Virtual Soil Science Laboratory Sessions: Delivery and Student Perceptions

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Abstract

Laboratory classes effectively enhance student understanding and appreciation of course concepts. With course delivery suddenly shifted into the online format due to the COVID-19 pandemic, four laboratory exercises in each of two introductory-level soil science courses were converted into virtual sessions delivered in the form of student-accessible videos. Each laboratory video included a pre-lab discussion, demonstrations of a process or experiment, prompts to answer questions and record data, and/or explanation of relevant calculations. The online link to the video was provided in a laboratory guide which doubled as the report document that students submitted online. Semester-end surveys (n=130) reveal that at least 97% of students agreed or strongly agreed that virtual labs successfully demonstrated key processes and at least 96% thought that the virtual labs enhanced student understanding of soil science concepts. Over 90% of students considered the virtual labs as successful substitutes for hands-on exercises in COVID19-affected semesters. The absence of instructors who could immediately address questions and classmates to discuss results were the two main challenges. Students liked the ability to review the video if things were unclear the first time. While it has its limitations, virtual lab sessions were perceived as successful substitutes to in-person laboratory activities.

Keywords: virtual laboratory, distance learning, soil science teaching

Learning in the laboratory setting provides students with opportunities to gain knowledge in three ways – by learning from doing, by learning from interactions with classmates, and by learning from the instructor. Because of these multiple ways of learning in a laboratory setting, laboratory classes have been utilized by courses across disciplines. Activities that are conducted in laboratory classes are designed not only to enhance understanding of difficult concepts and their applications, but also to spark student interest and appreciation of the subject. Hence, the importance of learning from laboratory activities in different sciences, particularly in natural science disciplines, has long been given its distinctive role (Hofstein & Lunetta, 2003; Hofstein & Mamlok-Naaman, 2007). Laboratory activities may range from traditional in-person classroom sessions, field trips, virtual experimentation, video recordings, and short-term projects. Over the years, the use of traditional in-person laboratory classes, wherein students perform well-designed activities, has been preferred by many teachers and students alike (O'Malley & McCraw, 1999; Pomerantz & Brooks, 2017; Deslauriers et al., 2019).

The soil is a very complex material and the understanding of its properties as well as the processes that go on in it is vital in formulating land use decisions. Teaching soil science, particularly at the introductory level, generally involves a lecture component that is delivered in tandem with a laboratory or hands-on component. In fact, laboratory sessions that involve field work and active learning activities were formally identified as two of the 11 key teaching principles in soil science (Field et al., 2011). A study by Abit et al. (2018) reported that the incorporation of a laboratory component to an otherwise lecture-only intro-level soil science course improved the understanding and appreciation of soil science concepts of at least 94% of students surveyed with 89% indicating that some concepts would have been difficult to understand without the laboratory activities.

So beneficial is the laboratory component in soil science learning that even when student access to in-person laboratory is cut or deemed impractical due to health and safety concerns, such as during the height of the COVID-19 pandemic, soil science teachers found ways to have an experiential component to their respective courses. Some teachers created hybrid-virtual or fully virtual field trip activities for an introductory soil science class that used a narrative format supported by ground-level and drone photos, newspaper articles, videos, websites, and landscape diagrams (Schulze et al., 2021). Others implemented a creative way to remotely deliver field experiences for an upper-level soil science course (Aleman et al., 2021) and even conducted remote soil judging competitions (Owens et al., 2021). There was even an effort to adopt an introductory soil science laboratory class into an online format wherein field-based labs were modified so that students could complete the activities from home using household equipment while the pre-lab instruction was delivered using online videos (Wolters & Lepcha, 2021).

Virtual laboratory sessions have been adopted in many classes even before the COVID-19 pandemic and were delivered either by simulation of an environment (virtual reality), application programs, and/or the use of recorded videos. In most cases, virtual laboratory is used as a cost saving strategy in place of activities that involve field trips, expensive equipment, demonstrations that are expensive to replicate or visualize in real-world scenario, and those that are dangerous or time-consuming (Ramasundaram et al., 2005; Zacharia, 2007; Hawkins & Phelps, 2013; de Vries & May, 2019; Sherrer, 2020; Reeves & Crippen, 2021). Virtual labs are also beneficial in distance education due to their inherent flexibility, convenience, and ability to accommodate different learning styles (Elliott & Kukula, 2007) or learners. Thus, teaching science courses through virtual laboratory have been evaluated across different science disciplines including physics (Zacharia, 2007; Ranjan, 2017; Faour & Ayoubi, 2018; Gunawan et al., 2018), chemistry (Hawkins & Phelps, 2013; Altowaiji et al., 2021), biology (Toth et al., 2009; Dyrberg et al., 2017), animal physiology (Durand et al., 2019), biochemistry (Sherrer, 2020), environmental science (Ramasundaram et al., 2005), soil science (Eick & Burgholzer, 2000; Reuter, 2007; Reuter, 2009) and information technology (Elliott & Kukula, 2007). Findings in some literatures have shown promising results. Some studies reported that performance of students in virtual laboratory classes were just as good (Hawkins & Phelps, 2013; Durand et al., 2019) or if not better than students taking in-person laboratory class (Reuter, 2007; Zacharia, 2007; Reuter, 2009; Ranjan, 2017; Faour & Ayoubi, 2018; Gunawan et al., 2018). Elliott and Kukula (2007) obtained varying success in their modular laboratory activities for distance learner of information technology students. Other studies, however, have recommended the use of both in-person and virtual/online laboratory to make the most of what each method has to offer and complement each other (Zacharia, 2007; de Jong et al., 2013; Kapici et al., 2019).

