JPPIPA 9(10) (2023)

Jurnal Penelitian Pendidikan IPA
Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Literature Review of Online Learning Technology in Chemistry Lab Activities

Riva Ismawati[1*], Arif Widiyatmoko[2], Adi Nur Cahyono[2]

[1] Science Education Undergraduate Study Program, Universitas Tidar, Magelang, Indonesia.
[2] Science Education Doctoral Program, Universitas Negeri Semarang, Semarang, Indonesia

Received: April 12, 2023
Revised: September 15, 2023
Accepted: Octoober 25, 2023
Published: October 31, 2023

Corresponding Author:
Riva Ismawati
rivaismawati@untidar.ac.id

DOI: 10.29303/jppipa.v9i10.3635

Abstract: Chemistry learning is inseparable from lab activities. Strengthening scientific concepts, skills and attitudes go through some experiments. Online learning is a consequence of the Covid 19 pandemic. It is a must option to make sure that students do not lose knowledge and skills causing academic setbacks. Online learning technology does not only aim to convey theoretical materials but also facilitates lab activities. This article tries to identify online learning technology applied to support activities in chemical laboratories and identify the advantages and disadvantages of their applications. This researcher writes this paper based on a review of the literature collected using the ERIC search. There are 17 selected readings reviewed manually. The analysis results show that Zoom meetings, video conferencing platforms, and the DryLab20 network technology are useful for synchronous laboratory learning. Video experiments, simulations, online modules, web-assign, Schoology, formative, Canva, and learning management systems can be used for asynchronous laboratory learning. There is a possibility of combining synchronous-asynchronous laboratory learning programs. Online laboratory learning has advantages in visualizing laboratory activities even though it cannot yet practice the skills acquired in real laboratories. There should be deep considerations regarding the use of online learning technology in laboratories after the pandemic regarding its advantages and disadvantages.

Keywords: Chemical experiment; Laboratory; Online learning

Introduction

Laboratory activities are a significant part of chemistry learning. There have been considerations for involving laboratory activities in chemistry learning from the 1980s until the last few years (DeKorver & Towns, 2015; Seery et al., 2019). There are so many studies on activities in chemical laboratories. Many practitioners encourage lab activities for students. Student reflection on their experiences is the main factor in designing proper activities in the laboratory (Seery et al., 2019).

The Covid-19 pandemic hit suddenly as a global threat and had many negative impacts on human individuals and social life. During the pandemic, there must be remote and restricted social interactions. Schools and universities have shifted their face-to-face conventional to distance learning by utilizing educational digital platforms and technology (Campbell et al., 2020). Distance learning runs without any direct meetings between educators and students. The implementation of distance learning emphasizes independent learning. There should be appropriate learning techniques in designing and conveying the materials and activities. It is also necessary to organize good communication between educators and students (Abidin et al., 2020). Interaction in distance learning can be through recordings, audio and video teleconferences, multimedia, and written correspondence (Yeşİloğlu et al., 2021). Meanwhile, online learning is one kind of distance learning that requires a strong internet network

How to Cite:
Ismawati, R., Widiyatmoko, A., & Cahyono, A.N. (2023). Literature Review of Online Learning Technology in Chemistry Lab Activities. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 751–759. https://doi.org/10.29303/jppipa.v9i10.3635

to perform many types of learning interactions (Fikri et al., 2021).

All educational levels must be able to adapt to online learning. People think that universities can adjust themselves easily to remote learning during the pandemic. It is because they have been familiar with online learning (Rudenko et al., 2020). This is not entirely true, considering that there are several types of classes such as lectures, tutorials, workshops, laboratories, and fieldwork works that can run more effectively in direct meetings (Yeşİloğlu et al., 2021).

Before the pandemic, there had never been a sudden and large transition that disrupted students' learning in the chemistry laboratory. Many educators find it an uphill task to provide online laboratory experiences concerning pedagogical goals and actively involve the students (Tran et al., 2020). Chemistry learning must be able to provide valuable laboratory experience within pandemic constraints (Holme, 2020). Chemistry educators face many issues in carrying out activities in the laboratory due to the rapid transition from direct to remote learning (Tran et al., 2020).

Research related to effective learning in laboratories, which was originally the best, is now receiving increasing attention (Bretz, 2019; Cooper & Stowe, 2018; Eubanks, 2015). This is in line with the argument that ineffective laboratory learning may be due to inappropriate skills or learning design (Hancock & Hollamby, 2020; Hensen & Barbera, 2019; Seery, 2020; Walker et al., 2016) as well as reports that virtual laboratory experiences can achieve the same learning goals (Dunnagan et al., 2020; Ferrell et al., 2019; Makransky et al., 2019; Winkelmann et al., 2017).

