Received: 11 November 2020 | Accepted: 22 March 2021

DOI: 10.1002/nse2.20053

Natural Sciences Education

SPECIAL SECTION: NATURAL SCIENCES EDUCATION IN A COVID-19 WORLD

The pros and cons of teaching soil fertility live versus online

Robert L. Mahler

Dep. of Soil and Water Systems, Univ. of Idaho – Boise Water Center, 322 E. Front Street, Suite 120, Boise, Idaho 83702, USA

Correspondence
Robert L. Mahler, Dep. of Soil and Water Systems, Univ. of Idaho – Boise Water Center, 322 E. Front Street, Suite 120, Boise, ID, 83702, USA.
Email: bmahler@uidaho.edu

Assigned to Associate Editor Bethann Garramon Merkle.

Abstract

The COVID-19 pandemic in 2020 has changed the way higher education delivers materials to students. The purpose of this study is to compare the pros and cons of teaching Soil Fertility and Plant Nutrition (Soils 446), a class with a history of being taught live and online, from both the live and online perspectives. For our comparison, the following data was gathered: (a) history of when and how the class was offered, (b) content of Soils 446, (c) assessment of student achievement, (d) student evaluations of the course conducted by the University of Idaho, and (e) a post-class survey of online students. Reasons for live classroom teaching being superior include: (a) classroom interaction with the instructor and other students, (b) allowing students to ask questions of the instructor during the lecture, right after class or on a face-to-face basis during designated office hours, and (c) the availability of local library resources and other staff to help with questions and projects. Reasons for online teaching being superior include: (a) distance students can take this class, (b) the online course may offer better time management for distance students, and (c) email, bblearn, ZOOM, and SKYPE are tools that allow frequent contact between the student and instructor. Motivated students were successful in both approaches. For less or unmotivated students both delivery methods are equally mediocre.

1 | INTRODUCTION

Moving higher education to an online format in times of political unrest, public health emergencies, natural disasters, or armed conflict is not new (Bebe, 2010; Lorenzo, 2008) However, the scope of COVID-19 impacts on higher education were in that the pandemic's onset was swift and global in nature in 2020. This pandemic caused most institutions of higher education to rapidly develop a teaching plan to deal with this disruption (Quezada et al., 2020). This rapid increase in non-traditional distance education (hybrid classes and online delivery) burdened most institutions of higher education (Brom et al., 2020). This rapid movement to online education was observed worldwide (Dhawn, 2020; Osman, 2020; Wotto, 2020). For example, since March 2020 Chinese universities experienced a massive movement from traditional classroom education to online education (Bao, 2020). In the United States, faculty with and without experience in online teaching rapidly moved to online teaching to allow students to continue their studies (Johnson et al., 2020). Unfortunately, the movement to distance education may have placed some minority and special needs students at a disadvantage (Harper, 2020). The scientific literature is mixed about this concern; however, studies in the United Kingdom show that the attainment gap between ethnic minority students and ethnic majority students taking courses online was not greater than in live classroom settings (Richardson, 2011, 2012).

Abbreviations: CALS-REC, College of Agriculture Research and Extension Center; ENVS 446/546, Drinking water and human health; LGU, land grant university; Soils 446, Soil fertility and plant nutrition course; UI, University of Idaho.

In the past year, institutions of higher education in the United States and Canada with agricultural and natural resource programs have used distance learning to educate both college students and the public through programs provided by Extension (Jepson et al., 2020). One roadblock to this educational process is that educators in general, and agricultural educators specifically, do not have uniform definitions or approaches for remote instruction and distance education (Dooley et al., 2005; Moore, 1997; Linder et al., 2020).

The COVID-19 pandemic in 2020 has also changed the way higher education delivers materials to students. Although many believe that once the pandemic subsides educational delivery will return to the normal delivery method of conducting live classes with students in the classroom, some educators believe that the COVID-19 pandemic will change traditional delivery methods at institutions of higher education forever. Traditional colleges and universities in the United States and Canada that have agricultural and natural resources programs have primarily used face-to-face (live) education for the last 100+ years. This changed abruptly in March 2020. Basically, overnight many of these agricultural institutions were forced into alternate methods of educational delivery because in many cases traditional students were banned from campus. Instead of traditional face-to-face classes in classrooms, hybrid classes, classes conducted by ZOOM and several types of distance education classes including online classes were hurriedly developed to allow students to continue their education.

The soil fertility and plant nutrition course (Soils 446) at the University of Idaho (UI) has been taught for the last 100 years. It has been taught by the same instructor (author) for the last 40 years. The initial format of the course was face-to-face teaching in a classroom setting between 1981 and 2012. Since 2013 this class has been offered online only. The Internet-based course management system, bblearn, has been used to deliver and evaluate the online version of this class.

