

# Student Perceptions of Undergraduate Chemistry Laboratory Shaped by the COVID-19 Pandemic

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## Abstract

Laboratory activities are essential and important components of learning chemistry at the undergraduate level. The COVID-19 pandemic led to disruption of traditional modes of teaching and learning over the whole education spectrum including laboratory courses in chemistry. Although unfortunate, the COVID-19 lockdown period and following years challenged well accepted norms leading to new opportunities for higher education. The purpose of this work is to synthesize useful lessons from student experiences during COVID-19 pandemic and post-pandemic era aiming for improved future chemistry laboratories at the college and university level. Previously published studies addressed advantages and disadvantages of face-to-face vs. remote and online teaching of chemistry laboratory courses. However, there are only a few student-centered studies which analyze students' perceptions of undergraduate chemistry laboratories in the post-pandemic era. Although the study was conducted at the university in the United States, we believe the lessons learned could be used globally. The present study contributes to the existing body of knowledge in this field of research. It is unique because surveyed students experienced different modalities of the laboratory and were given an opportunity to compare both modalities side by side. Therefore, student experiences provide stronger foundations of their preferences and perceptions described in this work. Based on our findings, it appears that post-pandemic undergraduate students taking a non-major course prefer hands-on experiments and a hybrid modality of chemistry laboratory.

**Keywords:** modality, students' perceptions, undergraduate chemistry laboratory

## 1. Introduction

### *1.1 Recent Changes in Teaching Chemistry Laboratories Brought by COVID-19 Pandemic*

Chemistry is an experimental science and major discoveries have taken place in laboratories (nobelprize.org). Laboratory experience plays an important and significant role in learning chemistry at the college level (Reid & Shah, 2007). Coronavirus disease 2019 (COVID-19) pandemic brought new challenges to chemistry laboratory teaching, which was done mostly face-to-face before the pandemic. Since the first U.S. case of COVID-19 infection was identified in Washington State on January 20, 2020, more than 235,000 cases had been reported in the U.S. in the next two months (Omer et al., 2020). On March 13, 2020, the Federal Emergency Management Agency (FEMA) declared a state of emergency. The COVID-19 lockdown had a tremendous impact on the U.S. higher education. In spring 2020, colleges and universities all over the country transitioned from face-to-face to remote learning in a matter of weeks based on Centers for Disease Control and Prevention (CDC) guidelines (CDC, 2020). This transition and following post-pandemic situation led to the rapid development of technologies and teaching strategies which support remote learning and online courses. In this study, we focus on student perceptions of undergraduate chemistry laboratory modalities shaped by the transition from face-to-face to online teaching during COVID-19 lockdown and following adjustments to teaching to satisfy safety requirements.

### *1.2 Review of Literature*

The importance of the laboratory component of chemistry courses is easily illustrated by comparative search in ERIC database, an online library of education research and information, sponsored by the Institute of Education

Sciences (IES) of the U.S. Department of Education (eric.ed.gov). When searching for “chemistry lecture” as a key word among peer-reviewed publications in higher education, we obtained 438 results. The search for “chemistry laboratory” with same search criteria resulted in 2,605 publications at the time of writing this paper. In the recent article by Seery, the author refers to chemistry laboratory as “the part of a chemist’s identity” and urges to “focus on the role of the laboratory as one where students learn how to do chemistry” (Seery, 2020).

It is important to recognize that most pre-COVID-19 pandemic undergraduate chemistry laboratories were offered in face-to-face format with regular class meetings. During the COVID-19 lockdown all university courses, including chemistry laboratories, were taught online as per CDC requirements. Reflection study of COVID-19 era laboratory experiences by Kelley indicated that “a lack of hands-on laboratory experience was detrimental to certain types of learning and engagement but that other types of learning were successfully achieved remotely” (Kelley, 2021). Based on current American Chemical Society (ACS) recommendations for bachelor’s degree programs, in-person laboratory teaching is highly valued (ACS Guidelines for Bachelor’s Degree Programs). In addition, ACS guidelines adjusted for COVID-19 state that “once campuses reopen without social distancing requirements, chemistry and laboratory skills courses must resume in-person, too” (ACS Guidelines Adjusted for COVID-19).