When our university cancelled in-person classes halfway through the spring 2000 semester because of the onset of the COVID-19 pandemic, the four remaining laboratory exercises of an introductory-level soil science course had to be delivered virtually. In the subsequent fall semester, laboratory sessions of another introductory-level soil science course were also delivered virtually to meet health and safety protocols. Unlike most virtual laboratory activities previously developed and reported in several literatures that required complex programming and animation, our version of virtual laboratory exercises simply mimicked the process that the students would have experienced in in-person laboratory sessions. Ours involved a recorded pre-lab discussion and then a series of step-by-step demonstrations and discussions by the instructor that were captured in a series of amateur video clips, which were later combined into a composite virtual laboratory video. This was the first time that laboratory exercises were delivered virtually for any soil science course at our university. Hence, this paper articulates the method of delivering the laboratory sessions and presents the results of surveys designed to assess student perception about this alternative teaching technique. This study aimed to: (1) develop and refine the method of delivering soil science virtual laboratory sessions and (2) assess the impact of virtual laboratory sessions in enhancing student understanding and appreciation of important soil science concepts.

Methods

Virtual laboratory sessions were implemented in the Fundamentals of Soil Science (SOIL 2124) and the Land, Life and the Environment (SOIL 1113) courses in the 2020 spring and fall semesters, respectively. SOIL 2124 is a sophomore-level college core course that serves as prerequisite for upper-division soil science courses. It comes with a required laboratory session that normally involves 13 in-person laboratory exercises. SOIL 1113, on the other hand, is a freshman-level course that is taken by students who need to satisfy a general education science requirement. It was originally developed as a lecture-only course but given that many students in the course do not have prior experience with the use or understanding of the soil resource, it was deemed necessary to conduct a few drive-through laboratory sessions to facilitate learning of key, basic soil science concepts. Details about the drive-through laboratory sessions in SOIL 1113 are discussed in Abit et al. (2018).

The last four laboratory exercises of SOIL 2124 were converted into virtual laboratory sessions because in-person instruction during the last seven weeks of the spring 2020 semester was cancelled due to the COVID-19 pandemic. These exercises include: Ion Exchange Properties of Soils, Soil pH and Liming of Acid Soils, Fertilizers and Fertilizer Calculations, and Soil Erosion. In line with safety protocols in the fall semester of 2020, drive-through labs for SOIL 1113 were also converted into virtual laboratory sessions. The specific activities performed, or topics covered in each virtual laboratory session of SOIL 2124 and SOIL 1113 are listed in Table 1.

Table 1

Topics covered and activities performed in the virtual laboratory exercises/sessions.

	Spring 2020 (SOIL 2124: Fundamentals of Soil Science)			
	Virtual Lab 1: Ion Exchange Properties of Soils	Virtual Lab 2: Soil pH and Liming of Acid Soils	Virtual Lab 3: Fertilizers and Fertilizer Calculations	Virtual Lab 4: Soil Erosion
Topics/ Activities Performed	• Demonstration of soil charge • Effect of soil texture on cation exchange capacity (CEC) • CEC calculation	• Soil pH measurement • Lime material and adjusting soil pH • Effect of soil texture on lime requirement • pH range of crops • Adjusting soil pH to stabilize heavy metal contaminants	• Fertilizer material identification • Fertilizer solubility • Fertilizer calculation	• Simulation of soil erosion process • Effect of surface cover on measured soil loss
	Fall 2020 (SOIL 1113: Land, Life, and the Environment)			
	Virtual Lab 1: Soil Physical Properties	Virtual Lab 2: Soil Chemical Properties	Virtual Lab 3: Fertilizers	Virtual Lab 4: Soil Erosion
Topics/ Activities Performed	• Soil color characterization • Soil texture determination • Effects of soil texture on water flow • Relationship of soil texture and specific surface	• Soil pH measurement • Lime material and adjusting soil pH • Demonstration of soil colloid charge • Effect of soil texture on treatment of pollutants	• Fertilizer material identification • Fertilizer solubility	• Simulation of soil erosion process • Effect of surface cover on measured soil erosion

Revision of Laboratory Guides

The laboratory guides for the four remaining exercises in SOIL 2124 were revised so that students could follow along the virtual activity. In addition to a step-by-step description of the activities performed or demonstrated in the virtual activity, each revised laboratory guide included an online link to access a virtual lab video that was posted in YouTube®. Also added into the laboratory guides were prompts on when to play or pause the video, some questions, and tables that needed to be filled-in with data.