Idaho's land grant university (LGU) location in Moscow, ID, was based on a political compromise to obtain statehood in the late 1880s rather than being physically located where most of the agricultural industry was developed more than 450 kilometers away. This distance makes it impractical for many students and professionals working in the agriculture industry to travel to Moscow to take Soils 446. This is a major problem because more than 100 major agricultural commodities are produced on the 2.7 million hectares of irrigated land that is far away from Idaho's LGU. Because of the perceived need to offer this class to clientele in southern Idaho, a delivery method other than the traditional classroom setting was developed.

In 1990, a proposal was made to the dean of the College of Agriculture and Life Sciences to turn this course into a distance class that would geographically serve the entire state. This proposal was approved, and Soils 446 became the first course in the college to be offered via distance. Because of the need for Soils 446 in southern Idaho, the courses' lectures were put on VHS tapes and shipped to four CALS Research and Extension Centers (CALS-RECs) at Parma, Twin Falls, Aberdeen, and Idaho Falls. Distance students could pick up and borrow the lecture tapes and have three exams proctored at one of the four Centers. Approximately eight students per year took the course this way between 1991 and 1998. By 1999 the lectures were recorded on compact discs and mailed to individual students in southern Idaho. At predetermined intervals, the enrolled students received open note, open book exams emphasizing problem-solving skills, then mailed back to the course instructor who in turn graded student progress. Approximately six students per year used this technology to take Soils 446 between 1999 and 2011.

Core Ideas

- This study compared the pros and cons of teaching Soils 446 live in the classroom vs. using an online version.
- Student evaluations for both delivery methods were very good and above the university average.
- Online students expanded enrollment by 33%.
- The use of SKYPE, ZOOM, and email allow frequent contact between the student and instructor partially offsetting the advantage of live teaching.
- For the motivated student, both the live class and the online version can provide an equally good experience.

The number of students taking Soils 446 using VHS tapes and compact discs between 1991 and 2011 was equivalent to almost 30% of the live (on campus) enrollment. Consequently, it appeared that the demand was great enough to create an online version of this course. The online version was initiated in 2013 and included prerecorded lectures and was built and operated through UI's bblearn system. At this point the decision was made to offer Soils 446 online only.

The Soils 446 class contained 40 lectures identified in Table 1 and are identical in the live and online versions of the class. The class was taught live between 1981 and 2012. It was taught as an online course only since 2013. Between 1992 and 2012 a hybrid delivery method was offered for a few distance students in southern Idaho. Between 1992 and 2000 lectures were videotaped and mailed to a limited number of off-campus graduate students. Between 2001 and 2012 lectures were placed on compact discs that were mailed to a few dozen off campus students. By 2012 the decision was made to

TABLE 1 Content of the soil fertility and plant nutrition course taught at the University of Idaho for the last 40 years (1981–2020)

Section	Theme	Lecture number	Lecture topic
I	Soil essentials	01	Introduction
		02	Essential elements required for plant growth
		03	Importance of fertilizer
		04	Ion exchange
		05	Nutrient mobility in soils
		06	Soil pH management
		07	Soil pH – acidification
		08	Soil pH – aluminum and hydrogen
		09	Soil pH management – lime
II	Nitrogen		
		10	Nitrogen cycle
		11	Nitrogen fixation
		12	Mineralization
		13	Nitrification and nitrates
		14	Nitrogen losses from soils
		15	Plant responses to nitrogen
		16	Predicting nitrogen needs
		17	Nitrogen fertilizers
III	Phosphorus, potassium, and sulfur		
		18	Soil phosphorus
		19	Phosphorus technology
		20	Phosphorus fertilizers
		21	Using phosphorus fertilizers/placement
		22	Potassium
		23	Potassium fertilization/fertilizers
		24	Sulfur in soils
		25	Sulfur fertilization/fertilizers
IV	Micronutrients		
		26	Boron
		27	Zinc
		28	Molybdenum
		29	Copper and chlorine
		30	Iron
		31	Manganese and nickel
V	Sampling		
		32	Soil variability/sampling
		33	Soil sampling
		34	Special sampling in soils
		35	Soil test correlation
		36	Plant diagnostics
		37	Crop logging
		38	Nutrient deficiencies
		39	Fertilizer recommendations
		40	Snake oils/wonder products

make the class available as an online class. This online class replaced the traditional live lecture class in 2013. A textbook has not been used in this class since 1998.

