

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

Natural sciences education in a COVID-19 world

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Assigned to Associate Editor Bruce Erickson.

1 | BACKGROUND

The COVID-19 pandemic of 2020–2021 presented numerous challenges to higher education in North America and around the world, causing universities and colleges to change the way courses were delivered practically overnight. Most North American universities offering agriculture and natural resources curricula were able to meet this challenge, as did many K-12 schools. Even institutions that had very small or non-existent hybrid or on-line course offerings rapidly evolved to meet this challenge and need. The purpose of this paper, and the *Natural Sciences Education (NSE)* journal special section, “Natural Science Education in a COVID-19 World”, is to highlight many of the ways course instructors, along with K-12 and postsecondary institutions, met this challenge. This special section of *NSE* consists of 23 papers developed to demonstrate the abilities of 20 universities and two secondary settings in North America to meet the challenges in teaching and learning regarding agriculture and natural sciences during this difficult time period (Figures 1 and 2).

Abbreviations: CALS, College of Agriculture and Life Sciences; CNR, College of Natural Resources; CTLT, Centre for Teaching, Learning and Technology; DSU, Dickinson State University; ECTL, Ellbogen Center for Teaching and Learning; KSU, Kansas State University; NSE, Natural Sciences Education; UBC, University of British Columbia; UI, University of Idaho; UWyo, University of Wyoming

The 23 papers included in this special section deal with a range of technologies, philosophies, and teaching methods that were rapidly developed to cope with challenges at the college and K-12 educational levels during the COVID-19 pandemic. In addition, several articles evaluate student and instructor perceptions of the value of these recently devised teaching techniques, while two case studies highlight attempts to cope with rapid changes in educational delivery. These 23 papers are placed into five broad categories (Table 1).

One group of papers outlines some of the challenges, successes, and failures associated with transforming the field laboratory portion of a traditional college class into the online delivery of relevant materials. Here papers explore adopting introductory soil science labs to online format (Wolters & Lepcha, 2021), visualizing soil science field trips (Schulze et al., 2021), remote delivery of field experiences in soil science (Aleman et al., 2021) and using video and photography for remote field instruction of a forestry course (Culbert, 2021). A study by Owen et al. (2021) evaluates changing an in-person collegiate soil judging event into a virtual experience, while a paper by Janke (2021) flips the adult natural resources classroom to build community and learn directly in nature.

A second group of papers focuses on technological approaches to enhance online education. These papers focused on the use of both high- and low-tech solutions to



FIGURE 1 The COVID-19 pandemic of 2020–2021 required modification of teaching practices for science classes at most educational institutions in North America (Photo credit: Paul H. Joseph / UBC Brand & Marketing)



FIGURE 2 Modified teaching strategies such as using zoom were utilized at most universities during the COVID-19 pandemic of 2020–2021 (Photo credit: Paul H. Joseph / UBC Brand & Marketing)

teach soil science (Mashtare et al., 2021), rural broadband on teaching with Zoom (Beorngen & Rickard, 2021), different types of teaching technologies (de Koff, 2021), the Science of Agriculture digital tools (Brevik et al., 2021), decision support tools to link management practices with environmental emissions (Jabbour et al., 2021), and podcasts to enhance agricultural education (Barnes et al., 2021).

A third group, consisting of six papers, evaluates student and instructor perceptions of engagement. Article topics include using student-led workshops (LaTourrette et al., 2021), collaboratively investigating scientific literature (Stengel et al., 2021), student and instructor perceptions of engagement (Walker & Koralesky, 2021), student and faculty perceptions of the rapid transition to online education (Rees et al., 2021), student participations of an online soil physics course (Wyatt, 2021), and student perceptions of higher education (Moorberg et al., 2021).