In previous semesters, students in SOIL 1113 were only provided with a data sheet and list of questions to answer for each drive-through lab. Step-by-step written instructions were not provided because the laboratory instructor described or demonstrated the process or activity in front of the students as they moved from one activity station to another in the teaching laboratory. When the laboratory sessions were converted into virtual labs, step-by-step descriptions of the activities were added to the data sheet along with a link to an online video.

The students in both classes were required to read the detailed step-by-step description of the activities prior to undergoing the virtual lab and were instructed to have the laboratory guide handy when watching the video. Students were also instructed to watch the video in its entirety and given instructions on how to submit their report.

Preparation of the Virtual Lab Video

Each virtual laboratory exercise in SOIL 2124 and SOIL 1113 involves a specific video file that is a composite of a series of video clips. Each composite video is comprised of three basic components. The first component is a video wherein the laboratory instructor provides general instructions and then a pre-lab discussion about important concepts related to the exercise. The second component includes a series of amateur video clips that has the lab instructor discussing important concepts using hand-held or bench-top visual aids, performing an activity to demonstrate a process, and/or conducting a bench-top activity to generate results that needed to be recorded by the students. Each of the video clips ended with instructions to the students to record results into a particular table, answer a given set of questions, and/or perform necessary calculations. Students were also given prompts to pause and answer questions before proceeding to view the video clip of the succeeding activity. The third component is a video that summarized the laboratory activity and provided instructions regarding the submission of their reports. All three components were then combined into one composite virtual lab video file. The composite video was then posted as a non-searchable video in YouTube®.

Delivery and Management of the Virtual Sessions

Each modified laboratory guide was posted at the university's online classroom management system (Canvas®) at the beginning of each week when a virtual laboratory exercise was scheduled. The students were then provided with a five-day period to accomplish the virtual laboratory exercise. Additionally, laboratory instructors held scheduled virtual class meetings. These virtual class meetings served as an avenue for the students to consult with their respective laboratory instructors whenever they have specific questions about the exercise or needed assistance in accomplishing their report.

Survey Instrument and Data Collection

An eight-question survey instrument was developed to gather data from students in both courses. Details of the survey instrument are presented in Table 2. Five of the questions consisted of a 4-point Likert-type scale answers, ranging from "strongly agree" to "strongly disagree", allowing students to indicate their level of agreement to statements that were related to the ability of virtual lab activities to enhance understanding and appreciation of soil science concepts, and in SOIL 2124 as a successful and total substitute to in-person hands-on activities. A 4-point scale (no midpoint choice) was chosen to increase the likelihood that students would thoughtfully decide whether they are in the positive or the negative side of the statements provided and more importantly, to prevent students from interpreting the midpoint choice differently. Work by Kulas and Stachowski

Table 2

Survey instrument used in data gathering of students' perception.

Statements	Possible Answers
1. Understanding of some important soil science concepts would have been difficult without the virtual laboratory exercises.	strongly agree; agree; disagree; strongly disagree
2. The virtual laboratory exercises successfully demonstrated important processes that were important in the understanding of soil science concepts.	strongly agree; agree; disagree; strongly disagree
3. The virtual laboratory exercises enhanced my appreciation of important soil science concepts.	strongly agree; agree; disagree; strongly disagree
4. The TWO most challenging aspects of the virtual lab exercises are ______:	Not having the lab instructors in class to address my questions; The absence of the actual hands-on experience; Internet connectivity; Issues with quality of the audio or video; Not having classmates to discuss answers with
5. The TWO most BENEFICIAL aspects of the virtual lab exercises are______:	The step-by-step activities are explained by the instructor; All the results gathered were explained by the instructor; I can have the flexibility to review the video if things weren't clear the first time; I can do it on my own time
6. Considering the unexpected change in course delivery into the online format (because of the Covid19 pandemic), the virtual laboratory activities were successful substitutes to in-person, hands-on laboratory activities.*	strongly agree; agree; disagree; strongly disagree
7. The virtual lab can totally substitute an in-person, hands-on laboratory exercise.*	strongly agree; agree; disagree; strongly disagree
Please provide comments about the virtual lab exercises.	students typed-in their comments

Note. *- Data presented only include responses from students in SOIL 2124.

(2009) show that the midpoint could be interpreted either as: it depends, uncertain, average, or not applicable. Two questions allowed the students to choose their two most important beneficial and challenging aspects of the virtual laboratory from a list provided. The last question was an open-ended response question that allowed the students to provide additional comments about the virtual labs.

The survey was set-up in Canvas® and students were informed about the survey on several occasions such as during pre-recorded online lectures, via online announcements, and by emails. Students were only given access to the online survey for a week after the scores of all graded items in the laboratory and in the lecture were posted. This was done to assure the students that their response to the survey would not in any way impact their grades. Participation in the survey was highly encouraged but voluntary. Eighty percent of students in SOIL 2124 (82 out of 103), and 77% of students in SOIL 1113 (48 out of 62) participated in the survey.

