General Chemistry Education in a Pandemic

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ABSTRACT

With the start of the Covid-19 pandemic and the decision to close post-secondary schools to in-person teaching, an opportunity was presented to examine the challenges, benefits and ability to pivot to an online teaching environment, both from the student and instructor perspectives. In the Summer 2020 semester at Simon Fraser University, Chemistry 121 (General Chemistry and Laboratory I) ran for the first time as an online course. In this paper, we will explore the experience of developing and running the course.

KEYWORDS

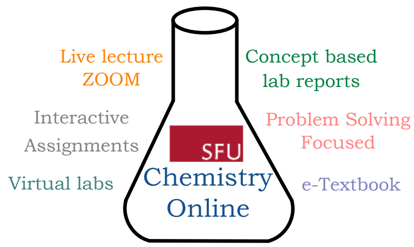
Audience: First-Year Undergraduates/General

Domain: Curriculum

Pedagogy: Hands-on Learning/Manipulatives, Inquiry-Based/Discovery Learning

Topics: Computer-Based Learning, Multimedia-Based Learning, Testing/Assessment

GRAPHICAL ABSTRACT



INTRODUCTION

Every educator has experienced the anxieties of teaching from the middle of night panics that the final exam will be too easy, to worries about how the lectures will go, apprehension about what to do if a student gets ill during class or simply wondering "why don't they laugh at my lecture jokes?", but no one could have envisioned the turmoil the education system would undergo in the wake of the Covid-19 pandemic. In March 2020, most if not all instructors in post-secondary schools in Canada received a similar notice from their institute administration: "All in class education is cancelled. Instruction will shift online." With only a few weeks left in the semester, instructors were able to scramble to complete the term. However, it became clear that summer semester was going to be entirely online. Finishing a few weeks online is different than running a whole semester online, especially for instructors who have never taught in such a way and students who are unaccustomed to learning remotely. Instructors were required to teach a course that was not designed for the online curriculum, determine effective online teaching strategies, and learn new technology in only a few short weeks. This was the situation we found ourselves in April 2020 as we started planning the online version of our Chemistry 121 (Chem 121) course: General Chemistry and Laboratory I. We needed to determine effective methods to teach both the lecture and laboratory components.

CHEMISTRY 121

Standard method of Instruction

Our Chem 121 course, which has a full lecture and laboratory component, normally runs at two campuses (Burnaby and Surrey). At the larger Burnaby campus, in the fall and spring semesters, due to the larger enrollment, the course runs with two instructors. One instructor is responsible for the lecture and the other the laboratory sections. In the summer, one instructor is responsible for both comments of the course. At our smaller Surrey campus, again one instructor runs both aspects of the course. The two offerings of the course are run in a similar manner. The lectures consist of 3 x 50 minute in-person lectures and 1 x 50 minute in-person tutorial per week. Students are asked to complete 7-8 online problem sets via LON-CAPA[1] and write one midterm and one final exam (both in-person). In the laboratory, students complete 6 x 4-hour experiments and 1 x 2-hour experiment. Each experiment is accompanied with an online LON-CAPA prelab assignment (the exception being the 1 x 2-hour experiment) and a report sheet to be completed during the laboratory period. Our semesters run with 13 weeks of instructions followed by a 2-week final exam period. A laboratory manual is provided to the students along with extra support through the course textbook: *Chemical Principles* by Zumdahl & Decoste.[2]

Online method of Instruction

In response to the move to online instruction, the two offerings of the course were combined into one online section, with all instructors tasked to work together to develop the online course. Dr. Goyan focused on adapting the lecture to the online platform, while Dr. Canal and Dr. Mund devised the online laboratory portion of the course. All three instructors contributed to the exams and overall running of the course.

Based on Dr. Goyan's previous experience with running a semi-flipped classroom,[3] she implemented many new approaches in presenting the lecture materials. Due to the online restrictions, an asynchronous 50-minute lecture was presented using a ZOOM webinar, three times a week, with recording made available post lecture. The questions and answers feature in ZOOM allowed for student-instructor interactions during the lectures. The lectures shifted from a traditional delivery of the lecture notes to a focus on problem solving. The textbook was changed to Interactive General Chemistry[4] due to its interactive learning tools. The problem set was expanded from the standard LON-CAPA based assignments to include daily assignments generated by the Sapling Learning Online Homework system.[5] This added a mix of low and high stakes assignments, which helped the student identify weaknesses in their understanding.

