Organic Chemistry Virtual Laboratory Enhancement

Sarah M. Eljack¹, Fayez Alfayez², Nawal M. Suleman³

¹,² Department of Computer Science
College of Science
Majmaah University
Zulfi 11932, Saudi Arabia

³ Department of Chemistry
College of Education
Khartoum University
Omdurman 406, Sudan

email: s.alshiekh@mu.edu.sa, f.alfayez@mu.edu.sa,
nawalmahgoub@uofk.edu

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Abstract

Practical work presents a vital role in education, especially in physical sciences like chemistry. A virtual laboratory is one of the most significant educational technologies in the recent century. Some universities develop their own laboratory software and make it available on their websites. This research reviews some organic virtual laboratories on the Internet and then attempts to develop a virtual laboratory e-learning tool for Organic Chemistry 1 (Chem 121), which is taught in the Chemistry Department, Zulfi Faculty of Education, Majmaah University, Saudi Arabia. This paper compares six organic virtual labs’ software that can cope with the e-learning proposed tools. The result demonstrates that the proposed work improves the performance to achieve the learning outcomes and make it easy for both faculty and students.

Key words and phrases: Organic virtual labs., e-learning, evaluation tool.

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1 Introduction

Chemistry is a crucial field to understand because it requires critical thinking about the behaviors and interactions of atoms, molecules, and ions. Visualizations in chemistry can help to make chemistry at the particulate level less abstract. Also, Chemistry is a fundamental science because it plays a critical role in most aspects of all other natural sciences and it influences different issues in the environment, space sciences, medicine, and more [1]. In chemistry and natural science, the experimental learning and laboratory are important and, at the same time, it is the most significant method for understanding related knowledge and retention of material by learners [2]. However, applying some scientific experiments as traditional forms at real laboratory environments have rarely been conducted due to the scarcity of economic resources and other insufficient facilities, which often required for the construction of the complete laboratory, particularly in developing countries [3].

There is a major growth in the technology used to support education in the last several years. Hence, simulations play a major role in education; they provide realistic models with which students can interact to acquire real-world experiences. In addition, they create safe environments in which students can repeat processes without any risk in order to perceive easier concepts and theories. A virtual laboratory is becoming one of the most significant educational technologies in academic and technological development. The virtual laboratory could replace traditional laboratory [4], So such experiments can be accessible by two- or even three-dimension simulated virtual environments [1]. In addition, a virtual laboratory is a good tool for distance learning and/or experimentation that allows individuals to share knowledge, data, voice, video, tools, and other resources. It offers a suitable environment to spread, develop, integrate, upgrade, and support the learning and/or experimentation process of many subjects, thus contributing to an increase of the effectiveness of scientific research and spreading the use of rare or costly equipment.

The effective usage of a virtual laboratory was studied in [5], [6], and its contributions and importance [7] to the improvement of student learning [8], [9], especially when it is compared to traditional teaching methods [10]. The virtual laboratory application founds a cost-effective solution for schools and universities, and a valuable tool for distance learning and life-long education in chemistry [11]; it offers a distinctive level of interaction [12]. A curriculum for the organic chemistry laboratory [13] was developed during the period 2007-2014. Virtual and real laboratory applications on constructive learning
environment using interactive virtual chemistry laboratory (VCL) development was used in the academic year 2009-2010 for a six-week period [14]. A wide range of communication and collaboration services was offered by using virtual laboratory process [15], chemicals, glassware, and equipment like realistic [16]. The virtual chemical lab was used to study the influence on student understanding of some basic organic chemistry laboratory techniques [17]. The diversity of models and structures for virtual laboratories is large and varies according to the nature of the project under investigation, the goals, and the technologies involved.

An alternative environment could be found in the adaptation of virtual laboratory technology, which will simulate a real laboratory environment and processes. This interactive technology delivers many advantages.

I) the possibility of making virtual practical experimentation accessible by students who cannot physically attend the actual laboratory for any reason.

II) Simulating dangerous experiments that require careful handling of incendiary or toxic chemical materials without any danger exposure.

III) Strengthening students’ ability of investigation and independent knowledge.

IV) Providing students with a high level of continuous lifetime learning where they might need to repeat the experiment as many times to comprehend the concepts well.

This paper presents and examines the development of a Virtual Organic Chemistry Laboratory (VOCL) where the learner will navigate, visualize, and simulate a real laboratory environment and processes. It represents an e-learning tool to be used after performing a virtual lab experiment. The paper organized as follows: In section 2 we elaborate on a variety of related studies in the field of VOCL while in section 3 we present the proposed work. In section 4 we discuss and compare the available Virtual organic Chemistry laboratories that suit our proposed work. Finally, in section 5 we conclude our paper.

2 Material and Methods

Previous studies have designed web-based modules that simulate laboratory assignments, and students interact with these learning modules virtually [3]. However, other studies have combined remote and local laboratories so that students can manipulate real laboratories devices by performing simulated activities with web interfaces [4]. Still, others have supported the importance
of providing students with flexible access to information on the underlying concepts behind experiments and laboratory work, intelligent tutoring systems have been developed to facilitate learning in the virtual laboratory environment [5]. In the following paragraphs, some of these virtual laboratories will be presented.