The methodology of this study and the survey instrument was approved by the university's Institutional Review Board (IRB) office. Results were downloaded and organized in a spreadsheet. Collected responses for each question were summarized and interpreted in graphs based on percentage of responses for each category.

Results and Discussion

Enhancing Understanding and Appreciation

There are several parameters mentioned in literatures that can be used as indicators of success when evaluating teaching strategies. Students' perceptions that are gathered through surveys have been identified as one of those effective evaluation parameters because the students themselves are the ones who experienced the teaching strategy and are the direct recipient of class information.

Survey results reveal that students perceived the virtual laboratory sessions to have successfully enhanced student understanding of important concepts. Figure 1 shows that 97% and 98% of student-respondents in the spring and fall semester, respectively, agreed or strongly agreed that the virtual lab sessions have successfully demonstrated processes that are important in the understanding of soil science concepts. In addition, at least 96% of the students in both semesters agreed or strongly agreed that it would have been difficult to understand some of the soil science concepts in the absence of the virtual laboratory exercise (Fig. 2). These findings are similar to those by Zacharia (2007) and Ranjan (2017) which showed that conceptual understanding of students was improved by virtual experimentation. The same learning success was also reported by Reuter (2009) after conducting a pre- and post-assessment between "in the classroom" versus "online" in a soil science course.

Aside from enhancing student understanding of soil science concepts, the virtual labs also enhanced student appreciation of the lessons that they have learned. In fact, at least 93% of the student-respondents from both semesters agreed or strongly agreed that the virtual lab sessions enhanced their appreciation of soil science concepts (Fig. 3). The enhanced student appreciation and understanding of course concepts may be partly attributed to the manner that the virtual laboratory sessions were designed. The integration of clear instructions and pre-lab discussions at the beginning of each composite video, as well as the thorough step-by-step instructions in the succeeding show-and-tell activities therein, could have allowed the students to clearly grasp the introduced concepts in each exercise. In addition, the virtual laboratory provided the students the flexibility to replay the video whenever things were not very clear the first time. Furthermore, students were also allowed to accomplish the laboratory at their own pace and time. Hence, the flexibility and self-paced aspects of the virtual laboratory were ideally suited for distance education, as was also mentioned in the study of Eick and Burgholzer (2000).

Figure 1

Level of student agreement to the statement: The virtual laboratory exercises successfully demonstrated important processes that were important in the understanding of soil science concepts.

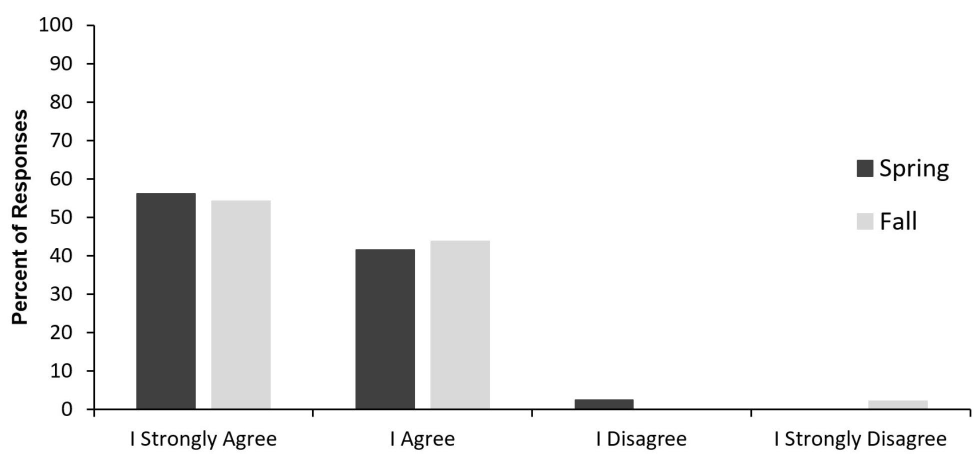


Figure 2

Level of student agreement to the statement: Understanding of some soil science concepts would have been difficult without the virtual laboratory exercises.