Recent studies address advantages and disadvantages of face-to-face and online teaching of chemistry courses (Bhute et al., 2021; Chan et al., 2021; Link & Gallardo-Williams, 2022; Mosiagin et al., 2021). However, there are only a few student-centered studies which analyze students’ perceptions of undergraduate chemistry laboratories in post-pandemic era in the U.S. (Kelley, 2021). The article by Dost and others focuses on student perceptions of the role of online teaching during COVID-19 pandemic based on 2,721 surveys of UK medical students (Dost et al., 2020). Based on their findings, the authors suggest combining in-person and online teaching to achieve greater learning efficiency of education related to medical field. Another study from Eastern Europe shares experiences of secondary chemistry teachers and reflections by their students on online teaching of chemistry experiments during COVID-19 school closures (Babinčáková & Bernard, 2020).

### *1.3 Purpose of the Study*

A great body of recent publications describes the transition from in-person to online laboratory teaching from the instructor’s perspective, reviewed by Chan and others (Chan et al., 2021). In this work, we attempt to view changes to an undergraduate laboratory course from a student perspective. We believe that these insights will help educators to provide students with quality learning opportunities. The COVID-19 pandemic enforced rapid transformations in higher education. The purpose of this work is to synthesize useful lessons from the pandemic and post-pandemic era to plan for future undergraduate chemistry laboratories.

## **2. Method**

In our present study, an anonymous survey was completed by undergraduate students enrolled in College Chemistry I laboratory in the Fall 2021 semester, across five sections of the course. The total number of students who completed the survey was eighty-five (two students completed the survey partially). Students completed the survey during the last part of the course before taking the final exam to ensure that they participated in both hands-on experiments and remote learning activities and therefore were able to provide meaningful feedback. Below is the survey with questions and possible answers.

1. Your major is:
  - a) Pre-nursing
  - b) Agriculture
  - c) Education
  - d) Other
2. In this course, you performed both hands-on laboratory experiments and virtual activities. Which format do you prefer:
  - a) hands-on laboratory experiments
  - b) virtual activities
  - c) no preference
3. Given a choice, you prefer this course to be taught in which format:
  - a) 100% face-to-face

- b) 100% online
  - c) 50% face-to-face & 50% online (hybrid)
  - d) no preference
4. In this course, you were provided with instructor's recorded instructions before experiments. Did they help you to understand and perform experiments better?
- a) Yes
  - b) No

### 3. Results

#### 3.1 Undergraduate Students by Major

The university where the current study took place is a public regional university. The majority of students in College Chemistry I laboratory course are undergraduate students pursuing four-year degree plans in pre-health area (predominantly nursing) and agriculture. Based on the analysis of question 1 answers, the majority of students who completed the survey report their major as pre-nursing, 42.5% of students. 21.8% of students are majoring in agriculture, 14.9% in education, and the remaining 18.4% chose option "other" to describe their major field of study.

#### 3.2 Preferred Course Format of a Chemistry Laboratory Course

Questions 2 and 3 focused on students' perceptions of the desired format of the course. In question 2, when students were asked about their preference of hands-on laboratory experiments or virtual activities, majority (48.3%) chose hands-on laboratory experiments, minority preferred virtual activities (20.7%), and 28.7% of students reported no preference. The predominant answer for question 3 about the format of the course was 50% face-to-face and 50% online (hybrid) format chosen by almost half of surveyed students (47.1%). The next most popular preference was fully face-to-face format (28.7%), followed by fully online format (13.8%) with only 8.0% of students who indicated no preference.

#### 3.3 Benefits of Instructor's Recorded Pre-lab Instructions

As a pilot project to accommodate student learning in post-pandemic era, the course instructor provided students with recorded pre-lab instructions. When students were requested to share their opinion on usefulness of this additional learning tool in question 4, over ninety percent of students (91.8%) reported that the recordings helped them to understand and perform experiments better.