The students first participated in an online and optional Learning Curve Assignment, which directed students to extra resources when answering questions incorrectly. The lecture material covered each week was reinforced in a graded Homework, with unlimited attempts allowed, though a 5% penalty was applied to each incorrect attempt. Final mastery of the week's material was assessed using the online Concept Mastery Quiz. More complex problems, which often integrated topics from previous weeks of the course, were presented to the students using the standard LON-CAPA assignments. Unlike traditional in-person semesters, the lecture tutorials were based on interactive figures from the textbook and were graded. ZOOM sessions replaced the tutorial time and office hours for the lecture Teaching Assistants (TAs) and were used by the students to ask questions about the tutorials, Homework, and LON-CAPA assignments. The in-person mid-term and final exams were replaced with exams developed and completed online using LON-CAPA (See the Supplementary Material for an in-depth analysis of all the course lecture components).

The laboratory component was run with a mix of new and established resources. During the even numbered weeks of the semester the students were asked to approach the experiments in the same manner as in previous semesters. Students reviewed an experiment in the lab manual and completed a modified version of the existing online LON-CAPA pre-lab assignments. These assignments tended to focus on the calculations related to the experiment, and where based on sample data. In lieu of the traditional report sheet based on a completed in-person experiment, students were asked to answer concept-based problems, getting them to investigate why certain steps in the experiment would have been performed. In the odd numbered weeks, the students completed an online virtual experiment related to the pre-lab assignment and experiment they reviewed the previous week. We made use of the Connect for LearnSmart Labs – Chemistry system by McGraw-Hill Connect.[6] The LearnSmart Labs consisted of a virtual hands-on laboratory experience and related lab assignments.

TEACHING ON-LINE STRATEGY

Once the panic and anxiety of converting an in-person lecture/laboratory chemistry course into an online course had passed, we commenced with the implementation of the changes. The task was made easier by combining the two campus course offerings into one section. This allowed for three instructors to combine their efforts into developing the course. In order to make the transition successful collaboration was imperative allowing us to play off each other's strengths and know when to ask for help. Dr. Goyan, with her experience running a semi-flipped classroom and having taught a chemistry distance education course, was an obvious choice to run the lecture component. The task of devising the online laboratory component was split between Dr. Mund and Dr. Canal. Dr. Mund, with his years of experience teaching this course, populated the course website, developed the concept-based labs reports, and directed the teaching assistant in their tasks. Dr. Canal (JPC), who is the Chair of the Department's Teaching Technology Committee, which is tasked with supporting the programs employed in the department, focused his efforts in coordinating the computer programs which were used by the students, including LON-CAPA, Turnitin,[7] and Connect for LearnSmart Labs – Chemistry.

The course design decisions were made based on our experience and expertise, as well as through a collaborative sharing of ideas among our chemistry colleagues at other post-secondary institutions. One of our authors, JPC, created an online forum where Canadian based instructors share resources and approaches on how to transition to an online environment. This group consists of over 35 members from more than 18 post-secondary institutions.[8] We were also able to discuss ideas with international colleagues through a Facebook Group, Strategies for Teaching Chemistry Online.[9] It is through this sharing that we were able to refine some of our ideas and were made aware of new resources.

The strategy of our online lecture format was guided by three principles, namely, to provide an interactive/personal education, to support the students in their new experience with eLearning systems[10] and provide a level of instruction comparable to the in-person course. The interactive/personal experience was achieved by the use of the ZOOM webinar, which provided students with regular, live lectures and tutorials that focused on problem solving and allowed for meaningful interactions with students.[9] This approach was furthered by the adoption of a textbook designed for the online teaching experience.[4]

As eLearning is a new approach to most of our students, we used a 4-part assignment strategy to help students stay focused and on schedule in the course. This provided students with a structured workload and course expectations. The initial reaction by the students was mixed; many complained about the workload and the set schedule. It was only after the first mid-term that the advantages of the format became apparent, and acceptance of the format increased.[11]

In our laboratory section, a three-part assessment (LON-CAPA assignments, Canvas Lab Reports and the LearnSmart Labs) was chosen in order to:

- Provide a similar experience as students would have obtained in the in-person labs. The LON-CAPA pre-lab assignments were continued and were used to make sure that students understood the general calculations associated with the experiments.
- Initiate the experimental thought process by the development of the concept-based Canvas Lab Reports. This allowed the students to think about the experimental steps, why certain things are done in a particular experiment and potential sources of error in an experiment.
- Obtain a "hands-on" experience. The virtual labs were chosen as they provided (to some degree) a visualization of the typical glassware used, and the experimental procedures conducted in an undergraduate experiment. We attempted to provide the students a degree of the overall laboratory experience.

EFFECTIVENESS OF THE APPROACH

To garner the effectiveness of our approach to teaching first-year chemistry online, we evaluated both the students' academic results and the results of a student survey.