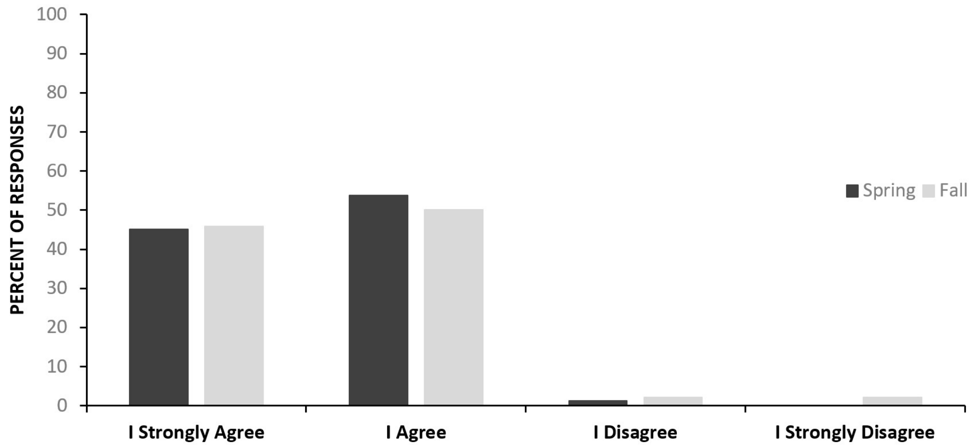


Figure 3

Level of student agreement to the statement: The virtual laboratory exercises enhanced my appreciation of important soil science concepts.

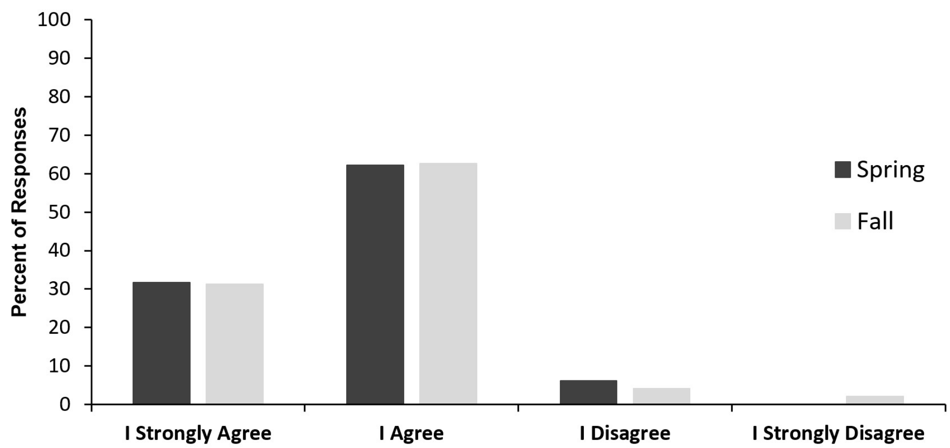
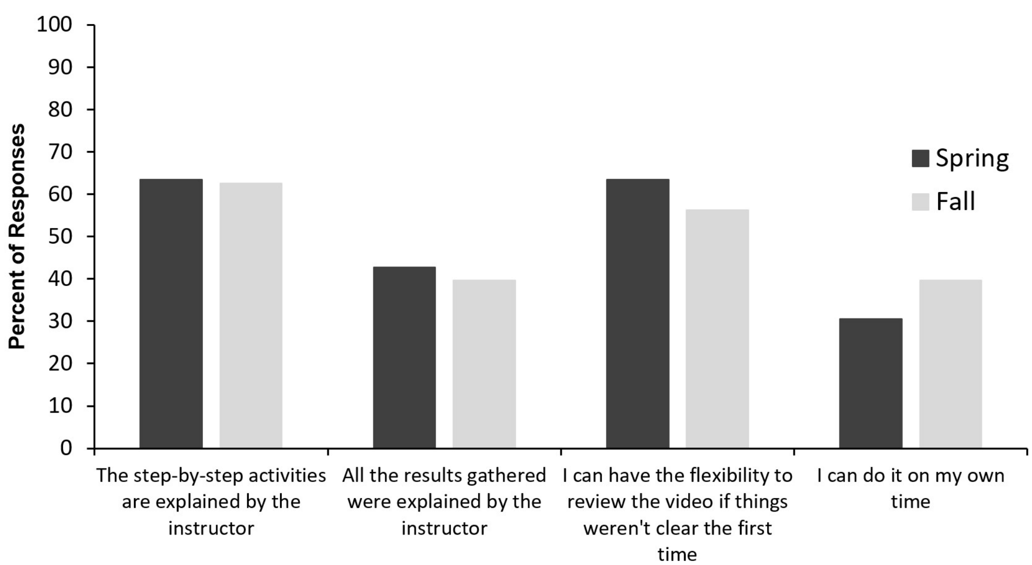


Figure 4

Top beneficial aspects of the virtual laboratory exercises chosen by the students.



Note. *Students were asked to identify their top two benefits.*

Benefits and Challenges

Instructor guidance and flexibility in doing lab activities were considered by students as very important aspects of a lab session. An average of 63% of student-respondents across two semesters considered the "step-by-step explanation of activities by the instructor" as the primary benefit of the virtual labs (Fig. 4). The "flexibility to review the videos" was the second-ranked benefit (60%). While not rated highly in the survey, at least 35% of student-respondents have chosen "results gathered explained by instructor" and "I can do it on my own time" as the benefits that they have gotten from the virtual labs. These inherent positive attributes of virtual laboratory, among others, were also reported in earlier reviews and studies that used the same or a different version of virtual laboratory (Ramasundaram et al., 2005; Ma & Nickerson, 2006; Elliot and Kukula, 2007; de Jong et al., 2013; de Vries & May, 2019; Kapici et al., 2019; Reeves & Crippen, 2021).

