International Journal of Mathematics and
Computer Science, **15**(2020), no. 1, 309–323

Organic Chemistry Virtual Laboratory Enhancement

Sarah M. Eljack[1], Fayez Alfayez[2], Nawal M. Suleman[3]

[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

(Received May 13, 2018, Accepted April 21, 2019)

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.
AMS (MOS) Subject Classification: 97R70.
ISSN 1814-0432, 2020, http://ijmcs.future-in-tech.net

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 environment 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 deliver 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 elaborates 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 suites 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].

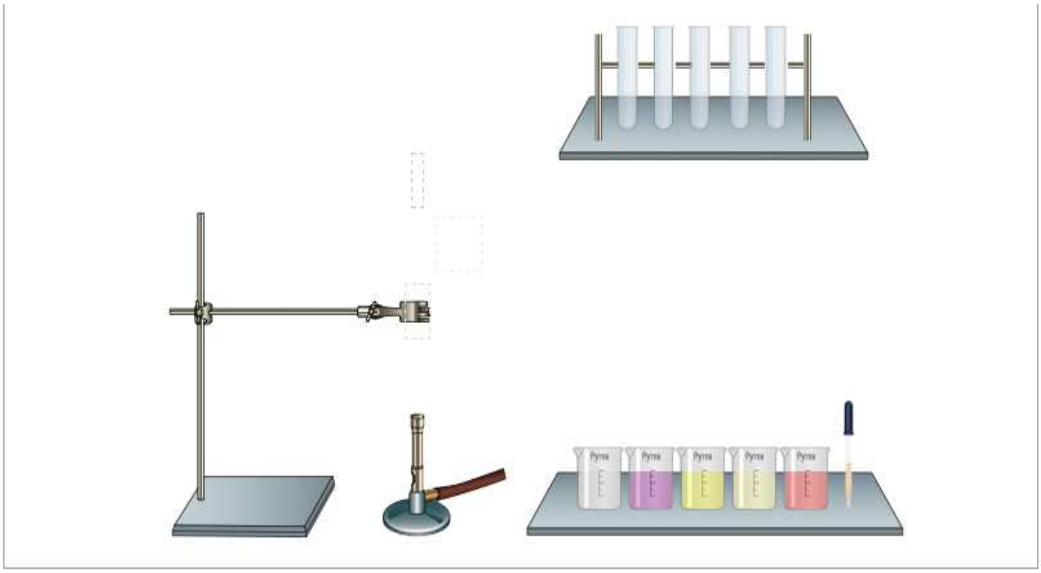


Figure1. Chemistry Virtual lab at Helwan University

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.

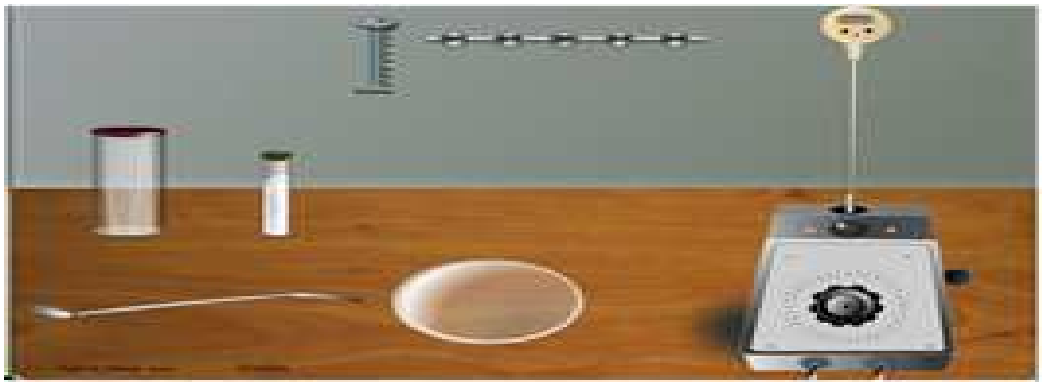
2.4 The visual organic chemistry laboratory

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]

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].