TABLE 1 The papers published in the *Natural Science Education* (NSE) special section focused on natural science education in a COVID-19 world are organized into five categories

Paper category and theme	Author(s)
Transitioning field trips/laboratory to online setting	Schulze et al.
	Wolters & Lepcha
	Aleman et al.
	Culbert
	Owen et al.
	Janke
Using technology to enhance online education	Mashtare et al.
	Beorngen & Rickard de Koff
	Brevik et al.
	Jabbour et al.
	Barnes et al.
Student/instructor perceptions of engagement	LaTourrette et al.
	Stengel et al.
	Walker & Koralesky
	Rees et al.
	Wayatt
	Moorberg et al.
Instructor perspective on challenges brought by online teaching	McKim
	Mahler
	Brown & Krzic
Challenges for animal sciences courses	Gomez
	Erickson & Wattiaux

Somewhat similar to the previous group of papers, the fourth group (consisting of three papers) examines student and instructor participation in courses revised to serve online needs. One article examining the challenges faced by teachers in agricultural education (McKim et al., 2021), while another paper evaluates the pros and cons of teaching a soil fertility and plant nutrition course live versus online (Mahler, 2021). A paper by Brown and Krzic (2021) examines the types of changes that should be made in large science classes to optimize student learning in an online format.

The fifth set of papers is focused on the evaluation of challenges specifically related to teaching and learning in animal science courses. One of those papers dealt with teaching animal science at the high school level in California (Gomez, 2021), while Erickson and Wattiaux (2021) surveyed instructors and college students in animal and dairy sciences in the Midwest.

The speed with which traditional in-class teaching was changed to hybrid forms or on-line instruction was truly astounding. This transition not only met student needs at the beginning of the pandemic in March–April 2020 at most institutions, but reinforced that on-line education may be used

to reach students that do not have the opportunity to attend residential postsecondary institutions. To emphasize and consider the longer-term impacts of this widespread development in postsecondary institutions, in this introduction to the *NSE* special section, we also briefly outline approaches taken by five North American universities representative of different sizes, structures, and pre-pandemic level of commitment to online education. Our goal in doing so is to highlight a range of institutional readiness for online education pre-pandemic, consider how context and readiness impacted pandemic-induced online delivery, and offer some observations regarding how these universities and the educational institutions discussed in the *NSE* special section may leverage lessons learned during the pandemic in an on-going way.

2 | EXAMPLES OF TEACHING APPROACHES DURING THE PANDEMIC AT FIVE NORTH AMERICAN UNIVERSITIES

2.1 | The University of British Columbia, Vancouver, British Columbia, Canada

The University of British Columbia (UBC), with about 67,000 students, is Canada's second-largest research-intensive university (University of British Columbia, 2020). It is consistently ranked among the top 50 best universities globally and was recently recognized as North America's most international university. During the last several decades, UBC has experienced a steady increase in undergraduate and graduate student enrollment. Even though the majority of UBC students are from British Columbia (53%) and other parts of Canada (20%), 27% of current students are international (University of British Columbia, 2020). A good portion of those international students select UBC not just because of its international reputation but also due to its geographical setting, a mild climate (at least by Canadian standards), and socio-political location. Out of UBC's 16 faculties, 18 schools, and 2 colleges, the Faculty of Land and Food Systems and Faculty of Forestry offer degrees focused on natural resources. Collectively, these two Faculties have about 3,600 undergraduate and graduate students (University of British Columbia, 2019), who typically would take campus-based courses. As a matter of fact, prior to the COVID-19 pandemic, just over 300 courses were offered online at UBC, representing about 5% of all courses offered (University of British Columbia, 2020) (C. Longhi, personal communication, 2021).

The UBC has a strong commitment to supporting its teaching and learning community either through activities carried out by the Centre for Teaching, Learning and Technology (CTLT) and the Emerging Media Lab (established in 2017), or funding for innovative educational projects provided by

the Teaching and Learning Enhancement Fund (established in 1991). Initial distance learning courses at UBC were offered in 1974, which in 1984 led to creation of the UBC Access program that encompassed several distance learning programs. Those initial efforts focused on distance education resulted in 2002 in creation of the Office of Learning Technology, which was restructured to CTLT in 2010 (University of British Columbia, 2021). When the pandemic started in March 2020, those central units were able to mobilize relatively quickly and offered support to students and instructors regarding online teaching and learning. Despite all the help that these central UBC units have been able to provide, it has still been a tremendous undertaking to transfer almost all courses to the online mode of delivery in a short period of time.