The Covid-19 pandemic has ended and most of the learning activities at schools have been carried out normally as they were. Even so, educators continue to utilize technology and online learning media to make a more varied and interesting atmosphere for the students. It also makes them active, independent, and creative (Widyasari, 2022) through hybrid learning (Lapitan et al., 2021).

Budai & Kuczmann (2018) explained that online laboratory activities can run in the form of remote and virtual laboratories. Remote laboratories facilitate the students to conduct experiments in real-time supported by the internet. Meanwhile, in the virtual laboratories, the students simulate experiments using special software. Both methods can unite into a learning management system (LMS). The LMS can control user access and ensure that learning resources are presented under the same conditions (Ruano et al., 2016). (Yeşİloğlu et al., 2021) have also used images and videos in online learning in the chemistry laboratory.

There have been many studies examining the use of online learning technology in activities in chemical laboratories. However, there are no articles that review these studies. Previous research needs to be summarized to provide teachers with a description of online learning technology that can support activities in the laboratory as an effort to overcome the limitations of equipment and materials in the laboratory, as well as explaining the research that has been carried out. This article aims to determine the online learning technology that has been used to support learning activities in the chemistry laboratory and to review the advantages and disadvantages of this online learning technology.

Method

This paper is prepared based on a literature review through an explicit and systematic mapping of thinking with the boundaries of knowledge (Tranfield et al., 2003), explicitly and systematically (Garza-Reyes, 2015). The following figure briefly presents the research method:

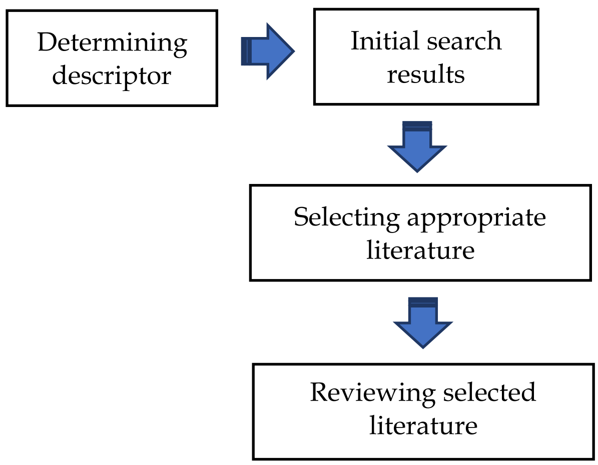

Figure 1. Stages of Literature Review

The literature reviews are carried out in February 2023 with the ERIC's search sources. The descriptors consist of online courses in chemistry since 2019. The initial search results select the most appropriate literature for this research. Next, there are 17 selected kinds of literature to be studied in depth, and the information obtained is compiled into a text.

Result and Discussion

Online Learning Technologies in Chemistry Laboratories

Table 1 shows that online chemistry laboratory learning can be done synchronously, asynchronously, or in a synchronous-asynchronous mixture.

Synchronous learning

Synchronous learning gathers the educators and the students at one time by utilizing the internet network. It has the same system as traditional classroom learning because educators and students can interact directly through cyberspace. The media used in synchronous learning include video conferencing, Google Meet, and Zoom meetings (Sulistio, 2021; Firman et al., 2021; Ramadhan et al., 2022). The use of synchronous learning does not only support learning in the classroom but also the laboratory.

Bruce et al. (2021) designed distance learning related to activities in the chemical laboratory. The students carry out all laboratory activities synchronously in the Zoom virtual lab room. They simplified experiments in real laboratories using simple tools and materials around the students' environments. Experiments using UV-VIS and FTIR use Arduino-based instruments that can be made at home. Campbell et al., (2020) also developed synchronous laboratory learning using the DryLab20 network technology. This software contains a breakout room according to the main branch of the chemistry subject. The breakout room is useful for having discussions according to interest groups.

Davy & Quane (2021) utilized narrative laboratories in teaching real-time laboratories online. They turned the face-to-face laboratory experience into a written document with text, images, and pictures that describe the setup, process, results, and calculations of the experiment. They used videos recorded from a secondary computer at a separate location using the online Zoom platform. The narrative laboratories with instructor videos require texts to explain or describe certain situations. For example, describing changes in temperature during acid/base titrations should add necessary text in the video.