The virtual laboratory sessions evaluated in this study have their own share of issues and challenges. Figure 5 shows that in both semesters, students consistently ranked the top three challenging aspects of the virtual laboratory sessions to be as follows: 1) the absence of actual hands-on experience, 2) not having the lab instructors to address questions, and 3) not having classmates to discuss answers with. Seventy percent of the students in the spring ranked the absence of hands-on experience as the most challenging aspect and 81% of the students in the succeeding fall semester also thought the same. These results indicate that a majority of students still favor active in-person sessions over virtual laboratory delivery despite the latter's perceived effectiveness in achieving learning. This can possibly be explained by the fact that in-person settings could have a positive influence on students' motivation (Dyrberg et al., 2017) to engage and complete the lab exercise considering that they have access to help from classmates and immediate guidance from lab instructors. It should be noted, however, that some studies have reported students' preference for virtual labs and increased motivation compared to traditional face-to-face labs (Flowers, 2011; De Vries & May, 2019). In addition, students seemed to value the importance of student interaction with at least 38% of the respondents choosing the absence of classmates as one of the top challenges.

Interestingly, while 62% of student-respondents considered the absence of the instructor as a challenging aspect in the spring semester, only 50% of the students in the following fall semester thought the same. This was possibly because, having experienced distance learning in the spring semester of 2020, more students have become more accustomed to learning without the in-person guidance of instructors in the fall of 2020.

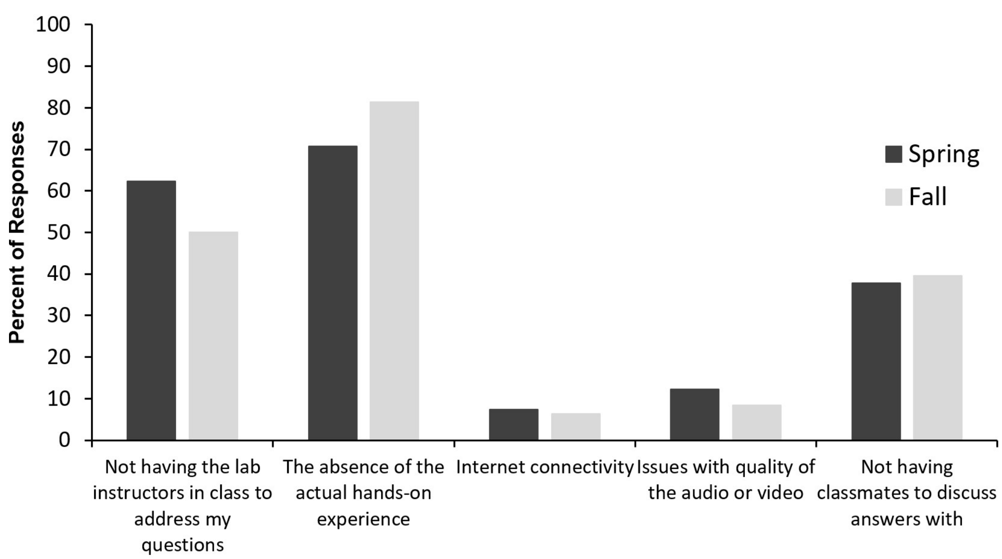
Virtual as a Substitute to In-person

Although both classes were asked whether the virtual laboratory activities were successful and total substitutes for in-person laboratory sessions, only the responses by students in SOIL 2124 are presented in Figures 6 and 7. This is because while the students in SOIL 2124 have experienced both in-person and virtual laboratory activities and are then able to judge the relative effectiveness of the virtual labs, students in SOIL 1113 did not have any in-person sessions to compare and evaluate the relative effectiveness of the virtual laboratory activities . Results indicate that considering the sudden shift to an online course delivery because of the COVID-19 pandemic, greater than 90% of students in SOIL 2124 agreed or strongly agreed that the virtual laboratory sessions were successful substitutes for the in-person, hands-on laboratory activities (Fig. 6).

Students were divided when asked whether the virtual laboratory sessions can totally substitute in-person laboratory exercises. Figure 7 indicates that only 51% of

Figure 5

Top challenging aspects of the virtual laboratory exercises chosen by the students.



Note. *Students were asked to identify their top two challenges.*

Figure 6

Level of agreement by students in SOIL 2124 to the statement: Considering the unexpected change in course delivery into the online format due to COVID-19, the virtual laboratory activities were successful substitutes to in-person, hands-on laboratory activities.

