p-ISSN 2549-9947
e-ISSN 2614-1426
IJCER doi: 10.20885/ijcer.vol4.iss2.art4

Virtual Laboratory in Chemistry: Recent Information and Communication Technologies (ICT) in Chemistry Practical Course

Imam Sahroni[a,*], Wiyogo Prio Wicaksono[a], Maisari Utami[a], Lutfia Isna Ardhayanti[b]

[a] *Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Islam Indonesia, Yogyakarta, Indonesia*

[b]*Department of Environmental Engineering, Faculty of Civil Engineering and Planning, Universitas Islam Indonesia, Yogyakarta, Indonesia*

**Corresponding author: sahroni@uii.ac.id*

Received: October 1, 2020; Accepted: October 15, 2020; Published: November 3, 2020

ABSTRACT: The covid-19 has impacted many sectors to change how they run their activity, including the learning and teaching activity at higher education. Many departments at the educational institution have been affected seriously due to the physical laboratory closing, especially for the chemistry laboratory activity. The physical laboratory has been transformed into the online laboratory or distance laboratory to accommodate the student to study the experimental course. Using the Information and Communication Technology (ICT) innovation in teaching and learning methods, the student can still experiment and continue the lecture through the online system. In this mini review, we will review the recent ICT application that may contribute to providing the chemistry practical course activities to support online studies. We focus on providing the role of digital tools, such as online video conferences, virtual laboratory and these combinations as an alternative to teach chemical experiments. Finally, This effort may help the lecturer, instructor, and the student choose the best method to play an active role even while participating in the learning process.

Keywords: virtual laboratory, Information and Communication Technology (ICT), chemistry, teaching, learning method

INTRODUCTION

The Corona Virus Disease 2019 (Covid-19) pandemic that is befalling the world today forces us to change the entire order of life that we have lived so far. All sectors of activity have felt the impact of Covid-19, including the education sector. Through concerning Implementation of Education Policies in an Emergency for the Spread of Covid-19, the Ministry of Education in every country issued an appeal to learn from home with an online learning system[1]. As a response to this issue, the readiness of educators and students at the Higher Education level is the main thing that must be considered. Changing a physical learning system into an online learning system requires careful preparation, especially in the practical course[2, 3]. The student needs the physical laboratory to do the experiment to get the specific skill based on their study program.

Before covid pandemic happens, chemistry educators have already created the online learning media for the practical course such as computational chemistry as the simulation and virtual laboratory as the supplementary data to support the experiment in the laboratory[4, 5]. However, the number of sudents who have used those digital media for their learning process to replace the laboratory's physical activities is very low. One of the main reasons is the online media's reality for chemistry. The student must handle the real apparatus, equipments, and also chemicals to know their function in the practical course.

The importance of getting knowledge of the laboratory activities is the main consideration in the practical course. To overcome this issue, we discuss the recent Information and Communication

Technology (ICT) innovation in teaching and learning methods to provide some approaches to providing the online laboratory for practical chemistry courses during covid pandemic and post pandemic. The combination between ICT and internet development have been implemented deeply in chemistry study program to strengthen the comprehension of chemistry concepts, students' attitudes and interests, and other skill achievements [2, 5-7].

This mini review provides detailed insight for the chemistry educators and the students, from the early, middle, and the last grade in Higher Education level, to prepare and do chemistry laboratory activities during online chemistry practical course. We will highlight some of the online activities and good methods that possibly supported to achieve the students' learning outcome in the practical course as mentioned by Reid (i. skill related to chemistry learning, ii. practical skill, iii. scientific skills, iv. general and transferrable skills.) [8, 9].

The Updated Information and Communication Technologies (ICT) in Chemistry

Incorporating Information, Communication, and Technology (ICT) in the chemistry study program usually uses computer-based communication into learning and teaching. The chemistry educators use the program or application to predict, analyze, and simulation for the chemical reaction to support their teaching media. This effort aims to help the student better understand some of the course, i.e., organic chemistry, chemical kinetic, chemical instrumentation, etc. They are expected to be the key participant in using ICT to deliver the materials to the students in achieving the learning outcome [10]. Some researchers suggested that the chemistry educators who used the ICT to support their teaching methods are more effective than those who only used conventional teaching methods (seldom used the integration of internet and technology [11-13].