Even though both the live and online versions of the class were identical in lecture topics covered, assessment methods to determine the success of enrolled students were different (Table 2). Exams and attendance were emphasized in the live class version. The live version contained five exams, one covering each of the five main course sections. Attendance comprised between 10 and 20% of the course grade. In some semesters an additional project was required of students. The additional project was the development of either a farm nutrient management plan or compiling a set of images showing the nutrient deficiency symptoms for a particular plant species. Conversely, student assessment consisted entirely of homework assignments in the online class version. In the online version of the course there were 10 required homework assignments – approximately one assignment after every four lectures. These assignments consisted of 6–10 questions and students submitted their assignment answers through the university bblearn system. Exams, attendance, and projects were not used to assess student learning objectives for the online version of the course.

The hypothesis associated with this study initiated in 2013 was that live classroom teaching (based on historical data such as student evaluations and grades between 1980 and 2012) would be superior to distance learning for Soils 446. In addition, it was hypothesized that a distance class version of Soils 446 containing frequent student interaction and frequent homework assignments would keep student engagement at a high level and partially offset the negative impacts of not having live face-to-face teaching.

2 | MATERIALS AND METHODS

The following data from the Soil Fertility and Plant Nutrition (Soils 446) live and online course were gathered: (a) history of when and how the class was offered, (b) the lecture topic content, (c) assessment of student achievement, (d) student evaluations of the course conducted by the UI, and (e) post-class survey of online students.

TABLE 2 Assessment methods used to determine the success of students enrolled in the soil fertility and plant nutrition class at the University of Idaho between 1981 and 2020

Assessment parameter	Live class, 1981–2012	Online class, 2013–2020
Attendance	Used(10–20% of grade)	Not used
Exams	Used(70–85% of grade)	Not used
Homework assignments	Not used	Used (10 assignments–100% of grade)
Projects	Used sometimes(0–10% of grade)	Not used

2.1 | Survey of online students

A 12-question survey of online students enrolled in Soils 446 was developed and sent to approximately 65% of the online students taking the class between 2013 and 2020. Course enrollment was 235 during this 7-year period of time. Surveys were sent to 148 of the 235 enrolled online students. Students to be surveyed were selected each term in a random, but simple manner. At the end of each semester after grades were determined each student was sent their final grade and asked to acknowledge the receipt of their grade. The first 65% of the students that responded to this request at the end of each term were sent the survey. The 65% value was based on the historic records that only about two-thirds of students acknowledge that they have received their final grade in both the live and distance versions of the class. Student answers to these surveys were anonymous. Even though approximately 20% of the students enrolled in the online version of the course were ethnic minority or special needs students because these surveys were anonymous and did not ask demographic information questions this study was unable to evaluate differences due to ethnicity or special needs.

The seven objective survey questions were: (1) Would you have been able to take this class if it were only offered live? (2) How many times did you contact the instructor with questions about the lectures or course materials? (3) Do you feel that your grade would have been higher if you took the class live? (4) Given a choice (if you had been living in Moscow) would you have preferred to take the course live or online? (5) Will you be able to use the information from this class in your profession? (6) There were 10 homework assignments associated with the course.- comment on their frequency; and (7) Compared to other courses that you have taken at the University of Idaho, rate the value of this course.

The five open-ended survey questions were: (1) Comment on the value of the voiced-over recorded PowerPoint lectures; (2) Comment on the value of the handouts provided with the class; (3) Comment on the type of homework questions provided in the class – were they primarily a regurgitation of the lecture material or were they actually problem solving questions? (4) Comment about the course lecture materials – could you identify topics that were inappropriate for this class? and (5) Were there any topics that you could identify that should be added to this course?

Answers to the objective questions from the 2013, 2014, 2015, 2016, 2017, 2018, 2019, and 2020 semesters were added together to generate tables that showed student percentage answers. Answers to open-ended questions were compiled from the seven study years and the most frequent answers are discussed in this paper.

2.2 | Comparison of pros and cons of course delivery to students

The data collected using the above methodology and first-hand observations were used to determine: (a) the delivery pros of the live Soils 446 class, (b) the delivery cons of the live Soils 446 class, (c) the delivery pros of the online Soils 446 class, (d) the delivery cons of the online Soils 446 class, and (e) an overall assessment of the live vs. online Soils 446 class.

Motivated students. Motivated on-line students in this class were defined based on three criteria: (a) students that completed all online homework assignments on time, (b), students interacted with the instructor, via email, SKYPE or ZOOM, at least 11 times during the term, and (c) students that received an A or B in the class. All three criteria had to be met for the student to be defined as motivated. Less motivated students were those that met only two of the three criteria that were used to define motivated students. Conversely, unmotivated students met less than two of the criteria that determined motivated students.