All natural resource courses, with the exception of several courses in the Professional Master of Forestry Program, were transferred online but with varying degree of success (Walker & Koralesky, 2021). Based on informal discussions with colleagues, it appears that the main focus has been on development of course material that more or less mimicked the campus-based educational activities, with less focus on educational activities that are well-aligned with online delivery. This was mainly due to lack of time to develop such activities and also lack of instructors' experience since most instructors had never previously taught courses online. Faculty members and the CTLT staff indicated that students felt stressed and overworked; this reaction is attributed in large part to instructors focusing solely on the development of online content and using a wide, inconsistent variety of online tools. However, there were also positive outcomes such as broad, university-wide and faculty-wide discussions on teaching and learning practices that led to creation of a much stronger community of learners relative to the pre-pandemic time.

It is difficult to predict post-pandemic changes regarding types of course delivery at UBC, but a couple of factors suggest that the majority of courses will be kept as campus-based. First, most international and also domestic UBC students are keen to experience life on campus and in Vancouver in general. Second, courses offered by the Faculties of Land and Food Systems and Forestry, with their strong focus on field-based learning and community engagement, are not well-aligned with online teaching and learning and will most likely go back to in-person modes of delivery. A hybrid model of combining in-person and online teaching is also a possibility for some courses.

2.2 | University Of Idaho, Moscow, Idaho, USA

The University of Idaho (UI) is the smallest flagship institution (major university in the state) in the United States. In the last five years annual full-time student enrollment has

averaged 11,000. This is a residential university with less than 10% of the students considered commuting students. The UI has two colleges that provide students with degrees in agriculture or natural resources - Agriculture and Life Sciences (CALs) and Natural Resources (CNR). CALs trains students in traditional agricultural fields and in consumer sciences, while CNR trains students in forestry, range, wildlife, natural resources and society and environmental sciences. Collectively, these two colleges have approximately 2,000 undergraduate and graduate majors. Of this enrollment, 340 students are in M.S. degree programs, while 140 students are in Ph. D. programs (University of Idaho, 2020a).

The UI is the state's Land Grant Institution and serves the state by providing education, extension, and research. Extension offices are located in 42 of the state's 44 counties. From a research standpoint, the institution is classified as R2 – a doctoral university with a high level of research activity (Indiana University Center for Postsecondary Research, 2017). For the last few years outside funding has exceeded \$110 million in research support (University of Idaho, 2018; 2020b).

Despite research productivity, declining enrollment has been considered to be the major challenge facing the UI for the last five years. Two major problems contributing to the enrollment decline are (a) the best high school graduates leave the state to attend college, and (b) over 70% of the state's population lives more than 300 miles from Moscow where the UI campus is located. The last two incoming presidents of the institution have said that increasing distance education programs are an important part of the solution to combat declining enrollment; however, few programs had been initiated by 2018. Prior to the COVID-19 pandemic both CALs and CNR offered several distance courses; however, there were only two undergraduate degree programs available to non-campus students. Enrollment in distance courses constituted less than 5% of the credit hours taught by both colleges.

The COVID-19 pandemic of 2020 changed the way courses were offered to resident students in both CALs and CNR. Practically overnight the majority of faculty in both colleges transformed their courses into either on-line or hybrid formats to allow students to learn at a distance. While the quality of many of the courses were not up to par because most faculty members were doing this for the first time, the new delivery methods were considered successful because fall semester 2020 enrollment declined only 4% compared to the previous fall. Without distance delivery students would have not been able to continue their education and it would have been a financial disaster for the university and the Moscow community.

It is hard to predict the future of distance education in CALs and CNR at the UI post pandemic. Although faculty and the university showed their resilience in being able to rapidly change in a time of crisis, the post COVID-19 world will again see classroom teaching as the norm in Moscow.

The fact that distance education was successful in 2020 will probably result in increasing numbers of courses being offered online. Should the UI commit to meeting the trend of enrollment decline head-on by offering more classes and degrees online, the shift could transform the future of higher education in Idaho.