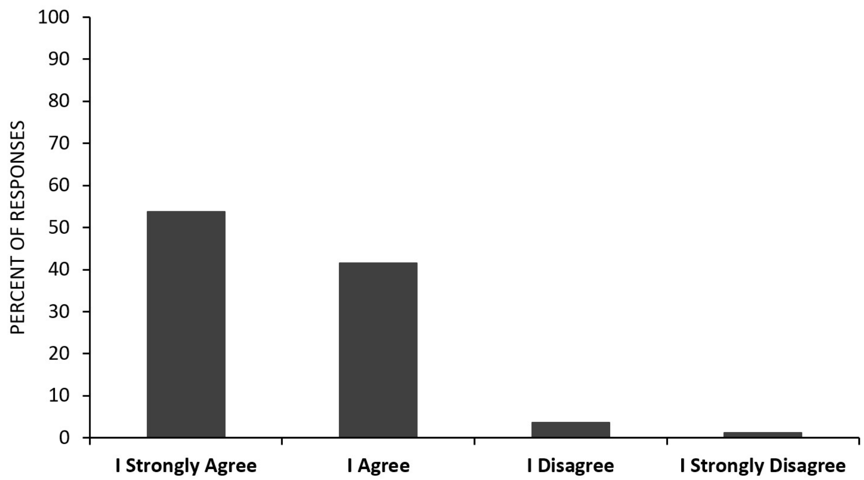
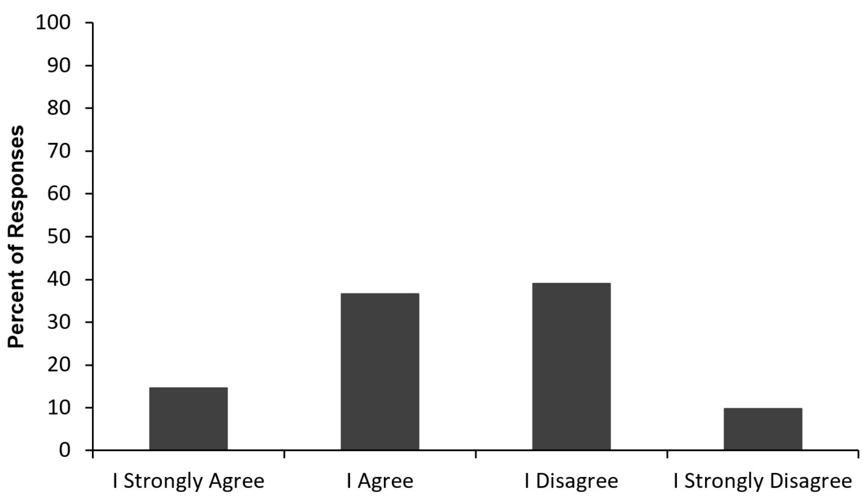


Figure 7

Level of student agreement by students in SOIL 2124 to the statement: The virtual laboratory session can totally substitute an in-person, hands-on laboratory exercise.



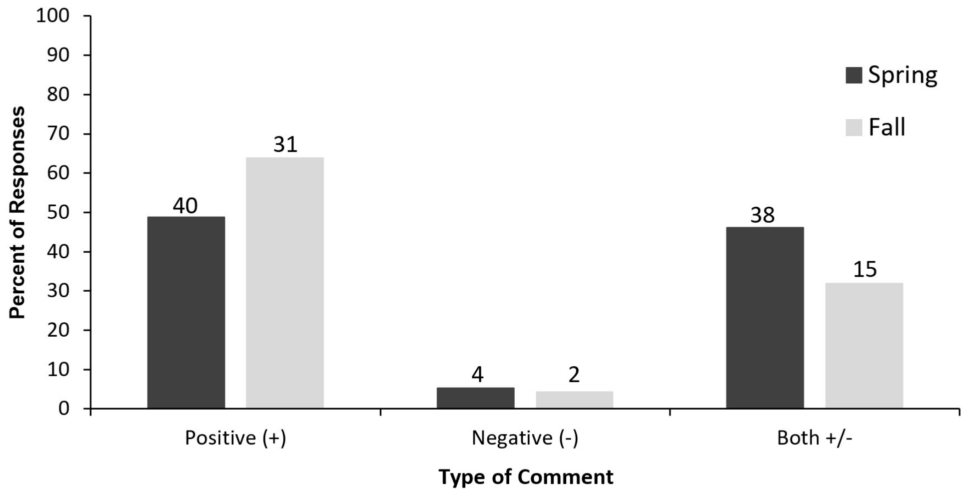
the students in SOIL 2124 agreed or strongly agreed that virtual labs can totally substitute for in-person sessions. This means that although the virtual laboratory sessions were effective teaching tools for extreme circumstances like in a pandemic, many students still do not consider it as a total substitute to in-person learning. However, slightly more than half of the students indicated that virtual laboratory sessions can substitute an in-person laboratory class and as shown in some studies, the use of a virtual laboratory was equivalent to the typical hands-on laboratories (Hawkins & Phelps, 2013; Kapici et al., 2019) in terms of effectiveness. The same was reported in the study of Durand et al. (2019) when comparing the use of live specimen versus recorded videos for physiology practical classes. They found no difference in terms of final grade among the different tested groups.