2.1 Chemistry virtual lab at Helwan University

In this site, you find some experiment with the reaction of aldehydes and ketones in Arabic Language (Fig. 1). This virtual lab aims to determine the physical and chemical properties of aldehydes and ketones. They take acetone and formaldehyde as an example for studying of some reactions of these compounds such as iodoformism test, oxidation and reduction reactions using some reagents like potassium permanganate [18].

Figure1. Chemistry Virtual lab at Helwan University

2.2 Model ChemLab

Model ChemLab originated from academic work in computer simulation and software design at McMaster University. It has continued to be developed with extensive input from instructors interested in the possible application of computer simulations for classroom and distance learning. ChemLab comes
with a range of pre-designed lab experiments for general chemistry at high school and college level. Users can expand upon the original lab set using ChemLab’s Lab Wizard development tools thus allowing for curriculum specific lab simulation development by teachers. The designer designed simulations to combine both text-based orders and the simulation into a single distributive file [19].

2.3 Value virtual labs at Amrita University

Virtual Lab at Amrita University develops smart virtual laboratories with up-to-date computer simulation technology to generate real-world environments. Problem behavior abilities are required to tie the gap between institutions (or industries) that retain the physical laboratory and distantly placed economically challenged educational institutions [20], [21]. These virtual experiments and labs will be presented for open access through the main project website [22]. Our interest is focused on the following labs.

2.4 The visual organic chemistry laboratory

This web site is planned for Chem 113A students at San Jose State University. The purpose of this website is to act as a visual lab. In addition to the current methods, by using visual means; i.e. photos, short videos, and hyperlinked flow diagrams. Learners gain visual familiarity with several organic chemistry lab techniques and tests. It is suggested that this information is studied before the beginning of each laboratory period [23].

2.5 University of Alberta undergraduate organic chemistry laboratory website

The laboratory experiments are designed to support students to advance their essential basic organic chemistry laboratory skills as well as to provide an outline for useful organic spectroscopic techniques. The data and videos on this website, in combination with laboratory lectures and sessions, are proposed to assist the student in the learning process of experimental organic chemistry [24].

Figure 2. Melting point experiment at University of Alberta
2.6 Y Science Laboratories

Y Science Laboratories is a set of realistic simulations including many disciplines including chemistry. In these laboratories, learners are positioned into a virtual atmosphere where they are free to make the selections and decisions that they would meet in the real laboratory and gain knowledge from resulting consequences. These products were produced at Brigham Young University and include the individual products of Virtual ChemLab [25].

Figure 3. The virtual organic chemistry laboratory
2.7 Web chem lab

Complete Online Chemistry Virtual Laboratories for Universities, Schools and Personalities. These Interactive Chemistry games can help Learners to know Chemical Names & Formulas easily, but they must pay $250 per school for the entire academic year. This website has four programs, our interest is in the following program [26].

![Image](image_url)

**Figure 4.** The main page

### 2.7.1 The Virtual Organic Chemistry Laboratory

This lab (Figure 3) is planned to match an introductory level organic chemistry course that is also delivered online. The instructors have the freedom to use their own notes and material to complement each lab experiment. The objective from this lab is to provide the student experience and knowledge that would approximate what they would have learned in a real lab setting [26].
3 Result

Depending on the result of the previous review, the appropriate organic virtual laboratories were selected that includes the intended experiment. Accordingly, an e-learning tool developed to facilitate the communication between students and their teachers to send the result of each experiment done by using the virtual lab tool immediately after finishing. Our proposed work main page (Figure 4) which includes the menu bar with eight options (experiment registration, equipment and tools, risk, get rid of the residue, work steps, settings, calculations, transactions and student’s performance) from which the students can select the required experiment.
Figure 6. The experiment details

Figure 5 illustrates the experiment main information report, including the experiment title, objectives, equipment and tools needed, procedure description, and the risk.

Figure 7. The experiment Risk
From the window in Figure 6 below the student can understand the experiment’s concept, objectives, and steps in detail. Figure 7 points out the risk of the experiment as theoretical background inform students to avoid any risk in real life experiment. Thus the student can understand what should be done in case dangerous reactions of organic materials are used.

Figure 8 illustrates the student’s window to answer the questions that assess the learning outcomes achievement from the experiment.

\textbf{Figure 8.} The student workspace
Figure 9 shows the student’s experiments report after he/she finished his/her work, and was ready to submit it to the teacher.
4 Discussion

Table 1 summarizes the six programs comparison, the Organic Chemistry Virtual Lab- Amrita University is the most popular one. In this lab, six experiments were found including Detection of Elements (Lassaigne’s Test) Purification by Fractional distillation, Estimation of Aspirin, Boiling Point of an Organic Compound, Melting Point of an Organic Compound, and Purification of Impure Samples by Crystallization. The missed experiments regarding our syllabus specification are Tools and equipment used in the organic chemistry lab, distinguish between aromatic and aliphatic hydrocarbons, Synthesis of Acetanilide, and Synthesis of Aspirin. The user can use the ink of this website, via Facebook, Yahoo, Gmail accounts, and others. Every experiment in this lab has complete information, including aim, the theory of experiment, self-evaluation (include some questions about the experiment), animation, assignment, references and feedback.