2.3 | Kansas State University, Manhattan, Kansas, USA

Kansas State University (KSU) is a public Land-Grant Institution founded in 1863. The university is categorized as an R1 research institution – a doctoral university with very high research activity (Indiana University Center for Postsecondary Research, 2017). The university has satellite campuses in Olathe, KS, and Salina, KS. Kansas State University has two colleges that train students in Natural Sciences, the College of Agriculture and the College of Arts and Sciences. The College of Agriculture consists of nine academic departments and 16 undergraduate degree programs (Kansas State University, 2020a). The College of Arts and Sciences consists of 31 academic departments and 35 undergraduate degree programs (Kansas State University, 2020b).

Declining enrollment and decreases in financial support from the state legislature are major challenges that faced KSU over the last five years. Two strategies are being implemented to address the decreased enrollment. First, a new budget model is being implemented that prioritizes enrollment and student credit hour growth (Meyers, 2017). Second, the university has partnered with a consulting firm to develop a strategic enrollment management plan (Kansas State University, 2021). Components of this plan address marketing and communications; financial aid and sustainability; undergraduate recruitment; undergraduate retention and student success; global, graduate, and international student recruitment; and data, technology, and systems.

Kansas State University has been offering distance and online classes and degrees through the KSU Global Campus since 1966 (Kansas State University, 2020b). In addition to offering individual online courses, Global Campus offers 11 online bachelor's degrees, 35 master's degrees, four doctoral degrees, one secondary degree, 17 minors, 37 certificates, and four endorsements (Kansas State University, 2020b). Global Campus offers development grants to KSU colleges and departments to develop online courses, programs, and conferences.

In 2020 Global Campus and the KSU Teaching and Learning Center created a website and an online community to support faculty through the pivot to remote teaching and learning which occurred in conjunction with the COVID-19 pandemic (Kansas State University Global Campus, 2020). Global Campus took the "K-State Online Essentials" course, which is

normally only offered to a small number of faculty each summer and transformed it into the “Online Course Design Institute” to support all KSU instructors as they transitioned courses to online modes of instruction. This institute had 435 participants in 2020 (Kansas State University Global Campus, 2020).

Kansas State University has experienced great success with Global Campus since its inception in 1966. Global Campus’s Dean, Karen Pedersen, reported that KSU had its greatest number of students graduate with bachelors, masters, and doctoral online degrees in 2020, which signifies the continued growth in online education the university has recently experienced (Kansas State University Global Campus, 2020). The financial impact of online education through Global Campus has also been a significant source of tuition revenue, bringing in \$30.7 million to the university in 2020 (Kansas State University Global Campus, 2020). It is difficult to predict how interest in online education will shift following the COVID-19 pandemic. However, online education and professional development through online courses, online degrees, and other training opportunities will likely remain steady if not increase in years to come. Further, online academic programming will continue to be a significant source of tuition revenue for KSU.

2.4 | University of Wyoming, Laramie, Wyoming, USA

The University of Wyoming (UWyo) is a doctoral university with high research activity (Indiana University Center for Postsecondary Research, 2017). Based in Laramie, UWyo is the state’s only institution that provides four-year degrees and graduate degrees. It has a satellite campus in Casper, Wyoming. As a Land Grant Institution, UWyo is located on the ancestral and traditional lands of the Cheyenne, Arapaho, Crow, and Shoshone Indigenous peoples along with other Native tribes who call the Great Basin and Rocky Mountain region home (Lee & Ahtone, 2020). These are lands impacted by the still-disputed Cession 426 and the 1851 and 1861 Treaties of Fort Laramie.

At UWyo, four units offer degrees focused on natural resources: College of Agriculture and Natural Resources, College of Arts and Sciences, Haub School of Environment and Natural Resources, and School of Energy Resources, along with two relevant degrees in law and engineering. Collectively, UWyo graduates an annual average of 476 undergraduate and graduate students in 25 natural sciences degrees and graduate programs (University of Wyoming, 2019). Most of these students would typically be enrolled in on-campus, in-person coursework. The university disbanded a distance education entity called the Outreach School in 2017 (Klamann, 2017) and offers a handful of distance education programs.

However, these offerings are not situated in the natural sciences.