3 | RESULTS AND DISCUSSION

Courses in soil fertility and plant nutrition have been offered at the UI since the early 1920s. Soils 446 has traditionally been a lecture class worth three credits (semester system). The author of this paper has taught this class since 1981 every spring semester. In this 40-year period approximately 975 students have successfully completed this class. The average semester enrollment has been 24 students with a range of 13–59 students each time it was taught. The basic components of the

TABLE 3 Average student evaluation scores of the soil fertility and plant nutrition class for both live and online versions on a four-point scale. (Scale: 4 = Strongly Agree; 3 = Agree, 2 = Neutral, 1 = Disagree, 0 = Strongly disagree)

Evaluated aspect	Live class, 1981–2012	Online class, 2013–2020
	Score	
Instructor expressed clear expectationsfor learning objectives	3.7[a]	3.4
The content and organization of thewere clear	3.8	3.3
Instructor delivery and effort contributedto the understanding of thecourse material	3.7	3.2
University average of above threescores	3.1	2.8

[a]In certain years between 1981 and 1995 some student scores were based on a five-point scale; these numbers were converted to a four-point scale to compare delivery methods.

course have remained the same since 1981 (Table 1). The five main sections of the class have included: (1) soil essentials; (2) nitrogen; (3) phosphorus, potassium and sulfur; (4) micronutrients; and (5) sampling and recommendations. These five main themes are taught in virtually all college soil fertility and plant nutrition classes in North America.

3.1 | University of Idaho student evaluations

Students evaluated the quality of their classes using a UI-wide evaluation system that was based on a four-point scale. The rating scale was as follows: 4 = strongly agree with the rating statement; 3 = agree with the rating statement; 2 = neutral about the rating statement; 1 = disagree with the rating statement; 0 = strongly disagree with the rating statement. Near the end of each term the UI evaluation system asked students a series of questions about the course they took. All evaluations were anonymous and average student evaluation scores are shown in Table 3. It should be noted that the last row of Table 3 provides university average scores for both live and online classes. Average live class evaluation scores were 3.1, while the average score was 2.7 for online classes. The difference in score averages seems to indicate that students in general, were generally less satisfied with their experience with online classes. This numerical difference was also apparent for the Soils 446 class. However, the evaluation scores for both the live and online versions of Soils 446 were above the university average. Basically, the average online student at least agreed (score >3.0) that learning objectives, course organization, and instructor delivery were good. However, they provided lower evaluation scores than live versions of the class. This is further discussed in the context of the online student survey below.

3.2 | Survey of online students

A portion of the students taking soil fertility and plant nutrition online between 2013 and 2020 were surveyed to determine their experience in the course. Approximately 65% of the 235 online students during this time period received surveys after the semester ended. The surveys were completed and returned by 50.9% of the students receiving surveys. Relevant demographics of the surveyed students are shown in Table 4. Approximately 52% of surveyed students were female. Over two-thirds of the students completing the surveys were undergraduate students either enrolled in degree or non-degree programs. One-third of the students were in graduate degree programs. This distribution would be expected because the course was taught at the 400 (senior) level and provided credit to both undergraduate and graduate students.

TABLE 4 Demographic information about online students that filled out the survey about the soil fertility and plant nutrition course between 2013 and 2020

Demographic	Parameter	Percentage of students
Gender	Female	58
	Male	42
College status	Undergraduate	67
	Graduate	33
Major	Plant or soil science	38
	Environmental science	27
	Other	35
Physical location	Resident (Moscow)	63
	Distance (place-bound)	37

Ten different majors were represented by the students enrolled in this online class. The largest group of students (38%) were majoring either in plant or soil sciences. Another 27% of students were either enrolled in undergraduate or graduate environmental science programs. Eighteen percent of the students were general agriculture majors. The other 17% of students represented six other majors including agricultural economics, agricultural engineering, agricultural mechanization, agricultural education, animal sciences, and business and economics.

Sixty-three percent of the students were physically located at the UI on the Moscow campus, while the other 37% were distance students. The distance students represented 10

TABLE 5 Evaluation of online students about the soil fertility and plant nutrition coarse at the University of Idaho between 2013 and 2020

Question	Answer	Percentage
Would you have been able to take this class if it were only offered live?		
	Yes	63
	No	37
How many times did you contact the instructor with questions about lectures or course materials?		
	0	15
	1–3	22
	4–10	18
	11–20	28
	20+	17
Do you feel that your grade would have been higher if you took the class live?		
	Yes	17
	No	83
Given a choice (if you had been living in Moscow) would you have preferred to take the course live or online?		
	Live	38
	Online	44
	No preference	18
Will you be able to use the information from this class in your profession?		
	Yes	92
	No	8
There were 10 assignments associated with the course.Comment on their frequency.		
	Too many	18
	Appropriate number	74
	Too few	8
Compared to other lecture courses that you have taken at the University of Idaho, rate the value of this course:		
	Better than 90%	24
	Better than 75%	45
	Better than 50%	22
	Better than 25%	6
	Better than 10%	3

different communities in Idaho and four communities in other states. More than 80% of distance students were enrolled in undergraduate or graduate programs at the UI. Distance education was responsible for 37% of the enrollment in this course.