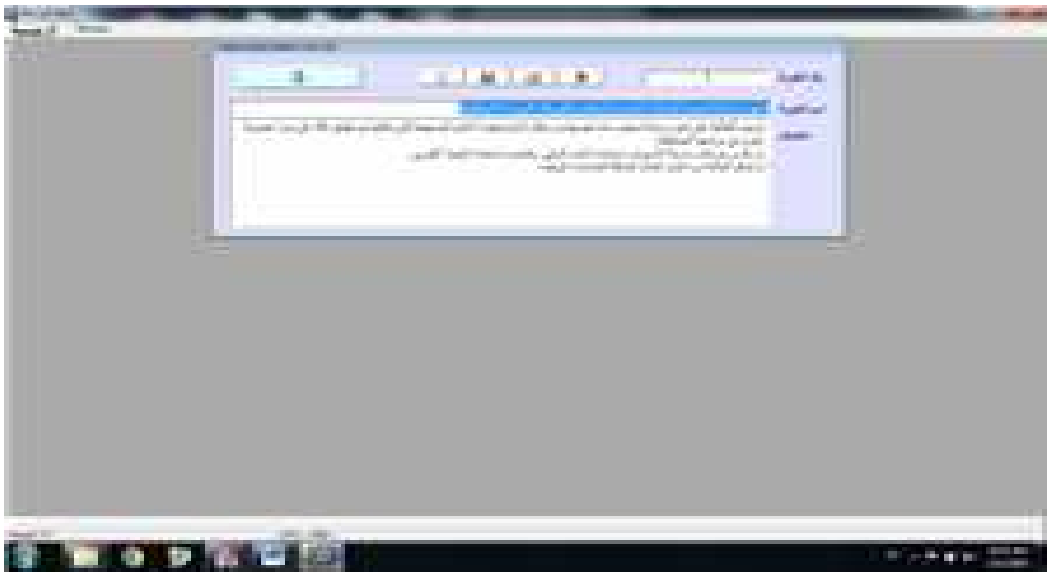


Figure 5. The experiment selection window

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.

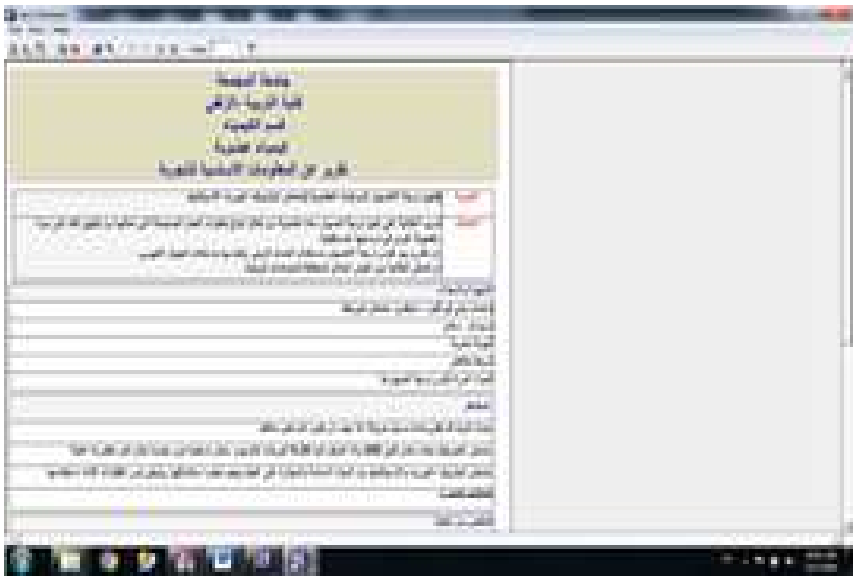


Figure 6. The experiment details

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.

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.

Figure 9. The student's experiment report

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

Field	**No. of Experiments**	**Language**	**Easiness**	**Price**	**Availability**
Holwan University Virtual Lab	0	Arabic	Moderate	Free	University Web
Model chem lab software	1	English	Easy	Not Free	CD and Online
Organic Chemistry Virtual Lab- Amrita University	6	English	Easy	Free	Online
The visual organic chemistry laboratory	1	English	Difficult	Not Free	Online
University of Alberta organic chemistry laboratory	2	English	Easy	Free	Online
Web Chem Lab	1	English	Easy	Not Free	Online

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.

Acknowledgements. The authors would like to thank the Deanship of Scientic Research at Majmaah University for supporting this work under project number No. 1440-97.

References

[1] Nataša Rizman Herga, Virtual Laboratory in the Role of Dynamic Visualisation for Better Understanding of Chemistry in Primary School, Eurasia Journal of Mathematics, Science & Technology Education, 12(3), 593-608. 2016.