It is noteworthy that chemistry educators' readiness and skills in using ICT are very important in using ICT in the lecture. Osborne and Hennessy [14] suggested to the educators to effectively used the ICT in chemistry learning activities:

1) Verifying that ICT use is relevant and enrich to the chemistry lectures,
2) Designing the activity to presenting students responsibility and opportunities for the active learning,
3) Encourage the students to think about new concepts, to actively engage in discussions, and to focus on research tasks
4) Connect the integration of ICT to teaching and learning activities so that it encourages students to share their ideas and findings
5) Find the readiness of the students in using the ICT for their learning methods

The application of ICT in chemistry lecture has gain many advantages for the students[15]. The student's profile in the 21th century has been changed on how they learn the chemistry. The young generation now refers to using the smartphone, iPad, tablet, or electronic pen to make the note on the lecture instead of using the traditional pen-based ink and traditional book [16]. They also used the e-platforms to search for the chemical information through online database such as youtube, google, and website related to chemistry. The application and programs for ICT-based learning applications for the young generation has become new learning tools and important needs in the chemistry program [17]. The students can access the chemistry information through online media whenever and wherever they want.

ICT supported achieving the learning outcome in the chemistry curriculum whether its theoretical skills or practical laboratory skills. ICT enables the comprehensive visualization contents that ease the student to fully understand the concept of some chemistry courses, especially in the practical course. To up to date, students now prefer to use programs like ChemDraw or ChemSketch to draw the compound's chemical structure compared to drawing in conventional paper or on the board using chalk.

The students can use chemical programs to study more information like 2D and 3D chemical structure, chemical properties, with characterization of its spectra, or even predict the result of chemical reaction [18]. However, based on our experience teaching the chemistry practical course, the chemistry educators still use the conventional physical laboratory activities, i.e. face-to-face meeting and hand-on with chemicals and instruments. But, suddenly all learning methods and approach for the practical course change 360 degree due to COVID-19 pandemic. They can not use the physical laboratory for the students to do the experiment directly to achieve the learning outcomes.

Chemistry Laboratory at Distance

Preparing the chemistry laboratory for the practical courses at a distance needs to pay more attention for chemistry educators and students. It is not easy to convert the physical face-to-face laboratory work to online laboratory work at a distance. But currently, the advanced digital technologies and the easiness of using the internet give the advantages for doing chemistry experiment although it is at the distance. The digital platform on e-laboratory, usually called by virtual laboratory, consists of figures and tables supporting the video and effortless discussion between the educators and the students. In addition, it is also more feasible compared to the physical laboratory.

Some institutions and universities have implemented the ICT to the online-based lecture even before pandemic happens [19-22]. Nais used the virtual chemistry laboratory (virtual chem-lab) and integrated it into blended learning on chemical bonding lecture [23]. Ratamun and Osman studied the effectiveness of virtual and physical laboratories when implemented in High School in Malaysia [24, 25]. It was noteworthy that the virtual laboratory would be a good program for the students to do and understand the laboratory work with no mistakes and problems.

This mini review is delimited to detailed study of ICT integration on preparing the virtual laboratory, how to start our own virtual laboratory to the chemistry practical course, and how the virtual laboratory can help the student achieve the learning outcome from the laboratory work.

Virtual Laboratory

In this section, we discuss more how do we develop the virtual laboratory for the chemistry practical course. Most of the chemical educators prepared the virtual laboratory based on the Kemp's Model. The Kemp's Model are posted at the list as follows:

1) Identify instructional problem
2) Identify student characteristics
3) Task analysis
4) Determine instructional objectives
5) Determine content sequencing
6) Determine instructional strategies
7) Planning messages in learning
8) Planning the ways to deliver content
9) Develop evaluation instrument

To develop and prepare our own virtual laboratory we can choose, from the Kemp's Model, which one is suitable for our practical course. Chemical educators need to built the storybroad before deciding to further convert all the information and content into multimedia or digital tools. Figure 1. Describe the step for preparing the virtual laboratory for the practical course.

