquisitions, the presented system have the potential to complement traditional e-learning assessment procedures, which are almost entirely based on testing the knowledge of the user through tests and questionnaires, by focusing on practical abilities, other than theoretical.

In future works, more effort would be required to enhance and improve the visualization interfaces. Future directions of the work would require to cover more and various types of chemical subjects. As a future extension, more efforts would be required to evaluate the system using cognitive knowledge tests. It also would require to be applied in educational environments and gather opinions and suggestions from students and instructors which could be used to make the system more effective.

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