Table 1. Online learning technology in the chemistry laboratory

Online learning technology	Materials
Phet simulation combined with Screencast (Vandenplas et al., 2021)	Bond energy and intermolecular attractions
Virtual Zoom laboratory (Bruce et al., 2021)	a. Measurement and calibration b. Introduction to the investigation c. Polymers and cross-links d. Paper chromatography e. Precipitation and COM (filtration system) f. Solution heating g. Spectroscopy
WebAssign, Schoology, Formative, PowerSchool, Zoom (Kelley, 2020)	Making rock candy and popping balloons
Zoom and Cavas (Baker et al., 2020)	Physical chemistry practicum
The virtual learning platform, YouTube, EZGC Pro chromatogram online simulation modeling, laboratory simulation program, Web Chromedia (Valle-Suárez et al., 2020)	a. Spectroscopy technique b. Chromatographic technique c. Engineering applications
Learning Manajement System (LMS) (Simon et al., 2020)	a. Chemical terms, chemical/physical changes, atomic theory, forensic chemistry b. Conservation of mass, theory of chemical bonds, food chemistry c. pH, chemical equilibrium, medical chemistry, cosmetic chemistry d. Ideal and real gases, nanochemistry, polymers, chemistry, and sports e. Environmental chemistry, spectroscopy, and astrochemistry
Emergency Remote Teaching (ERT) Chemical Experimentation uses a multimodal laboratory included in the Course Management System (CMS) (Sandi-Urena, 2020)	a. Lavoisier's combustion experiment b. Electroscope construction c. Periodic table d. Composition of the $NaHCO_3/Na_2CO_3$ mixture e. Measurement f. Separation g. Density h. Manufacture of acid-base indicators and pH of household materials i. Acid-base titration simulation j. Calorimeter simulation and heating curve demo k. Gravimetric analysis of chloride solutions
IONiC (Interactive Online Network of Inorganic Chemists), WebMO installed on TCNJ's Electronic Laboratory for Science and Analysis	General chemistry 1 & 2, analytical chemistry, organic chemistry 2, quantum chemistry, environmentally

Online learning technology	Materials
(ELSA), LabFlow (www.labflow.com), Google meet, Zoom LMS (Chan et al., 2020)	friendly and sustainable chemistry, and independent research
DryLabs20 (Campbell et al., 2020)	Organic chemistry, inorganic chemistry, physical chemistry, analytical chemistry
enzlab Simulation (Worrall et al., 2020)	Enzyme reaction kinetics
Synchronous Online Delivery (SOD) uses a video conferencing platform (VCP), ChemCollective Simulation, PhET, WebMO, and videos from YouTube integrated into SOD (Jones et al., 2021)	Introduction to chemistry
Zoom with the narrative lab in the form of a video experiment (Davy & Quane, 2021)	Titration, synthesis of compounds, and purification of substances
Synchronous online laboratory and LMS (Tran et al., 2020)	Organic and analytical chemistry
Blackboard collaborate ultra is integrated into LMS, Webex zoom, google drive, zoom, and Snapchat (Buchberger et al., 2020)	Analytical Chemistry
Learning and Content Management System (LCMS) (Yeşİloğlu et al., 2021)	General chemistry, analytical chemistry II, organic chemistry II
The online lab is based on a Raspberry Pi with a webcam and servo (Soong et al., 2021)	Titration
Online Module, LMS (Mahaffey, 2020)	Heat capacity

Asynchronous learning

Asynchronous learning is different from synchronous one. In synchronous learning, educators and students are at different times. In this case, the students have flexible time in accessing information and materials provided by the educators (Ismiyarti et al., 2021; Muyassaroh et al., 2022; Sulistio, 2021). The following sections explain the online learning technology in learning in the chemistry laboratory.

Vandenplas et al. (2021) studied the use of Phet simulations combined with Screencasts narrated by an expert. The results showed that the Screencast treatment did not have a significant impact on reducing cognitive load. However, the teachers can introduce new topics through simulations or Screencast assignments. The students can gain precious experiences that allow them to make observations and collect data. Therefore, they can align various understandings and compile scientifically accurate explanations.

Valle-Suárez et al. (2020) combined several media in online learning in instrumental analytical chemistry I, instrumental analytical chemistry II, and drug analysis courses. They used a virtual learning platform provided by the university combined with learning strategies adapted to the type of content and learning objectives. Some videos from YouTube and websites related to technical notes from providers of tools and materials support the learning of experimental procedures. For example, in teaching the analysis of pesticides on soil samples using gas chromatography, online videos are the media to explain the techniques and basic operations of gas chromatography. Pro EZGC chromatogram modeling online simulation is used in explaining compound separation experiments. The content of the Chromedia website and the NIST chromatogram generator can evaluate the student's understanding of the basic concepts of chromatography. The results show that online learning technology can reduce the percentage of students who fail these three courses. The average learning outcomes are better than that conducted through face-to-face learning. This is because the teaching and learning process is more individual and personal.

Simon et al. (2020) conducted online chemistry learning for non-chemistry students. They utilized the LMS to deliver materials and carry out assessments centered on laboratory activities. The assessment includes reading quizzes, reflection on laboratory projects, and participation. The readings are in the form of teacher notes and YouTube videos that contain quizzes to measure conceptual understanding of the reading. Project reflection is in the form of a laboratory activity report that consists of data and observation tables, questions, and reflection assignments. The students also hold discussions and provide feedback as a form of participation.