Lecture/Laboratory Comparison

To provide a meaningful evaluation of the student results, we compared six components from the online course to the student results obtained in Chem 121 during the past 4 summer semesters (2015—2019). The reason we limited the study to only the summer semester was the make-up of the student body tends to be different than in the fall or spring offering of the course. In the summer we often have a greater portion of students re-taking the course. The limitation to only the summer semester is an attempt to provide a more equal comparison. As shown in Table 1, the comparison of the lecture material was limited to three assessments, with two components used in the laboratory section assessment. In the lecture portion of the review, we compared both the mid-term and final exam grades, as the exams were similar in style and length to the exams used in the in-person course. The LON-CAPA assignments also did not change much between the online and in-person offering of the course. For the laboratory section, we used the laboratory specific LON-CAPA assignments and the total grade from the laboratory portion of the course.

A comparison of the student results from the 2015-2019 summer offerings of Chem 121 with the results from the 2020 semesters (see Table 1) indicates that the transfer of the course from in-person to online-only (with the related changes), did not adversely affect the student grades. In the lecture section of the course the average results from the LON-CAPA assignments was 78.45% which was in the historical range and close to the historical average of 80.41%. A similar result was observed with the mid-term exam. The average mid-term grade (65.28%) was only 1.20% outside the historical range and only 1.39% above the historical average of 63.89%. The final exam average of 62.11% was within the historical range and 2.29% above the historical average of 59.82%.

The results from the laboratory section illustrated the student's understanding of the experiments was similar to the in-person experience, as tested by their LON-CAPA assignments. The average value of 87.71% was within the historical range and 3.57% below the historical average of 91.28%. Although a comparison of the overall laboratory grade presents many variables that effect the results, the student value of 84.34% is only 2.59% outside the historical range and 6.12% above the historical average. This difference can be explained by the use of the virtual labs, which the students did not find as challenging as the in-person experiments.

The average final grade 74.93% was 9.43% above the historical average of 65.50%, but only 3.26% outside of the historical range. This higher result was due the higher laboratory grade as well as the grades marked obtained from additional online assignments that were added to the course. However, if we use the weighting associated with the elements available in a traditional class (LON-CAPA (10%), Laboratory (20%), Midterm (30%) and Final (40%)) the students' average grade of 69.14% was within the historical class averages.

The analysis of the grade obtained in the Covid-19 affected semester versus the average marks of the past four offerings of Chem 121, show that our changes did not have a detrimental effect on student learning. This suggests that our first-year students are adaptable and able to learn in different teaching environments. For a well-designed online course or a traditional in-person lecture environment, the mode of instruction does not seem as important as the effort that is put in by the students.[12]

Student Survey

To garner more information about the course we asked students to complete a voluntary and anonymous survey. Of the 290-students enrolled in the course 60 students provided feedback, which represents a 20.6% response rate. This survey was conducted in the last week of the semester, the busiest time for the students, which at least partially explains the low participation rate. Participation rates on course feedback surveys tend to be low, hence a participation rate of 20.6% is not out of the ordinary.[13] A number of the survey questions dealt with the logistics of attending an online course with other questions asking about specific aspects of the course.

Our analysis found that 98.3% of the respondents had easily accessible internet, with 70% suggesting that a high-speed internet was needed for this course. The preferred lecturing format (asynchronous versus synchronous) was examined and we found an almost equal preference. Of the respondents, 30% preferred the synchronous lectures, 25% preferring the asynchronous approach with 45% expressing an equal affinity for both methods. Some students preferred the structure of a set schedule and the ability to interact with the instructor while other students wanted to be able to set their own schedule. We also found that 51.7% of our students always or almost always attended lecture, with 40% only attending sometimes. The move to the online format limited our textbook options to an e-textbook. The preference of the e-books over the hard copy textbook was examined. Again, we found an almost even split. Of the respondents, 41.7% preferred the e-book with 40% preferring the hard-copy text. The remaining 18.3% of the student did not have a preference either way.

To gain knowledge on the student's opinion of the course components and their overall learning experience, we conducted a survey using a five-point Likert-type scale from "Very Poor" to "Excellent". The Likert-type rating means for each statement is shown in Table 2.

The results of the student analysis on the different components of the course were not surprising. As shown in Table 2, most students rated the components as either fair to good. The lowest values were for the LON-CAPA assignments (lab and lecture) but this was expected as the LON-CAPA assignments can be challenging and can require a significant amount of time to complete. This is contrasted to the Sampling Assignments, which had straightforward but interactive questions. It is not surprising that it received the highest rating from the students.

The addition of the virtual laboratory experiments and new online lab reports was one of the largest changes to this laboratory section of this course and warranted further investigation on it use. This was conducted using another five-point Likert-type scale from "Strongly Disagree" to "Strongly Agree" and the results shown in Table 3.

The results of the student's opinion to the virtual labs and Canvas lab reports provided us with an idea of their effectiveness. It is interesting that the students where fairly "neutral" in their opinion of both the virtual labs being engaging and the Canvas lab reports enhancing their laboratory skill knowledge. This result was expected as it is difficult to replace an in-person, hands-on experience with a virtual facsimile. It is also a difficult comparison for freshman students to make considering the lack of laboratory experience of these students.