The survey completed by the online students between 2013 and 2020 contained 12 questions. Five of the questions were open-ended, while the other seven questions were objective in nature. The summarized answers to the seven objective questions are shown in Table 5. Based on the answers shown in Table 5, 37% of the students would not have been able to take this class if it were only offered live. This percentage exactly corresponds to the percentage of distance.

Eighty-five percent of students in the online course contacted the instructor directly with questions about lectures and/or course materials. In fact, 63% of the students directly contacted the instructor by email, telephone, ZOOM, or SKYPE at least four times during the course. Contacts of 11 or more times were made by 45% of the students in the class. These relatively high numbers show that despite

taking an online course these students were actively engaged in the class.

Eighty-three percent of online students felt that the grade they earned would have been the same if they had taken the class live. Consequently, from an achievement standpoint they thought that the live and online versions of the class were comparable. If students had been located in Moscow (home of the UI) 62% of them would have preferred to take the class online or had no preference. This is an important information that shows that a majority of the students taking the class online did not feel at a disadvantage to students taking the live version of the class (Table 5). This survey answer contrasts with the UI evaluation system that showed less satisfaction with online courses.

More than 90% of the online students completing the survey felt that the information obtained in the class would be useful to them in the future. Compared to a live version of science-based classes, the online version of Soils 446 assessed the academic progress of students more frequently. There were 10 required assignments of students for course completion. This is twice the number of student assessments than the live version of the class required. Almost three-quarters of the surveyed online students considered the 10 assignments as an appropriate number for student assessment (Table 5). One-fifth of the students thought that 10 assignments were too many, while only 8% felt that the number of assignments was too few. The number of assignments was designed to keep students engaged in the class throughout the semester – an assignment was due after every four lectures. Based on the student survey, they agreed with the frequent assessment.

Online students were pleased with the class based on the survey as 69% of students considered soil fertility and plant nutrition better than 75% of the courses that they had taken at the UI (Table 5). This high level of satisfaction with the value of this class between 2013 and 2020 compared to other courses offered by this institution more than offsets the negatives associated with online teaching compared to live courses.

Five other open-ended questions were on the survey. The questions were about the voiced-over PowerPoint lectures, value of handouts and the need for a textbook. The students generally liked the voiced over PowerPoint lectures and the ability to print the lectures for their notes and as study aids. More than 87% of students indicated that they got value from the handouts ($n = 68$) and were glad that a textbook was not required. A textbook for this class has not been required for the live or online versions of the class since 1998. An additional series of 15 handouts about various aspects of soil fertility were made available on bblearn. Virtually all of the handouts were Extension publications on soil fertility issues from different western states and Canadian provinces. In the survey, 90% of students ($n = 70$) thought that the Extension-based handouts were excellent and they added significant value to the class.

3.3 | Pros and cons of Soils 446 delivery method

Based on the information collected about assessment of student achievement, UI-level student evaluations of Soils 446, post-class surveys on the online version of Soils 446 and instructor observations the major pros and cons of delivering Soils 446 live and online are presented below.

3.4 | Pros of delivering the soil fertility and plant nutrition class live

Colleges and universities with agricultural and natural resource programs in the United States and Canada have traditionally delivered coursework live on campus. More than 90% of soil sciences classes have been delivered live in the classroom to students since agricultural colleges were founded (communications). Many of the distance students were on campus because the traditional live version of the class was taught only prior to 2013. Based on the methodology used in this study and instructor observations the advantages (or pros) of delivering Soils 446 live include:

- Students in a classroom can interact with the instructor on a regular basis.
- The classroom setting allows students to ask appropriate questions during and after the lecture period.
- The classroom setting allows students to ask questions of the instructor right after the class period is over and possibly follow the instructor back to their office.
- Students taking the same class have the ability to interact with and get to know each other.
- Students taking the same class have the ability to help, study, and interact with each other.
- On-campus students have access to the library and can meet with the instructor during office hours.
- Plant and/or soil materials brought to class by the instructor can be passed around the classroom.
- On-campus plant materials can be used for live observations of nutrient deficiency symptoms.
- The campus setting allows students to interact with other faculty, graduate students, and teaching assistants about specific soil fertility and plant nutrition problems.
- The campus is a vast resource that can be used by students to enhance their course experience.