Recent enrollment declines amidst a \$42 million budget cut (Klamann, 2016) triggered a controversial (Jaschik, 2018) re-branding program developed by an external marketing firm. Subsequently, enrollment increased until the pandemic struck (University of Wyoming, 2018). From 2015–2019, UWyo averaged 12,866 students, based on end-of-fall-semester reports (University of Wyoming, 2020a). Undergraduates comprise the bulk, averaging 9,879 students. The majority of UWyo students are from Wyoming (70%; $n = 8,117$) and elsewhere in the United States. Only 3% of the students are international ($n = 429$ of 4,017 nonresidents; University of Wyoming, 2020a). In summer 2020, the state legislature and the governor partnered with UWyo to establish a grant program for students enrolled at UWyo. Using \$7.5 million in federal CARES Act stimulus/COVID-19 relief funding (University of Wyoming, 2020c), this partnership provided qualified students a one-time payment of up to \$3,250. This investment boosted enrollment that was lagging from the pandemic. Indeed, fall 2020 enrollment on day 15 of the semester was 11,829 (University of Wyoming, 2020b); this enrollment level was only slightly lower than the 5-yr average. It was also higher than projected and higher than end-of-semester enrollment for spring 2020 (11,548 students; University of Wyoming, 2020c), when enrollment only dropped by 3 from the day 15 count (University of Wyoming, 2020b).

UWyo shifted to 100% online teaching in mid-March 2020, precipitating a major need for support of faculty with no prior online teaching experience. Fall 2020 was a hybrid of online and in-person coursework for eight weeks mid-semester, with all classes meeting online-only at the beginning and end of the semester. The Ellbogen Center for Teaching and Learning (est. 1991; ECTL) was instrumental in the university’s response to the pandemic. In March 2020, the ECTL deputized 17 faculty mentors (including one of this paper’s authors, B.G. Merkle) to help approximately 790 instructors transition to online teaching. During summer and fall 2020, a new Digital Teaching and Learning program trained another 349 instructors, and the ECTL also supported 336 instructors and graduate students through direct consultations and coaching, online webinars, one-off online trainings and more. These numbers are roughly double typical, previous years’ support offered to campus instructors. UWyo also used \$4 million of state-allocated CARES Act funding to contract Wiley and Ease Learning to provide individualized online education support.

These investments in online capacity align well with UWyo’s strategy to deal with a current, second round of severe budget cuts. Faced with \$42 million in cuts from the state, UWyo administrators at all levels are looking for ways to both streamline and further capitalize on UWyo’s strengths. One of the Wiley/Ease support options focused on pivoting or

building out full programs as distance education options. It is likely the university will continue such efforts to diversify and expand revenue options and recruitment efforts.

Data are not yet available about the outcomes of this major, abrupt investment, but it is fair to say that individual instructors' experiences with contracted learning designers and ECTL personnel/mentors varied widely. Sustainability and efficacy of these online courses is unclear for two reasons: (a) Most 2020 online teaching was a triaged adaptation of in-person courses, and (b) Lacking centralized distance education, future online degree programs are likely department-specific, but most UWyo natural science departments are not currently set up for or invested in this model.

2.5 | Dickinson State University, Dickinson, North Dakota, USA

Dickinson State University (DSU) is a small public university with an enrollment of approximately 1,440 (Dickinson State University, 2020a). Dickinson State University is a primarily undergraduate institution classified as Baccalaureate Colleges: Diverse Fields (Indiana University Center for Postsecondary Research, 2017) with just two graduate programs that currently enroll less than 100 students combined. About 14% of course sections are typically offered online (K. Meyer, personal communication, 2020). Agriculture and natural sciences degrees are offered by the Department of Agriculture and Technical Studies (B.S. in Agricultural Studies with several options, including Natural Resource Management, Range Management, and Soil Science) and the Department of Natural Sciences (B.S. in Biology and B.S. in Environmental Science) (Dickinson State University, 2020b); the two departments combined have approximately 200 majors. These two departments are strongly focused on face-to-face programs. Agriculture and Technical Studies offers an Equine option via online delivery, but students must come to campus for any of the other bachelor's level options. Natural Sciences only offers one non-major biology class in regular online rotation, with sporadic online offerings of other individual courses.