The Learning and Content Management System (LCMS) is useful for learning in the chemistry laboratory (Yeşİloğlu et al., 2021). Online laboratory courses start with the delivery of theories using PowerPoint and web applications like Whiteboard. Next, the lecturer displays a video related to the experiment on the video-sharing platform. The lecturer explains the media and materials used in the experiments and emphasizes the experimental process. The students make observations and predictions related to the experiments. The experimental results are discussed after the video has been presented.

Mahaffey (2020) used online practices using the LMS modules. The students can work on experiments using the internet network in the online module. They must complete a pre-test and post-test quizzes, have discussions, and submit reports through the LMS. The Raspberry Pi online lab equipped with a webcam and servo can also teach and explain titration practices (Soong et al., 2021). Remote titration experiment uses some laboratory skills, thereby enabling other follow-up experiments. Titration over the internet has great potential to address accessibility issues

Worrall et al. (2020) developed the Enzlab simulation technology. It is a web-based application (*Javascript-AngularJS*) for simulating the kinetics of enzyme reactions. The simulation is more accurate and realistic than the original and has a capacity of 1,2 x 10^6different enzymes. It does not require downloading any software. The use of this simulation has proven to be successful as an exercise that the students can do at home.

Synchronous-asynchronous learning

Synchronous-asynchronous learning means learning that combines synchronous (direct meetings) and asynchronous learning (teachers and students are not in one meeting). The researcher has also developed a combination of synchronous-asynchronous learning (Mamahit, 2021).

Sandi-Urena (2020) applied the distance learning method to develop students' non-technical experimental skills and scientific practice. They implemented Emergency Remote Teaching (ERT) Chemical Experimentation using a Multimodal Laboratory included in the Course Management System (CMS). There are some kinds of learning assignments like problem-based projects and prescriptive online simulations. The students must complete the tasks asynchronously while discussions are carried out synchronously with a longer duration. During the learning, there are online modules provided related to learning topics. Educators supervise the students to make sure they stay focused on learning.

Kelley (2020) designed a chemistry laboratory learning by utilizing Zoom combined with some media like Webassign, Shcoology, and Formative. Webassign and Shcoology aim to distribute assignments and learning materials. The formative is to collect quiz and test results. Zoom functions for having synchronous question and answer and reflection discussions. The experiment is carried out by the students at home. In providing experimental materials, the students receive materials from the school (experiment 19) and work on practicum materials themselves (Experiment 20).

Synchronous zoom and asynchronous Canvas learning has been utilized in the implementation of the physics-chemistry practicum (Baker et al., 2020). Zoom aims to display experimental videos, discuss answers to lab questions, and assist the students in solving problems. Canvas helps the teachers to upload trial instructions and quiz questions and helps the students to upload quiz results before trials and send learning results. The students discuss their home works in synchronous learning. This concept can reinforce concepts in learning. The t-test results show no significant differences in communication skills, error analysis, data processing, and acquisition of interpretation of experimental reports during online and face-to-face learning

Chan et al. (2020) used different media for teaching chemical experiments, including IONiC (Interactive Online Network of Inorganic Chemists), WebMO installed on the Electronic Laboratory for Science and Analysis (ELSA), LabFlow (www.labflow.com), Google Meet, Zoom, and LMS. Technology selection varies by materials. Synchronous online meetings aim to facilitate group work. They are also space for the students to ask questions. Teachers create pre-class videos and reading assignments to create active learning time without compromising content.

Jones et al. (2021) applied synchronous online delivery (SOD) using a video conferencing platform (VCP) in laboratory teaching. They also used ChemCollective, PhET, and WebMO simulations for experiments supplemented with videos from YouTube. The students are divided into breakout rooms to complete simulation-based laboratory activities and return to the main room for in-class discussions.

Tran et al. (2020) used synchronous and asynchronous laboratory learning. Experimental video recordings and materials are uploaded to the LMS for organic laboratory activities. In analytical laboratory activities, the lecturers provide some notes, reading materials, and data that students will use in calculations. They found it difficult to make video experiments for the analytical laboratory because the experiments in the lab may take 3-5 hours long. The students can attend synchronous lectures, access online content, and submit assignments seamlessly and asynchronously.

Buchberger et al. (2020) transitioned projects in the analytical laboratory to online learning. Online learning activities focus on assessing the data obtained in face-to-face laboratory activities. They utilized Zoom combined with other media like Blackboard Collaborate Ultra integrated into LMS, Webexzom, Google Drive, and SnapChat.