[2] Z. Tatli, A. Ayas, Effect of a Virtual Chemistry Laboratory on Students' Achievement, Educational Technology & Society, **16,** no. 1, (2013), 159–170.

[3] Nataša Rizman Herga, Milena Ivanuš Grmek, Dejan Dinevski, Virtual laboratory as an element of visualization when teaching chemical contents in science class, The Turkish Online Journal of Educational Technology,**13,** no. 4, (2014), 157–165.

[4] S. Ramos, E. P. Pimentel, Maria das G. B. Marietta, W. T. Botelho Wagner T. Botelho, Hands-on and Virtual laboratories to undergraduate

Chemistry education: Toward a pedagogical integration, (FIE), IEEE 2016.

[5] Nataša Rizman Herga, Dejan Dinevski, Virtual Laboratory in Chemistry- Experimental Study of Understanding, Reproduction, and Application of Acquired Knowledge of Subject's Chemical Content, Organizacija, **45,** no. 3, (2012), 108–116.

[6] Cengiz Tüysüz1, The Effect of the Virtual Laboratory on Students' Achievement and Attitude in Chemistry, International Online Journal of Educational Sciences, **2,** no. 1, (2010), 37–53.

[7] J. Georgiou, K. Dimitropoulos, A. Manitsaris, A Virtual Reality Laboratory for Distance Education in Chemistry, International Journal of Social and Human Sciences, 1, 2007, 306–313.

[8] Huda Mohammad Babateen, The role of Virtual Laboratories in Science Education, 2011 5th International Conference on Distance Learning and Education IPCSIT, IACSIT Press, Singapore 12, 100104, (2011).

[9] Kathleen M. Hess, Lee A. Pedersen, Incorporating Chemical Information Literacy into Large Organic Chemistry Classes through the Laboratory, Chapter 6, pp 121–141, ACS Symposium Series, Vol. 1232, October 20, 2016.

[10] Zeynep Tatli, Alpaca Ayas, Virtual chemistry laboratory: effect of a constructivist learning environment, Turkish Online Journal of Distance Education, **13,** no. 1, (2012), 183–199, TOJDE.

[11] Antonios Alexiou, Christos Bouras, Eleftheria Giannaka, Virtual Laboratories In Education, 19-20, 2004.

[12] J. L. Davenport, A. Rafferty, M. J. Timms, D. Yaron, M. Karabinos, ChemVLab+: Evaluating a Virtual Lab Tutor for High School Chemistry, The Proceedings of the International Conference of the Learning Sciences. 2012

[13] M. S. Clement-Bellido, P. Martínez-Jiménez, A. Pontes-Pedrajas, J. Polo, Learning in Chemistry with Virtual Laboratories, J. Chem. Educ., **80,** no. 3, (2003), 346.

[14] B. Dalgarno, A. G. Bishop, D. R. Bedgood Jr., The potential of virtual laboratories for distance education science teaching: reflections from the development and evaluation of a virtual chemistry laboratory, UniServe Science Conference proceedings, 2003.

[15] Z. Tatli, A. Ayas, Effect of a Virtual Chemistry Laboratory on Students' Achievement, Technology & Society, **16,** no. 1, 159–170.

[16] Ogot, Elliot and Gulmac, 2003; Sivakumar, Robertson, Artimy, & Aslam, 2005; Spanis & Atti, 2005.

[17] S. Vaidyanathan, J. Williams, M. Hilliard, T. Wiesner, The development and deployment of virtual unit operations laboratory, In Chemical Engineering Education, 2007, 144–152.

[18] http://vlab-chem.com/index/0, Accessed Jan. 2018.

[19] http://www.modelscience.com/products.html

[20] http://vlab.amrita.edu/index.php?sub=1, Accessed August 19, 2016.

[21] http://vlab.amrita.edu/index.php, Accessed September 1, 2016.

[22] http://vlab.amrita.edu/index.php?sub=2&brch=191, Accessed September 1, 2016.

[23] http://www.chemistry.sjsu.edu/straus/visioche.htm, Accessed September 10, 2016.

[24] https://sites.google.com/a/ualberta.ca/organic-chemistry-laboratory-website, Accessed October 10, 2016.

[25] http://yscience.byu.edu/, Accessed October 12, 2016.

[26] http://www.chem.ox.ac.uk/vrchemistry/, Accessed October 20, 2016.