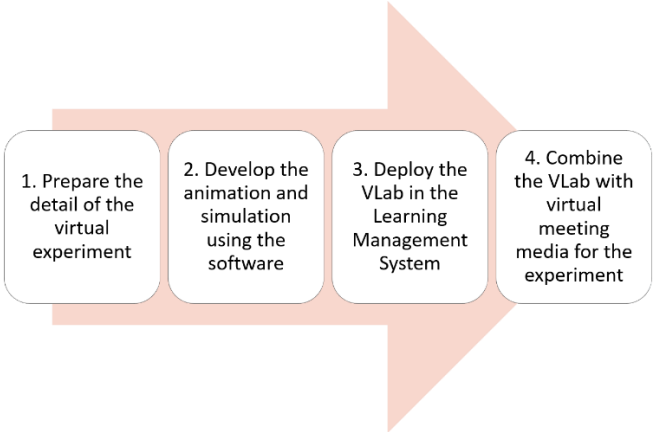

Figure 1. The step for preparing the Experiment based on Virtual Lab

Step 1: Prepare the detail of the virtual laboratory.

This step is crucial due to the design and storyboard of the product. The chemistry educators need to identify the title of the experiment for the syllabus, module, and the learning outcome of the practical course. The storyboard itself will determine how much time to convert the whole story of the design into digital tools. The storyboard's composition usually includes an introduction, materials and methods, experiments, discussion, results, and summary. Other than the composition of the storyboard, we can use more points from the Kemp's Model.

Step 2: Develop the animation and simulation using the software.

Using the virtual laboratory rather than the physical laboratory in practical chemistry courses must pay attention to the visualization of the animation and simulation of the chemical reaction prediction. In chemistry, the visualizations generate the students' understanding of the concept of modelling. The model and modelling are used as tools to make a hypothesis, descriptions, processes, and evidence of chemical reaction [26]. This model connects the knowledge from the theoretical and practical courses.

Step 3: Deploy the virtual laboratory in the Learning Management System (LMS)

The digital tools that have been created must be accessed by the students easily. Deployment and integration of the ICT with the internet server become essential to ensure that the storyboard has been inserted in the media. Each university must provide a good Learning Management System that can be used to deploy the media later this LMS. The student will be familiar with the system, and they can use it any time, anywhere, and there is no restriction for the student to access the LMS.

Step 4: Combine virtual laboratory with virtual meeting media conference.

We realize that the virtual laboratory can change the physical laboratory in conducting practical courses. But, the face-to-face meeting between the educators, the tutors and the student is still essential. Therefore, the virtual laboratory needs to combine with the virtual meeting media conference such as zoom meeting, google meeting, skype, etc. Figure 2. Shows the general scheme for combining the virtual laboratory with the virtual meeting media. When performing the virtual laboratory, the student must accompany the educator's assistant to explain what phenomena happen when they do the experiment virtually.

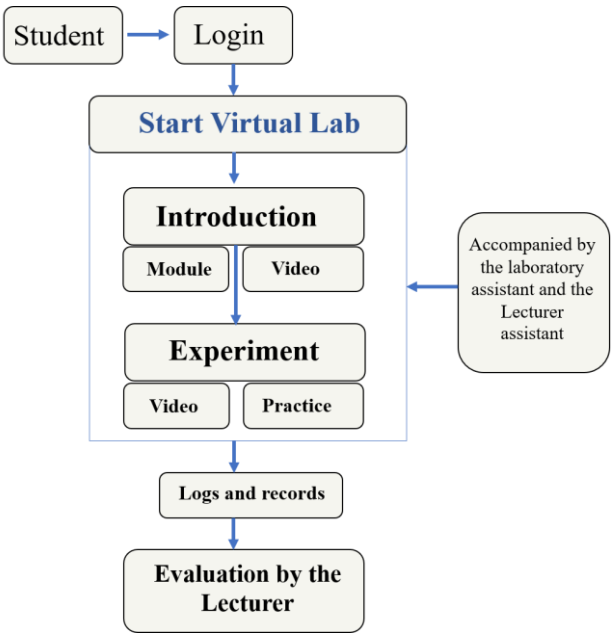

Figure 2. General Scheme for Chemistry Practical Course using Virtual Lab

Future Trends

The rapid development of technology in chemistry for the visualization and simulation and the major drives like Covid-19 pandemic directly changed the way we perform the practical chemistry course. Although many academicians suffer from the pandemic condition, there are still many rooms and opportunities to develop the novel virtual laboratory for the practical course. Virtual laboratory acts as the supplementary tools to achieve the learning outcome and the primary activities on gaining scientific knowledge and practical skill in chemistry. The chemical educators can enlarge the role of the virtual laboratory and specifically put it on the title of the practical course. Finally, university citizens need to improve significantly for the quality of education at the higher education level. As a result, they are ready to perform any education model that will be happening in the future.