Advantages and Disadvantages of Online Learning in the Chemistry Laboratory

Online learning plays a vital role during the Covid-19 pandemic. This includes learning in the chemistry laboratory. Even though the pandemic is over, online laboratory learning can still be carried out by considering the advantages and disadvantages. Online laboratory learning does not limit the students from conducting experiments directly at home (Bruce et al., 2021; Kelley, 2020). Direct experiments at home can help them visualize and improve their understanding of chemical interactions (Bruce et al., 2021). The students can also prepare work schedules independently (Kelley, 2020). However, experiments at home have problems the students cannot ask for help and see what their friends are doing, as well is the risk of using hazardous materials. Also, not all students get the materials they need for experiments, and it is difficult to use large kitchen equipment to handle small amounts of chemicals (Kelley, 2020). Inadequate rooms mean that experimental activities at home cannot be carried out optimally (Bruce et al., 2021).

Online laboratory learning can run by utilizing simulations, video experiments, and online modules that are integrated into synchronous learning such as zoom and other video conferencing platforms as well as asynchronous learning such as a learning management system (LMS). Zoom and synchronous learning can facilitate students for discussion, direct interaction, reflection, and asking questions in group work (Chan et al., 2020; Jones et al., 2021; Kelley, 2020). Meanwhile, the LMS automatically displays a list of tasks and due dates. This can train students' time management skills, planning, and responsible attitudes (Simon et al., 2020).

The advantages of simulations, video experiments, and online modules in online laboratory learning are that they can increase students' affective, cognitive, and motivation (Baker et al., 2020). Online learning provides comfort for students because face-to-face learning is intimidating, especially for those who are less confident about engaging in class discussions or asking questions (Potgieter et al., 2019). Laboratory simulation programs allow students to conduct experiments, make mistakes, and improve themselves (Blackburn et al., 2018). The students can also replay simulations and videos, thereby improving their understanding of the theory (Yeşİloğlu et al., 2021).

Online learning using simulations and video experiments is more efficient because it allows the students to explore the basic principles of analytical techniques better than in ordinary laboratories. Electronic platforms also assist educators in e-learning modalities, enhance learning strategies, and facilitate experimental learning needs (Valle-Suárez et al., 2020). Using simulation applications can save costs (Jones et al., 2021; Worrall et al., 2020; Yeşİloğlu et al., 2021) like in experiments that use enzymes, because enzymes are relatively expensive, save time, and work more safely (Yeşİloğlu et al., 2021).

There are advantages to using simulations, video experiments, online modules, and other platforms in synchronous and asynchronous laboratory learning. Nonetheless, many researchers still find some limitations. Among them are difficulties in controlling individual examinations (Valle-Suárez et al., 2020), difficulties in finding representative spaces and avoiding distractions during synchronous sessions (Chan et al., 2020), and difficulties in managing time outside campus time (Chan et al., 2020). They also cannot replace the skills acquired when there is an experiment in a real laboratory (Campbell et al., 2020; Tran et al., 2020; Yeşİloğlu et al., 2021). Technological limitations hinder students' participation, and poor internet connection disrupts online learning significantly (Baker et al., 2020; Jones et al., 2021). The students are less independent in making decisions because they depend on available platforms (Davy & Quane, 2021), and their understanding of equipment, materials, and laboratory activities is still weak (Tran et al., 2020; Yeşİloğlu et al., 2021). Students also report less experience in online learning (Jeffery & Bauer, 2020; Petillion & McNeil, 2020) such as a decrease in their involvement compared to real laboratory learning that provides interaction and communication between lecturers, assistants and students (Dekorver et al., 2020; Phipps, 2013; Tan et al., 2020).

Conclusion

Online laboratory learning can be run by utilizing proper technology or media. Laboratory learning can jonestake place synchronously, asynchronously, or both. The Zoom platform, video conference platform, and DryLab20 network technology have been used for synchronous laboratory learning. Meanwhile, asynchronous learning can use video experiments, simulations, online modules, web assignments, Sghoology, Formative, Canva, and a Learning Management System (LMS). Online labs can also incorporate synchronous and asynchronous learning. This method has many advantages, including helping the students to improve their understanding and visualize chemical interactions even though the implementation cannot train practical skills acquired in real laboratories.

Author Contribution

The main author contributed to selecting and reviewing literature, writing articles, and revising articles. The second and third authors guided in reviewing the literature and revising the article manuscript

Funding

This research did not receive any external funding.

Conflicts of Interest
The authors declare that there is no conflict of interest in the research conducted.