Instructor's Experience

Although the experience of developing a new online version of an existing course had its challenges, overall, it was a positive experience (for both students and instructors). Given the short timeline to develop the course, there was stress associated with having to make quick decisions and develop course content. Decisions were required on which course components were to be kept, discarded or changed. In doing so, we became more focused on what it is the course was trying to achieve. The process introduced us to a variety of new educational tools, which can be used in our other courses (and in the offering of this course).

The adoption of the online format increased the technical problems encountered by students. Although the programs we used worked properly for most, there were a few students that encountered issues, which were easily corrected.

We developed a strategy to handle the electronic based messages from students. This was to prevent instructors from getting inundated with emails, but also to provide clear communication paths for the students. All lecture-based communication was through one instructor with another instructor responsible for all the laboratory messages. Within the lecture or laboratory components, the TAs were also given specific tasks related to student communication. With this approach the students knew who to email and when (e.g. fixed office hours). In addition to emails, all course information was posted using Canvas,[14] which the course management system used at SFU (a separate page was developed for the lecture and laboratory, which further reduced any student confusion). Within Canvas, students could communicate with TAs and instructors and feedback could be provided in a timely and efficient way.

CONCLUSION

The analysis of the student results from the Covid-19 modified version of Chem 121, showed that the changes introduced did not alter the average student outcome (in terms of the average grades obtained). The online survey illustrated that the students did not have a strong opinion (either positive or negative) on the changes we introduced. Given these results and the time constraint in developing the online version of the course, we feel that we achieved the main goal in this course transition. We wanted students to have a positive educational experience and learn the material at the same level as they would in the in-person version of the course. The results of this study may best be summed up in a student's anonymous comment: "Nothing is better than actually going to school and attending lectures in person and actually doing the labs by hand, this course in my opinion did a fair job, keep it up!". We whole-heartedly agree that nothing can replace in-person learning but considering the extraordinary circumstances we found ourselves in at that moment, we could not have asked for a better result.

SUPPLEMENTARY MATERIAL

Supplementary material for this article are available on the journal website (www.nrcresearchpress.com/loi/cjc)

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TABLES

Table 1. Comparison of student results

Lecture:	**2020 Percentage (number of students)**[a]	**2015-2019 Percentage (number of students)**[a]	**2015-2019 Percentage Range**
LON-CAPA Assignments	78.45 (273)	80.41 (1074)	78.16 - 85.65
Midterm	65.28 (289)	63.89 (1296)	59.85 - 64.08
Final Exam	62.11 (276)	59.82 (1062)	58.07 - 67.22
Laboratory:			
LON-CAPA Assignments	87.71 (219)	91.28 (878)	89.40 - 93.68
Overall Laboratory Grade	84.34 (224)	78.22 (945)	77.10 - 81.75
Course Grade[b]	74.93 (285)[c]	65.60 (1081)	63.25 – 71.67
	69.14 (285)[d]		

[a] The lower student number in the lab vs. lecture is due to the students who are only enrolled in the lecture portion of this course.
[b] The "Course Grade" includes the both the lecture/lab and lecture only students
[c] The 2020 grade breakdown: 5% LON-CAPA (Lecture), 15% Midterm, 20% Laboratory, 30% Homework, 30% Final Exam.
[d] The 2020 grades based on the 2105-2019 grade breakdown: 10% LON-CAPA (Lecture), 20% Laboratory, 30% Midterm, 40% Final Exam.

Table 2. Student opinions the course components

Please rate the following lecture/laboratory components in terms of effectiveness as a teaching tool/resource	Mean Score[a]
Lecture	**(N=60)[b]**
LON-CAPA	3.00
Tutorials	3.80
Lecture	3.93
Homework and concept mastery quiz	4.15
Learning Curve Assignment	3.53
Laboratory	**(N = 51)[c]**
LON-CAPA	3.31
Canvas Lab Reports	3.36
McGraw-Hill Connect Virtual Labs	3.42
Overall, the quality of my learning experience in this course was:	**(N= 60)**
Lecture and laboratory	3.55

[a] Likert-type rating as follows: very poor = 1; poor = 2; fair = 3; good = 4; excellent = 5.
[b] N = number of student responses.
[c] The lower N values for the laboratory section is due to some students who are only enrolled in the lecture portion of this course.

Table 3. Virtual Experiment Analysis

How strongly do you agree/disagree with the following statements?	Mean Scores[a] (N = 48)
The McGraw-Hill Connect Virtual labs were engaging	3.60
My understanding of why certain things are done in a laboratory session were likely enhanced by the online Canvas lab reports	3.00

[a] Likert-type rating as follows: strongly disagree = 1; disagree = 2; neutral = 3; agree = 4; strongly agree = 5.