Like many other universities world-wide, DSU rapidly transitioned to distance delivery of all coursework in March 2020 (Brevik et al., 2021). When returning for the fall 2020 semester, DSU's administration was committed to providing a face-to-face experience for all students who wanted it, while also providing a distance option for all students in all classes with the exception of a select number of hands-on courses, such as those that included a laboratory. This commitment was in place as long as the administration felt face-to-face classes could be held safely using precautions such as wearing face masks and maintaining appropriate distancing. Dickinson State University stayed face-to-face until 23 Nov. 2020, when North Dakota became a COVID-19 hotspot within the

United States (Dickinson State University, 2020c). Classes resumed in the face-to-face with distance option format at the start of the spring 2021 semester and stayed that way until the end of the academic year.

Declining enrollment has been a serious concern at DSU over the last decade, but enrollment increased for the fall 2020 semester, with a 5% increase in full-time equivalent enrollment and 6% increase in headcount over fall 2019 (Dickinson State University, 2020a). Enrollment was up by the same percentage in spring 2021 as compared to spring 2020 (Dickinson State University, 2021). Dickinson State University was one of only two institutions in the North Dakota University System to report an increase in enrollment for fall 2020, and it had the largest increase in the system as measured by both student numbers and percentage. While several factors may have contributed to this increase, the commitment to face-to-face course delivery is thought to be a major driver, as a number of students on campus indicated a strong preference for face-to-face coursework.

There are faculty and administrators who feel DSU needs to move to a model where all classes are offered in both face-to-face and distance modes in all future semesters, including field- and laboratory-based coursework, and that this will provide a competitive advantage in the higher education marketplace. There are also many faculty who do not feel that their respective disciplines are well-suited to distance as a mode of delivery. Despite the concerns of these faculty, Stephen Easton, the DSU President, announced that face-to-face and simultaneous remote access would become the default delivery mode for all classes at DSU beginning in fall 2021 (S. Easton, personal communication, 2021). It would not have been possible for DSU to purchase the equipment needed to make this change in delivery modality without the funds provided to institutions of higher education by the federal government to address COVID-19 challenges. Nevertheless, it appears that the COVID-19 pandemic will lead to major changes in the way DSU delivers course offerings in the future.

3 | SUMMARY

The COVID-19 pandemic forced postsecondary educators to change their mode of teaching in a very short period of time, offering numerous courses that have not been offered online previously. This transition to online education also opened numerous questions for universities (as outlined in this paper and 24 papers of the *NSE* special section) regarding the role of online education after the pandemic.

Online education provides a number of challenges and opportunities for natural sciences curricula. These include, but are not limited to, overworked instructors and students (e.g. Collins et al. 2021; Yang et al., 2021), lower-quality educational experiences, opportunities to enhance teaching skills,

revenue diversification, flexibility for nontraditional students, and more. There are also significant, negative implications for ad hoc, online delivery exacerbating gaps in access to higher education across income and geographic boundaries (Garcia & Weiss, 2020). For universities to make good on their moral contract with society (including instructors and students), online education must involve at least four considerations: (a) planning should be comprehensive and long-range; (b) teaching and learning during the COVID-19 pandemic should be viewed as a test case, not a model; (c) implementation should be fully committed to justice, equity, diversity, and inclusion (e.g., Blundell et al., 2020; Schwartzman, 2020), and (d) we must budget time and funding to sustain current gains while supporting on-going instructor development (like that provided by UWyo's ECTL, KSU's Global School, and UBC's CTLT). Further, future studies are needed to assess student satisfaction and engagement in online courses across various disciplines, course types (e.g. lecture-based, discussion-based, problem-based learning, laboratory, field-based), or class sizes.

For schools at all levels to continue to thrive, they have to find ways to develop creative, innovative curricula. While this does not necessarily have to involve the latest and the most expensive technology, the papers in this *NSE* special section and the five universities we highlighted here underscore that online education will likely play a larger role in well-designed, meaningful education.

AUTHOR CONTRIBUTIONS

R. L. Mahler: Conceptualization Investigation; Methodology; Project administration. B. Garramon Merkle: Conceptualization Investigation; Methodology; Project administration

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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How to cite this article: Mahler RL, Krzic M, Garramon Merkle B, Moorberg C, & Brevik EC. Natural sciences education in a COVID-19 world. *Nat Sci Educ*. 2021;50:e20067. <https://doi.org/10.1002/nse2.20067>