3.5 | Cons of delivering the soil fertility and plant nutrition class live

Despite all the advantages associated with a live -formatted course there are some disadvantages which include:

- Soils 446 is taught at a specific time of the day – this time slot may conflict with other classes.
- Students have limited flexibility about the times they can learn soil fertility and plant nutrition – lectures, exams, etc.
- Students are expected to attend lectures and part of their grade may be based on attendance.
- Field trips in other courses may cause students to miss a number of lectures.
- Student progress in live courses is often evaluated using exams. Many students have exam anxiety and their performance on these may not adequately reflect their achievement in the class.
- Some students learn better on their own, not in a classroom setting.

3.6 | Pros of delivering the soils fertility and plant nutrition course to students learning online

Although most educators believe that live in-person education and learning is preferable at institutions of higher education (Seaman, 2009; Kizilcec & Halawa, 2015), there are several advantages to offering Soils 446 to students using the online technology that has delivered this course for the last 8 years. Also, over half of university presidents say that live and online courses have equal value and that most students are satisfied with the online format (Parker et al., 2011; Mahmood et al., 2012) Some of these major advantages of online education include:

- Distance students can take this college level class.
- The online course may offer better time management options for distance students; instead of each lecture being at a set time the students have several days to view each lecture.
- Email, bblearn, ZOOM, and SKYPE allow frequent and time convenient contact between the student and instructor.
- Students receive the same lecture material and handouts that students in the live class do.
- No exam anxiety.
- Frequent homework assignments keep the online students more engaged in the course materials.
- University of Idaho conducted evaluations were better for this course than for average evaluation scores for live classes.
- Final grades students obtained from the online and live versions of Soils 446 were similar, which suggests online students were not at a disadvantage to obtain high grades.
- Post-course student evaluations distributed by the instructor showed a high level of satisfaction with this class being taught using an online format.
- Students have access to the same handouts as students in the live version of the class.

3.7 | Cons of delivering the soil fertility and plant nutrition class to students online

Most administrators, faculty, and teaching assistants would agree that delivery of agricultural classes to students using an online platform is less desirable to reach desired learning outcomes for students (Parker et al., 2011; Seaman, 2009). The reasons for this belief include:

- A student taking an online class has no direct contact with other students in the class.
- Students have less contact with the instructor. Added effort is required to forge this learning bond between student and instructor.
- An online student cannot ask a question during the lecture and receive a rapid response from the instructor.
- Online lectures are probably more boring than live lectures. The online lectures offer no spontaneity to digesting course material.
- Online students have less contact with campus resources that could enhance the value of the class.
- Online students have no exposure to other campus faculty, graduate students, and teaching assistants that could serve as an additional resource for the class.
- Students need to be more proactive to get the most out of the course compared to students taking the class live.
- Distance students living in communities with limited bandwidth may have difficulty downloading some of the extra reading materials for the class.

3.8 | Comparison of live versus online education

Which method is best for delivery of Soils 446 to students? Based on the information presented above the correct answer is likely: It depends. Ten years ago, face-to-face instruction in a classroom was the best way to deliver Soils 446. However, today in the answer is not obvious. This is because technology now allows online students to interact one-on-one with the instructor more easily. The availability of email, bblearn, ZOOM, and SKYPE allow distance students to easily connect with the instructor. As shown by the student survey results

almost half of the students contacted the instructor at least 11 times during the semester. Because of the wider use of this newer technology the best mode of course delivery is different for different students.

Live classroom instruction is the best method of teaching Soils 446 to the average student. This option provides face-to-face learning, good contact with the instructor and other students in the class, and provides a structure that will make the average student more successful. This structural setting will allow this group of students to succeed in the Soils 446 class.

Live classroom instruction and the online version of Soils 446 both work well for high-achieving students. High-achieving students will use email, ZOOM, and/or SKYPE to contact and work directly with the instructor many times during the course. The use of this technology will help to negate some of the cons of the online version of the course.

Both face-to-face classroom instruction and the online version of Soils 446 are poor options for underachieving students. It is not easy to motivate underachieving students with moderate or large university classes.

Lessons learned. Even though many educators and researchers believe that live in-class instruction is superior to online (distance) instruction, several studies in recent years have shown that the innovative use of educational tools can greatly narrow the student success gap between the two methods of delivery (Bettinger et al., 2017). This study has tried to use some of these innovative tools including making online students more motivated and constant email contact with the distance student (Archibald & Barnes, 2017; Fuller & Yu, 2014; Dell et al., 2008).