References

Abidin, Z., Hudaya, A., & Anjani, D. (2020). Efektivitas pembelajaran jarak jauh pada masa pandemi covid-19. *Research and Development Journal of Education*, *1*(1), 131. https://doi.org/10.30998/rdje.v1i1.7659

Baker, R. M., Leonard, M. E., & Milosavljevic, B. H. (2020). The sudden switch to online teaching of an upper-level experimental physical chemistry course: Challenges and solutions. *Journal of Chemical Education*, *97*(9), 3097–3101. https://doi.org/10.1021/acs.jchemed.0c00776

Bretz, S. L. (2019). Evidence for the Importance of Laboratory Courses. In *Journal of Chemical Education*, *96*(2), 193–195. https://doi.org/10.1021/acs.jchemed.8b00874

Bruce, M. R. M., Bruce, A. E., Bernard, S. E., Bergeron, A. N., Ahmad, A. A. L., Bruce, T. A., Perera, D. C., Pokhrel, S., Saleh, S., Tyrina, A., & Yaparatne, S. (2021). Designing a Remote, Synchronous, Hands-On General Chemistry Lab Course. *Journal of Chemical Education*, *98*(10), 3131–3142. https://doi.org/10.1021/acs.jchemed.1c00559

Buchberger, A. R., Evans, T., & Doolittle, P. (2020). Analytical chemistry online? Lessons learned from transitioning a project lab online due to covid-19. *Journal of Chemical Education*, *97*(9), 2976–2980. https://doi.org/10.1021/acs.jchemed.0c00799

Budai, T., & Kuczmann, M. (2018). Towards a Modern, Integrated Virtual Laboratory System. In *Acta Polytechnica Hungarica 15*(3), 191-204. Retrieved from http://acta.uni-obuda.hu/Budai_Kuczmann_82.pdf

Campbell, C. D., Challen, B., Turner, K. L., & Stewart, M. I. (2020). #Drylabs20: A new global collaborative network to consider and address the challenges of laboratory teaching with the challenges of Covid-19. *Journal of Chemical Education*, *97*(9), 3023–3027. https://doi.org/10.1021/acs.jchemed.0c00884

Chan, B. C., Baker, J. L., Bunagan, M. R., Ekanger, L. A., Gazley, J. L., Hunter, R. A., O'Connor, A. R., & Triano, R. M. (2020). Theory of change to practice: How experimentalist teaching enabled faculty to navigate the covid-19 disruption. *Journal of Chemical Education*, *97*(9), 2788–2792. https://doi.org/10.1021/acs.jchemed.0c00731

Cooper, M. M., & Stowe, R. L. (2018). Chemistry Education Research - From Personal Empiricism to Evidence, Theory, and Informed Practice. In *Chemical Reviews*, *118*(12), 6053–6087. https://doi.org/10.1021/acs.chemrev.8b00020

Davy, E. C., & Quane, S. L. (2021). Assessment of technological setup for teaching real-time and recorded laboratories for online learning: Implications for the return to in-person learning. *Journal of Chemical Education*, *98*(7), 2221–2227. https://doi.org/10.1021/acs.jchemed.0c01457

Dekorver, B., Chaney, A., & Herrington, D. (2020). Strategies for teaching chemistry online: A content analysis of a chemistry instruction online learning community during the time of covid-19. *Journal of Chemical Education*, *97*(9), 2825–2833. https://doi.org/10.1021/acs.jchemed.0c00783

DeKorver, B. K., & Towns, M. H. (2015). General Chemistry Students' Goals for Chemistry Laboratory Coursework. *Journal of Chemical Education*, *92*(12), 2031–2037. https://doi.org/10.1021/acs.jchemed.5b00463

Dunnagan, C. L., Dannenberg, D. A., Cuales, M. P., Earnest, A. D., Gurnsey, R. M., & Gallardo-Williams, M. T. (2020). Production and Evaluation of a Realistic Immersive Virtual Reality Organic Chemistry Laboratory Experience: Infrared Spectroscopy. *Journal of Chemical Education*, *97*(1), 258–262. https://doi.org/10.1021/acs.jchemed.9b00705

Eubanks, L. P. (2015). Laboratory Instruction: Less Verification-More Discovery. *ACS Symposium Series*, *1208*, 195–217. https://doi.org/10.1021/bk-2015-1208.ch011

Ferrell, J. B., Campbell, J. P., McCarthy, D. R., McKay, K. T., Hensinger, M., Srinivasan, R., Zhao, X., Wurthmann, A., Li, J., & Schneebeli, S. T. (2019). Chemical Exploration with Virtual Reality in Organic Teaching Laboratories. *Journal of Chemical Education*, *96*(9), 1961–1966. https://doi.org/10.1021/acs.jchemed.9b00036

Fikri, M., Zaki Ananda, M., Faizah, N., Rahmani, R., & Adelia Elian, S. (2021). Kendala dalam pembelajaran jarak jauh di masa pandemi covid-19: sebuah kajian kritis. *Jurnal Education and Development*, *9*(1), 145–148. https://doi.org/10.1016/jjheduc.2013.06.00

Garza-Reyes, J. A. (2015). Lean and green-a systematic review of the state of the art literature. *Journal of Cleaner Production*, *102*, 18–29. https://doi.org/10.1016/j.jclepro.2015.04.064

Hancock, L. M., & Hollamby, M. J. (2020). Assessing the Practical Skills of Undergraduates: The Evolution of a Station-Based Practical Exam. *Journal of Chemical Education*, *97*(4), 972–979. https://doi.org/10.1021/acs.jchemed.9b00733

Hensen, C., & Barbera, J. (2019). Assessing Affective Differences between a Virtual General Chemistry Experiment and a Similar Hands-On Experiment.