Nature of Student Comments

All students who participated in the survey wrote some comments. Figure 8 shows that despite some challenges, most students still had a positive experience with the virtual labs. Common positive comments include: were well-planned and well-prepared, easy to follow and understood, can be performed at desired pace and can be replayed to verify key points, helpful in enhancing concepts discussed in the lecture, and considering the circumstance, the virtual labs were effective substitutes for in-person activities. There was also a marked increase in positive feedback from the spring (49%) to the fall semester (64%). The general increase in positive comments from spring to the fall semester may be attributed to the students getting more used to the virtual and/or online learning delivery of courses. Negative comments only accounted for 5% (4 out of 82) and 4% (2 out of 48) in SOIL 2124 and SOIL 1113, respectively. Common negative comments include: problems with the audio, inability to ask

Figure 8

Summary of the nature of student comments about the virtual laboratory exercises. Note: values on top of the bars represent the number of comments that belong to each category.



for immediate help, and not as good as in-person activities. The most common comment that included both a positive and a negative point was the virtual activities were effective substitutes for in-person activities but still not as good as having hands-on experience.

Teacher Experience

The set-ups for the virtual laboratory sessions were the same as those for the corresponding in-person labs and thus, there was essentially no difference in preparation time. Before shooting the video clips for each virtual lab session, the video preparation team needed around 30 minutes to discuss key items that needed to be included in the video clips, and sometimes, to rehearse the activity that needed to be captured in the videos. It took the teaching team between 2 to 3 hours to shoot all the video clips, including the pre-lab and the instructions video clips, that were needed for each virtual laboratory session. Another 1 ½ hours were needed to edit the video clips, prepare the composite video, and to upload it online.

The biggest challenge was in making sure that the audio was audible and clear, and that the lighting was effective. Having received no training in video production and post-production, shooting and editing videos were also challenging particularly in producing the first virtual lab. Despite the challenges and the extra time needed to prepare the virtual laboratory sessions, we believe that it was worth it because it allowed us to generate an alternative teaching tool that complemented the lectures, and effectively enhanced student understanding and appreciation of soil science concepts.

Limitations

Results of the survey are student perceptions and while their perceptions indicate that virtual laboratory activities have enhanced understanding and appreciation of soil science, it should be noted that no efforts were performed to quantify and ascertain the degree by which the virtual activities have improved learning. However, it has been shown that students' perceptions of the instructor and the course materials are good predictors of their course effort and subsequently, their course grade (Jones et al., 2021).

While the two courses involved in this study are both classified as introductory-level soil science courses and have considerable overlap in topics covered, they differ significantly in terms of course delivery. SOIL 2124 has a designated laboratory session and students in this cohort group expect to have some hands-on component in the course which they have experienced prior to the shift to virtual laboratory activities later in the semester because of the COVID-19 pandemic. Having experienced both types of laboratory sessions has equipped the students in SOIL 2124 with the capacity to assess whether virtual laboratory activities are successful substitutes to in-person laboratory sessions. Conversely, SOIL 1113 does not have a designated laboratory component which means that students do not expect any hands-on activities in the course. In addition, they took the course during a semester when the laboratory activities were all delivered virtually. As a result, students in SOIL 1113 are not able to evaluate whether the virtual laboratory activities can substitute in-person laboratory sessions. This was the reason why Figures 6 and 7 only contained survey results from SOIL 2124 students.

Summary and Implications

In reaction to health and safety protocols that were implemented during the height of the COVID-19 pandemic, virtual laboratory sessions were developed for two introductory-level soil science courses. This study/survey was designed to gather student perceptions about utilizing virtual laboratory sessions as substitute to in-person laboratory exercises. Survey responses reveal that a great majority of students agree or strongly agree that virtual labs successfully demonstrated important processes and that understanding of key soil science concepts would have been difficult without them. The virtual labs also enhanced student appreciation of important soil science concepts.

While it came with challenges, 90% of students considered the virtual labs as successful substitutes for hands-on exercises when considering the sudden shift to fully online class delivery during the height of the COVID-19 pandemic. Interestingly, survey results show that while the virtual labs are successful teaching tools, only 50% of the students agreed that the virtual labs could totally substitute in-person laboratory sessions. Judging by the nature of student comments in the survey, it seemed that they have grown to positively adjust to the virtual delivery of the labs from one semester to the next and they really liked the ability to review the laboratory video if things were unclear the first time. The absence of instructors who could immediately address questions and classmates to discuss results were the two main challenges highlighted by the students. Despite these challenges and the extra work needed to prepare the virtual laboratory materials, they really were worth doing because they allowed for the effective delivery of the laboratory classes during semesters when instructors and students had to deal with health and safety concerns.

The positive perceptions by students concerning the ability of the virtual laboratory activities to enhance understanding and appreciation of soils science concepts was enough justification for the decision to keep virtual laboratory activities a post-pandemic component of both courses. Virtual laboratory activities that were prepared during the COVID-19 pandemic were improved and new ones were prepared and have since been used when in-person classes have been cancelled because of weather-related reasons and as a resource for student needing a make-up laboratory session.

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