### 4. Discussion

The COVID-19 pandemic undoubtedly led to disruption of traditional modes of teaching and learning over the whole education spectrum. Although unfortunate, the COVID-19 lockdown period and following years challenged well accepted norms leading to new opportunities for higher education.

The College Chemistry I described in this work is a general chemistry non-major course, the first part of General-Organic-Biochemistry (GOB) sequence. The laboratory course is an essential component of curriculum and is required in conjunction with a lecture course by most degree plans. As supported by survey results, most students enrolled in the laboratory are not majoring in chemistry. The leading major in the student sample is pre-nursing (42.5%) as the course is one of the pre-requisites of the nursing program, followed by agriculture majors (21.8%) as it is required course for undergraduate degrees at the department of agriculture. The popularity of the agriculture major among students is not surprising, because the school in focus is a regional university located in a rural area of Arkansas (web.saumag.edu). Students who voluntarily participated in the survey had a unique experience of "hybrid" undergraduate chemistry laboratory format-wise. During the COVID-19 lockdown, College Chemistry I laboratory was taught online for a brief period of time. After that it was offered on the rotation basis as per university COVID-19 safety guidelines: for one week, half of the class had face-to-face lab meeting while the other half had lab activities to be completed remotely and the next week groups were switched. Due to this arrangement, students experienced two modes of course delivery within the same semester. Not surprisingly and despite the fact that surveyed students were non-major students, the majority preferred hands-on laboratory experiments to virtual activities, 48.3% vs. 20.7% students correspondingly. That is consistent with (i) the most updated ACS guidelines (ACS Guidelines Adjusted for COVID-19), (ii) comprehensive literature review of chemistry laboratory learning during the COVID-19 pandemic published in Journal of Chemical Education (Kelley, 2021), and (iii) the way most chemistry laboratories had been taught in pre-COVID-19 times in the U.S. institutions. The most commonly mentioned

disadvantages of virtual chemistry laboratories are physical absence of peer students (Zuidema & Zuidema, 2021), missing real-life feel of the laboratory (Chan et al., 2021), and reduced student engagement (Kelley, 2021). During the COVID-19 lockdown and forced transition to online teaching, other non-academic barriers to using completely remote mode of instruction were revealed. Among these barriers the most typical are family distractions, poor internet connection, timing of tutorials, anxiety, and lack of space (Dost et al., 2020). All these barriers are still possible limitations of online learning in post-pandemic times. Based on the results of the survey, a relatively small group of students (20.7%) preferred virtual activities over hands-on lab. The advantages of virtual learning are increased flexibility of self-regulated learning and reduced cost and chemical waste (Babinčáková & Bernard, 2020; Chan et al., 2021; Link & Gallardo-Williams, 2022). Interestingly, 28.7% of students reported no preference for either hands-on or virtual activities. We speculate that these students were satisfied with the course activities at the time of their enrollment: combination of hands-on and virtual assignments. However, students' preference of course format is more obvious based on their responses to question 3: given a choice, you prefer this course to be taught in which format? The majority, 47.1% of students voted for the hybrid format (50% face-to-face and 50% online). Next by popularity was the face-to-face format (28.7% students), followed by the fully online format (13.8% students) with 8.0% students who indicated no preference. Our results are consistent with previous studies (Babinčáková & Bernard, 2020; Bhute et al., 2021; Chan et al., 2021; Dost et al., 2020; Mosiagin et al., 2021; Zuidema & Zuidema, 2021). However, what makes our study unique is the fact that surveyed students experienced different modalities of chemistry laboratory, and they had a chance to compare both modalities side by side in a single course during the same semester. We believe these experiences provided students with stronger foundations of their preferences and perceptions.

Based on our findings, post-pandemic students in non-major undergraduate chemistry laboratory prefer hybrid modality of the course predominantly based on hands-on experiments. Students value their instructor's recorded instructions developed also because of the COVID-19 pandemic in attempts to boost learning. In this work, we reported students' perceptions with the goals to enhance existing chemistry laboratory courses and develop future laboratories which address the needs of modern undergraduate students.

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### **Data availability statement**

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

### **Data sharing statement**

No additional data are available.

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