Journal of Chemical Education, *96*(10), 2097–2108. https://doi.org/10.1021/acs.jchemed.9b00561

Holme, T. A. (2020). Journal of Chemical Education Call for Papers: Special Issue on Insights Gained while Teaching Chemistry in the Time of COVID-19. *Journal of Chemical Education*, *97*(5), 1226–1227. https://doi.org/10.1021/acs.jchemed.0c00378

Ismiyarti, W., Hudaya, C., & Rodianto. (2021). Efektivitas Metode Pembelajaran Online Pada Masa Pandemi Covid-19. *Tambora*, *5*(3), 1–7. https://doi.org/10.36761/jt.v5i3.1295

Jeffery, K. A., & Bauer, C. F. (2020). Students' responses to emergency remote online teaching reveal critical factors for all teaching. *Journal of Chemical Education*, *97*(9), 2472–2485. https://doi.org/10.1021/acs.jchemed.0c00736

Jones, E. V., Shepler, C. G., & Evans, M. J. (2021). Synchronous Online-Delivery: A Novel Approach to Online Lab Instruction. *Journal of Chemical Education*, *98*(3), 850–857. https://doi.org/10.1021/acs.jchemed.0c01365

Kelley, E. W. (2020). Reflections on three different high school chemistry lab formats during covid-19 remote learning. *Journal of Chemical Education*, *97*(9), 2606–2616. https://doi.org/10.1021/acs.jchemed.0c00814

Lapitan, L. D., Tiangco, C. E., Sumalinog, D. A. G., Sabarillo, N. S., & Diaz, J. M. (2021). An effective blended online teaching and learning strategy during the COVID-19 pandemic. *Education for Chemical Engineers*, *35*, 116–131. https://doi.org/10.1016/j.ece.2021.01.012

Mahaffey, A. L. (2020). Chemistry in a cup of coffee: Adapting an online lab module for teaching specific heat capacity of beverages to health sciences students during the COVID pandemic. *Biochemistry and Molecular Biology Education*, *48*(5), 528–531. https://doi.org/10.1002/bmb.21439

Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction*, *60*, 225–236. https://doi.org/10.1016/j.learninstruc.2017.12.007

Mamahit, C. E. J. (2021). Pengaruh Pembelajaran Jarak Jauh Model Bauran Terhadap Hasil Belajar dan Persepsi Mahasiswa. *Polyglot: Jurnal Ilmiah*, *17*(1), 67. https://doi.org/10.19166/pji.v17i1.2792

Muyassaroh, I., Yulistia, A., & Pratikno, A. S. (2022). Analisis Pembelajaran Sains melalui Flipped-Problem Based Learning Berbantuan Zoom Meeting dan E-Campus Pelita Bangsa. *DWIJA CENDEKIA: Jurnal Riset Pedagogik*, *6*(2), 433–446.

Petillion, R. J., & McNeil, W. S. (2020). Student experiences of emergency remote teaching: Impacts of instructor practice on student learning, engagement, and well-being. *Journal of Chemical Education*, *97*(9), 2486–2493. https://doi.org/10.1021/acs.jchemed.0c00733

Phipps, L. R. (2013). Creating and teaching a web-based, university-level introductory chemistry course that incorporates laboratory exercises and active learning pedagogies. *Journal of Chemical Education*, *90*(5), 568–573. https://doi.org/10.1021/ed200614r

Potgieter, M., Pilcher, L. A., Tekane, R. R., Louw, I., & Fletcher, L. (2019). Lessons Learnt from Teaching and Learning During Disruptions. In M. Schultz, S. Schmid, & G. Lawrie (Eds.), *Research and Practice in Chemistry Education* (pp. 89–107). Springer.

Ruano, I., Gamez, J., Dormido, S., & Gomez, J. (2016). A Methodology to Obtain Learning Effective Laboratories with Learning Management System Integration. *IEEE Transactions on Learning Technologies*, *9*(4), 391–399. https://doi.org/10.1109/TLT.2016.2594771

Rudenko, E., Bachieva, R., Aligadzhieva, A., Temirhanova, Z., & Archilaeva, A. (2020). Distance learning during the pandemic: Managing the challenges. *E3S Web of Conferences*, *210*. https://doi.org/10.1051/e3sconf/202021018038

Sandi-Urena, S. (2020). Experimentation skills away from the chemistry laboratory: Emergency remote teaching of multimodal laboratories. *Journal of Chemical Education*, *97*(9), 3011–3017. https://doi.org/10.1021/acs.jchemed.0c00803