Many of the lessons learned from teaching Soil Fertility and Plant Nutrition on an online basis from the past 8 years can be translated to other general and specific soil science courses in North America. Some of these lessons learned include:

- Have a plan to turn online students into motivated students.
- Start with a detailed course syllabus with precise timelines for lectures and assignment due dates.
- A homework assignment required each week keeps the online student engaged in the course.
- Encourage student questions and feedback on a regular basis.
- Encourage one-on-one conversations with each student on a regular basis through the use of email, SKYPE, and/or ZOOM.

Frequent contact with students was promoted by providing an announcement (under bblearn) to the class 5 days a week. The announcements provided reminders about what the students should be doing each day in the class and outside information about current topics of concern associated with the class. The use of a daily announcement was considered successful because it stimulated questions from students and reminded them about course goals and deadlines.

3.9 | Evaluation of initial hypothesis

This study validated the initial hypotheses that: (a) face-to-face instruction was superior to distance education, and (b) a distance class version of Soils 446 containing frequent student interaction and frequent homework assignments would keep student engagement at a high level and partially counteract the negative impacts of not having live face-to-face teaching. The unexpected finding, based on student evaluations, was that for motivated students the live and online versions of the class were equally good for student learning.

4 | CONCLUSIONS

When online teaching methods are employed correctly students can receive an excellent experience taking Soils 446. The traditional classroom teaching methodology is a satisfying experience for motivated and average students. Conversely, the online versions of Soils 446 will effectively train students about the material in the course as long as the student is motivated enough to take advantage of all the online learning opportunities presented with the course. Motivated students, those that completed online assignments on time and interacted with the instructor via email, SKYPE, or ZOOM, at least 11 times during the term did well in this course. They would have probably also have done well in a live classroom delivery methodology.

The four obvious plusses of taking Soils 446 live in a classroom setting include:

- Students in a classroom setting interact with the instructor and other students in the class on a regular basis.
- The classroom setting allows students to ask questions of the instructor during the lecture, right after class, or on a face-to-face basis during designated office hours.
- Students have local library resources and other faculty, graduate students, and teaching assistants to help with questions, projects, and get other perspectives on soil fertility and plant nutrition.
- Plant and/or soil materials brought to class by the instructor can be passed around the classroom for students to immediately observe.

The four obvious plusses of taking Soils 446 online include:

- Place-bound students can take this college level class without giving up a full-time job or assuming living expenses associated with living on campus.

- The online course may offer better time management for distance students; instead of each lecture being at a set time the students have several days to view each lecture.
- Email, bblearn, ZOOM, and SKYPE are tools that allow frequent contact between the student and instructor.
- Students are evaluated by frequent problem-solving homework assignments rather than having the potential exam anxiety associated with live campus classes.

The UI student evaluations show that students are satisfied with both Soils 446 delivery methods. Historical final grade data shows no significant difference between the two delivery methods. In addition, both delivery methods work well for motivated students. Unmotivated students, however, do equally poorly with either delivery method.

While there are many critics of online delivery at the university level, this criticism should be offset by the simple fact that online delivery widens opportunities for place-based students and for residential universities. Society is changing rapidly, and our universities must change as rapidly as society or be left behind. The days of the best students going away to a residential college for 4 years is an idea of the 19th and 20th centuries. In our 21st century more college students are older and because of jobs and other responsibilities the residential college just does not fit their goals and lifestyles (personal communications, 2017, 2018). To remain relevant, residential universities need to reach the masses, and effective online courses will help achieve this need.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ORCID

Robert L. Mahler https://orcid.org/0000-0002-3233-4318

REFERENCES

Archibald, C., & Barnes, C.(2017). Reflection: Lessons learned from teaching online in undergraduate programs. *ABNF Journal*, *28*(4), 114–118.

Bao, W. (2020). COVID-19 and online teaching in higher education: A case study of Peking University. *Human Behavior and Emerging Technologies*, *2*(2), 113–115. https://doi.org/10.1002/hbe2.191

Bebe, M. (2010). *E-learning in Afghanistan*. https://linc.mit.edu/line2010/proceedings/session1.Beebe.pdf

Bettinger, E. P., Fox, L., Loeb, S., & Taylor, E. S.(2017). Virtual classrooms: How online college courses affect student success. *American Economic Review*, *107*(9), 2855–75. https://doi.org/10.1257/aer.20151193

Brom, C., Lukavsky, J., Greger, D., Hannemann, T., Strakova, J., & Svaricek, R.(2020). Mandatory home education during the COVID-19 lockdown in the Czech Republic: A rapid survey of 1–9 grader parents. *Frontiers in Education*, *09 July 2020*. https://doi.org/10.3389/feduc.2020.00103

Dell, C. A., Hobbs, S. F., & Miller, K.(2008). Effective online teacher preparation: Lessons learned. *MERLOT Journal of Online Learning and Teaching*, *4*(4), 602–610

Dhawan, S. (2020). Online learning: A panacea in the time of COVID-19 crisis. *Journal of Educational Technology Systems*, *49*(1), 5–22. https://doi.org/10.1177/0047239520934018

Dooley, K. E., Linder, J. R., & Dooley, L. M.(2005). *Advanced methods in distance education: Applications and practices for educators, administrators and learners*. Hershey, PA: IGI Global.