Organic Chemistry Laboratory Website-University of Alberta has two experiments of our syllabus trial chemical lab; one of them is melting point experiment. The other experiment was Recrystallization –Two Solvent and distillation that was presented as a video

Table 1: A comparison between the common organic chemistry virtual lab

<table>
<thead>
<tr>
<th>Field</th>
<th>No. of Experiments</th>
<th>Language</th>
<th>Easiness</th>
<th>Price</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holwan University Virtual Lab</td>
<td>6</td>
<td>Arabic</td>
<td>Moderate</td>
<td>Free</td>
<td>University Web</td>
</tr>
<tr>
<td>Model chem lab software</td>
<td>1</td>
<td>English</td>
<td>Easy</td>
<td>Not Free</td>
<td>CD and Online</td>
</tr>
<tr>
<td>Organic Chemistry Virtual Lab-Amrita</td>
<td>6</td>
<td>English</td>
<td>Easy</td>
<td>Free</td>
<td>Online</td>
</tr>
<tr>
<td>University</td>
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<tr>
<td>The visual organic chemistry laboratory</td>
<td>1</td>
<td>English</td>
<td>Difficult</td>
<td>Not Free</td>
<td>Online</td>
</tr>
<tr>
<td>University of Alberta organic chemistry</td>
<td>2</td>
<td>English</td>
<td>Easy</td>
<td>Free</td>
<td>Online</td>
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<tr>
<td>laboratory</td>
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</tr>
<tr>
<td>Web Chem Lab</td>
<td>1</td>
<td>English</td>
<td>Easy</td>
<td>Not Free</td>
<td>Online</td>
</tr>
</tbody>
</table>

The virtual lab has eight programs in the Arabic language was first proposed by Helwan University, but the experiments are less than the requirements of our course specification. This virtual lab includes some experiments
in reactions of aldehydes and ketones, which can be used in other courses like organic chemistry II.

The visual organic chemistry lab has only one Experiment: Synthesis of Aspirin in which you find the reaction equation of synthesis of aspirin, the background theoretical information of this compound, but without interaction.

5 Conclusion

This paper investigated virtual learning environments for chemistry fundamentals course as general and organic chemistry labs specifically. Virtual lab facilitates real laboratory work, due to instruments limitation or other reasons. After the comparison between the available and the most popular chemistry virtual laboratories, it is clear that Majmaah University students need an organic chemistry subject. The case study clarifies that report system enhances the virtual lab performance.

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References


Chemistry moves from in-person lab and the classroom to the computer, as working in a virtual chemistry laboratory and viewing simulations provide additional ways of learning chemistry. Simulations, Reviews & Blog Posts. MERLOT Materials: Chemistry Simulations The Multimedia Educational Resource for Learning and Online Teaching (MERLOT) at the California State University has collected descriptions and links to a huge number of chemistry simulations, with peer review ratings and comments, and information on appropriate grade levels. ChemCollective The ChemCollective, organized by a group from Carnegie Mellon, shares virtual labs, simulations, and molecular level visualizations for chemistry (See Resources by type in site’s sidebar.) In this laboratory experiment, sophomore-level organic chemistry students use a simple procedure to prepare a room-temperature liquid crystal, MBBA. The preparation can be carried out in about one hour with high yields. The students then prepare ordered samples of the liquid crystal and observe their optical properties. This exercise utilizes a fairly traditional laboratory preparation of a [Show full abstract] compound but also serves as an introduction to liquid crystals and materials chemistry. Project to develop a model organic laboratory curriculum that gives students the opportunity to be imaginative and creative by pursuing research projects in organic and polymer synthesis using a guided-discovery model. Keywords (Audience): Second-Year Undergraduate. Read more. Article. Organic Chemistry Virtual Laboratory Enhancement. The potential of virtual laboratories for distance education science teaching: reflections from the development and evaluation of a virtual chemistry laboratory. B. Dalgarno, Andrea G. Bishop, D. Bedgood. Computer Science. The VRMC is a novel VR classroom that supports immersive learning in molecular organic chemistry with haptics for multisensory learning. This is a preview of subscription content, access via your institution. Access options. Hauptman H (2010) Enhancement of spatial thinking with virtual spaces 1.0. Comput Educ 54(1):123–135. https://doi.org/10.1016/j.compedu.2009.07.013. Article Google Scholar. Merchant Z, Goetz ET, Keeney-Kennicutt W, Cifuentes L, Kwok O, Davis TJ (2013) Exploring 3-D virtual reality technology for spatial ability and chemistry achievement. J Comput Assist Learn 29(6):579–590. https://doi.org/10.1111/jcal.12018. Article Google Scholar. ChemLab comes. Organic Chemistry Virtual Laboratory Enhancement 313. with a range of pre-designed lab experiments for general chemistry at high school and college level. Organic Chemistry Virtual Lab oratory Enhancement 321. in reactions of aldehydes and ketones, whic h can b e used in other courses like organic chemistry II.