Seery, M. K. (2020). Establishing the Laboratory as the Place to Learn How to Do Chemistry. In *Journal of Chemical Education*, *97*(6), 1511–1514. https://doi.org/10.1021/acs.jchemed.9b00764

Seery, M. K., Agustian, H. Y., & Zhang, X. (2019). A Framework for Learning in the Chemistry Laboratory. *Israel Journal of Chemistry*, *59*(6), 546–553. https://doi.org/10.1002/ijch.201800093

Simon, L. E., Genova, L. E., Kloepper, M. L. O., & Kloepper, K. D. (2020). Learning postdisruption: Lessons from students in a fully online nonmajors laboratory course. *Journal of Chemical Education*, *97*(9), 2430–2438. https://doi.org/10.1021/acs.jchemed.0c00778

Soong, R., Jenne, A., Lysak, D. H., Ghosh Biswas, R., Adamo, A., Kim, K. S., & Simpson, A. (2021). Titrate over the Internet: An Open-Source Remote-Control Titration Unit for All Students. *Journal of Chemical Education*, *98*(3), 1037–1042. https://doi.org/10.1021/acs.jchemed.0c01096

Sulistio, A. (2021). Peningkatan Prestasi Belajar Bahasa Inggris Melalui Pembelajaran Jarak Jauh (PJJ) dalam Penerapan Pembelajaran Sinkron dan Asinkron Melalui Google Classroom, Google Meet Dan Aplikasi E-Learning. *SECONDARY : Jurnal Inovasi Pendidikan Kejuruan*, *63*(2), 63–69. Retrieved from https://jurnalp4i.com/index.php/secondary/article/view/128

Tan, H. R., Chng, W. H., Chonardo, C., Ng, M. T. T., & Fung, F. M. (2020). How Chemists Achieve Active Learning Online during the COVID-19 Pandemic: Using the Community of Inquiry (CoI) Framework to Support Remote Teaching. In *Journal of Chemical Education*, 97(9), 2512–2518. https://doi.org/10.1021/acs.jchemed.0c00541

Tran, K., Beshir, A., & Vaze, A. (2020). A Tale of Two Lab Courses: An Account and Reflection on the Teaching Challenges Experienced by Organic and Analytical Chemistry Laboratories during the COVID-19 Period. *Journal of Chemical Education*, *97*(9), 3079–3084. https://doi.org/10.1021/acs.jchemed.0c00649

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review *. *British Journal of Management*, *14*, 207–222. https://doi.org/10.1111/1467-8551.00375

Valle-Suárez, R. M., Calderón-Mendoza, G. L., Lanza-Sorto, N. A., & Ponce-Rodríguez, H. D. (2020). Teaching Instrumental Analytical Chemistry in the Framework of COVID-19: Experiences and Outlook. *Journal of Chemical Education*, *97*(9), 2723–2726. https://doi.org/10.1021/acs.jchemed.0c00707

Vandenplas, J. R., Herrington, D. G., Shrode, A. D., & Sweeder, R. D. (2021). Use of Simulations and Screencasts to Increase Student Understanding of Energy Concepts in Bonding. *Journal of Chemical Education*, *98*(3), 730–744. https://doi.org/10.1021/acs.jchemed.0c00470

Walker, J. P., Sampson, V., Southerland, S., & Enderle, P. J. (2016). Using the laboratory to engage all students in science practices. *Chemistry Education Research and Practice*, *17*(4), 1098–1113. https://doi.org/10.1039/c6rp00093b

Widyasari, N. F. (2022). Strategi Pelaksanaan Tatap Muka (Pembelajaran Luring) Pasca Pandemi Covid-19. *Journal of Instructional and Development Researches*, *2*(4), 153–161. https://doi.org/10.53621/jider.v2i4.98

Winkelmann, K., Keeney-Kennicutt, W., Fowler, D., & Macik, M. (2017). Development, Implementation, and Assessment of General Chemistry Lab Experiments Performed in the Virtual World of Second Life. *Journal of Chemical Education*, *94*(7), 849–858. https://doi.org/10.1021/acs.jchemed.6b00733

Worrall, A. F., Bergstrom Mann, P. E., Young, D., Wormald, M. R., Cahill, S. T., & Stewart, M. I. (2020). Benefits of Simulations as Remote Exercises during the COVID-19 Pandemic: An Enzyme Kinetics Case Study. *Journal of Chemical Education*, *97*(9), 2733–2737. https://doi.org/10.1021/acs.jchemed.0c00607

Yeşİloğlu, S. N., Gençer, S., Ekİcİ, F., & Işik, B. (2021). Examining Pre-Service Teachers' Views about Online Chemistry Laboratory Learning Experiences Amid the Covid-19 Pandemic. *Journal of Turkish Science Education*, *18*(Special Issue), 108–124. https://doi.org/10.36681/tused.2021.75