Fuller, P., & Yu, G. (2014). Lessons learned: Online teaching adventures and misadventures. *Journal of Social Sciences*, *10*(1), 33–38. https://ssrn.com/abstract=2976429

Harper, S. R. (2020). COVID-19 and the racial equity implications of reopening college and university campuses. *American Journal of Education*, *127*(1). https://doi.org/10.1086/711095

Jepsen, S. D., Pfeifer, L., Garcia, L. G., Plakias, Z., Inwood, S., & Rumble, J. N.(2020). Lean on your land grant: One university's approach to address the food supply chain workforce during the COVID-19 pandemic. *Journal of Agromedicine*, *25*(4), 417–422. https://doi.org/10.1080/1059924X.2020.1815623

Johnson, N., Veletsianos, G., & Seaman, J.(2020). US faculty and administrators experiences and approaches in the early weeks of the COVID-19 pandemic. *Online Learning*, *24*(2), 6–21. https://doi.org/10.24059/olj.v24i2.2285

Kizilcec, R. F., & Halawa, S.(2015). *Attrition and achievement gaps in online learning*. In D. Joyner (Ed.), Proceedings of the Second (2015) Association for Computing Machinery Conference on Learning @ Scale (pp. 57–66). New York: ACM. https://doi.org/10.1145/2724660.2724680

Linder, J., Clemson, C., Thoron, A., & Linder, N.(2020). Remote instruction and distance education: A response to COVID-19. 2020. *Advances in Agricultural Development*, *9*(2), 53–64. https://doi.org/10.37433/aad.v1i239

Lorenzo, G. (2008). The Sloan semester. *Journal of Asynchronous Learning Networks*, *12*(2), 5–40. https://files.eric.ed.gov/fulltext/EJ837474.pdf

Mahmood, A., Mahmood, S. T., & Malik, A. B.(2002). A comparative study of student satisfaction level in distance learning and live classroom at higher education level. *Turkish Online Journal of Distance Education*, *13*(1), 128–138.

Moore, M. G. (1997). Theory of transactional distance. In D. Keegan (Ed.), *Theoretical principles of distance education* (pp. 22–38). New York: Routledge.

Osman, M. E.(2020). Global impact of COVID-19 on education systems: The emergency remote teaching at Sultan Qaboos University. *Journal of Education for Teaching*, *46*(4), 463–471. https://doi.org/10.1080/02607476.2020.1802583

Parker, K., Lenhart, A., & Moore, K.(2011). *The digital revolution and higher education: College presidents, public differ on value of online learning*. Washington, DC: Pew Research Center. www.pewsocialtrends.org

Quezada, R. L., Talbot, C., & Quezada-Parker, K. B.(2020). From bricks and mortar to remote teaching: A teacher education program's response to COVID19. *Journal of Education for Teaching*, *46*(4), 472–483. https://doi.org/10.1080/02607476.2020.1801330

Richardson, J. T. E. (2011). The academic engagement of White and ethnic minority students in distance education. *Educational Psychology*, *31*(2), 123–139, https://doi.org/10.1080/0143410.2010.519471

Richardson, J. T. E. (2012). The attainment of White and ethnic minority students in distance education. *Assessment and Evaluation in Higher Education*, *37*(4), 393–408, https://doi.org/10.1080/02602938.2010.534767

Seaman, J. (2009). *Online learning as a strategic asset. Volume II: The paradox of faculty voices: Views and experiences with online learning*. Washington DC and Babson Park, MA: Association of Public and Land Grant Universities and Babson Survey Research Group.

Wotto, M.(2020). The future of higher education distance learning in Canada, the United States and France: Insights of before COVID-19 secondary analysis. *Journal of Educational Technology Systems*, *49*(2), 262–281. https://doi.org/10.1177/0047239520940624

How to cite this article: Mahler RL. The pros and cons of teaching soil fertility live versus online. *Nat Sci Educ*. (2021);*50:*e20053. https://doi.org/10.1002/nse2.20053