SUMMARY

The internet and communication technology (ICT) innovation can be one of the solution to conduction online and virtual laboratory activity. The virtual laboratory can provide the alternative solution for the experimental course in a higher education during covid-19 pandemic. By using the virtual laboratory, the students can feel the atmosphere as if they are doing an actual experiment in the laboratory. This effort help the student to actively engage the activity and complete the experimental course.

ACKNOWLEDGMENT

Authors would like to express appreciation for the support from the Directorate of Academic Development (DPA), Universitas Islam Indonesia through Hibah Pengembangan Pembelajaran Odd Semester 2020/2021, grant number: 2648/WR.I/01/DPA/IX/2020.

REFERENCES

1. C. L. Dunnagan and M. T. Gallardo-Williams, Journal of Chemical Education **97** (9), 3060-3063 (2020).
2. R. Radhamani, D. Kumar, N. Nizar, K. Achuthan, B. Nair and S. Diwakar, Education and Information Technologies **26** (6), 7477-7495 (2021).
3. R. Vasiliadou, Biochemistry and Molecular Biology Education **48** (5), 482-483 (2020).
4. N. Wilde and A. Hsu, International Journal of Educational Technology in Higher Education **16** (1) (2019).
5. X. Duan, S.-J. Kang, J. I. Choi and S. K. Kim, KSII Transactions on Internet and Information Systems (TIIS) **14** (4), 1673-1688 (2020).
6. N. Fitriyana, A. Wiyarsi, J. Ikhsan and K. H. Sugiyarto, Journal of Physics: Conference Series **1097**, 012064 (2018).
7. S. Ghavifekr and W. A. W. Rosdy, International Journal of Research in Education and Science **1** (2), 175-191 (2015).
8. J. Carnduff and N. Reid, *Enhancing undergraduate chemistry laboratories: pre-laboratory and post-laboratory exercises*. (Royal Society of Chemistry, 2003).
9. N. Reid and I. Shah, Chemistry Education Research and Practice **8** (2), 172-185 (2007).
10. O. Edvard Hatlevik and H. Christian Arnseth, Nordic Journal of Digital Literacy **7** (1), 55-69 (2012).
11. A. Winzenried, B. Dalgarno and J. Tinkler, Australasian Journal of Educational Technology **26** (4) (2010).
12. G. Finger, G. Russell, R. Jamieson-Proctor and N. Russell, *Transforming learning with ICT: making IT happen!* (Pearson Education Australia, 2007).
13. R. Jamieson-Proctor, in *Research Conference 2018 - Teaching practices that make a difference: Insights from research* (Australian Council for Educational Research (ACER), Melbourne, Australia, 2018).
14. J. Osborne and S. Hennessy, *Literature review in science education and the role of ICT: Promise,*

problems and future directions. (Futurelab London, United Kingdom, 2003).
15. J. Pernaa and M. Aksela, Problems of Education in the 21st Century (2009).
16. R. K. Dewi, S. Wardani, N. Wijayati and W. Sumarni, International Journal of Evaluation and Research in Education **8** (2), 265-270 (2019).
17. M.-H. Lin and H.-g. Chen, Eurasia Journal of Mathematics, Science and Technology Education **13** (7), 3553-3564 (2017).
18. W. Yu and L. Chen, Int. J. Educ. Manag. Eng **2** (12), 73-77 (2013).
19. K. Aljuhani, M. Sonbul, M. Althabiti and M. Meccawy, Smart Learning Environments **5** (1), 1-13 (2018).
20. P. Jagodziński and R. Wolski, Journal of Science Education and Technology **24** (1), 16-28 (2015).
21. S. Ramos, E. P. Pimentel, B. M. Maria das Graças and W. T. Botelho, presented at the IEEE Frontiers in Education Conference (FIE), 2016 (unpublished).
22. R. Wolski and P. Jagodziński, British Journal of Educational Technology **50** (1), 218-231 (2019).
23. M. K. Nais, K. H. Sugiyarto and J. Ikhsan, 2019 (unpublished).
24. M. M. Ratamun and K. Osman, Creative Education **9** (09), 1411 (2018).
25. M. M. Ratamun and K. Osman, Problems of Education in the 21st Century **76** (4), 544 (2018).
26. R. S. Justi and J. K. Gilbert, International Journal of science education **24** (4), 369-387 (2002).