Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #45663

Pandemic Educational Interventions - Minimal Impact on Student Grades as a Proxy for Student Learning

Dr. Benjamin Michael Wallen P.E., United States Military Academy

Benjamin Wallen is a Colonel in the United States Army and an Associate Professor teaching in the Department of Geography and Environmental Engineering at the United States Military Academy. He is also the Associate Dean for Faculty Development.

Major Chelsea Linvill, Department of Geography and Environmental Engineering
Dr. Michael A. Butkus P.E., United States Military Academy

Michael A. Butkus is a professor of environmental engineering at the U.S. Military Academy. His research has been focused on engineering education and advancements in the field of environmental engineering.

Lt. Col. Andrew Ross Pfluger P.E., United States Military Academy

Colonel Andrew Pfluger, U.S. Army, is an Associate Professor and Academy Professor in the Department of Geography and Environmental Engineering at the United States Military Academy. He currently serves as the director of the Environmental Prog

Pandemic Educational Interventions - Minimal Impact on Student Grades as a Proxy for Student Learning

Abstract

In response to the COVID-19 pandemic, collegiate-level educators developed numerous interventions and resources to maintain student learning in a remote environment. Many of the interventions took significant faculty time and effort, as remote teaching and learning was new for a large number of faculty and students. After pandemic-induced isolation and social distancing restrictions were lifted, many educational institutions returned to in-person teaching and learning. The return to an in-person environment provided an opportunity for educators to assess which COVID-19-realted interventions can (or should) be maintained. This study examines interventions used during various teaching modalities employed in a high enrollment (> 200 students) introductory environmental engineering course over the span of four years (2019 – 2022) prior to and through the post-pandemic. Due to changes in pandemic control measures, each year's course offering had a different teaching modality: in-person (2019), remote (2020), Hyflex (2021), and in-person / hybrid (2022). Assessment metrics used to identify the most useful interventions included student surveys, faculty surveys, and direct assessment of performance on graded events. The most useful interventions identified included narrated slideshow presentations, recorded class presentations, and virtual laboratories and field trips. Many of the practices introduced during the remote and Hyflex course offerings, such as the ability to teach remotely, were beneficial for faculty members and will be carried forward for future course offerings. This study suggests that student performance (as a proxy for student learning) remained largely unaffected despite the changes in teaching modalities over the four-year span.

Keywords: COVID-19 pandemic, Hyflex teaching, hybrid teaching, teaching modalities, pandemic teaching interventions

1. Introduction

1.1. COVID-19 Pandemic Impacts on Teaching Modalities

In March 2020, the World Health Organization (WHO) declared a pandemic in response to rapidly increasing cases of the novel coronavirus SARS-CoV2 (or COVID-19) [1]. Declaration of the pandemic prompted rapid closures of in-person learning venues and incited a near immediate transition to remote teaching and learning. This abrupt shift to online learning occurred at a time when a majority of faculty members in higher education felt unprepared to switch to an online teaching and learning model [2, 3, 4]. In total, more than 150 countries closed schools, colleges, and universities and transitioned to alternative online teaching methods. In some cases education was temporarily halted to distance students and slow the spread of COVID-19, which can easily transfer across different populations in classroom settings [5, 6]. Approximately 90% of students worldwide changed their educational plans in response to the pandemic [7, 8, 9, 10]. At the start of the pandemic many educators had mixed feelings about the effectiveness of online or remote teaching approaches compared to face-to-face approaches [11,

12]. However, the necessity of moving to remote teaching spurred a substantial demand for focused educational research to evaluate the effectiveness of new online teaching and learning approaches. After the initial push to move education online in spring of 2020, many educators tried to adapt their best practices in the following fall and spring semesters as it became apparent the pandemic would persist [6, 13, 14, 15, 16, 17, 18]. These adaptations included setting expectations for online conduct, confirming attendance during synchronous portions of online classes, encouraging student engagement through breakout groups and discussion boards, and investing in infrastructure needed to host online classes through a variety of learning management systems [13, 16, 19]. During later stages of the pandemic, many institutions returned to hybrid or Hyflex modalities, or even full in-person education. Hyflex teaching combines two modalities, hybrid and flexible [20, 21]. Here, students are required to do asynchronous work outside of class time to include reading, watching videos, and solving problems. During synchronous portions of instruction, they can choose their modality of attendance, to include in-person attendance or attendance via video conferencing software [21, 22, 23]. This demand to prepare in greater detail for each lesson is similar to a flipped classroom approach [24]. Flipped classrooms have proven benefits for students while Hyflex is "flipped" with additional flexibility on modality of attendance during synchronous sessions. Hyflex was popularly adopted during the pandemic because it increased student engagement through flexible synchronous sessions [18, 22, 23, 25].

1.2. Approaches to Evaluate Educational Success

The COVID-19 pandemic impacted the world in numerous ways. Scholars are still debating the severity of pandemic impacts on education; however, one opinion stands out as universal: higher education cannot return to the pre-pandemic status quo, but must instead adapt [26, 27, 28, 29]. While educators continue to grow and adapt post-pandemic, it is important that each continually evaluate the success each change has on student learning. One of the most common ways to evaluate student success and/or mastery of material is by looking at individual grades and course averages [30]. Grades not only provide feedback to the learner, but help to measure success for both internal and external reviews of courses and programs [31, 32]. For example, accreditation bodies like ABET certify higher education programs in applied and natural science, computing, engineering, and engineering technology [33]. During the accreditation process, ABET requires engineering programs to submit samples of student graded work.

Assessing changes born from the emergency transition to online teaching during COVID-19 is imperative when adapting courses to a post-pandemic classroom. Doing so can deliberately prevent thoughtless rebound to pre-pandemic teaching approaches, and a loss of lessons learned. While grades have long been relied upon to tell the story of success or failure of changes in coursework given to students, grades do not tell the whole story [34, 35, 36]. Other methods, such as end-of-course surveys and longitudinal studies, can help educators more completely understand how pandemic-induced changes to course curriculum have impacted students. End-of-course surveys are required at many undergraduate institutions in the US and abroad to evaluate student performance on course outcomes as well as student satisfaction with course design [37, 38, 39]. It is also commonplace to assess curriculum redesign, major course changes, and modified student experiences in the classroom (e.g., active learning interventions) via longitudinal studies [40, 41]. Longitudinal studies executed over several semesters allow instructors and institutions to see how measured outcomes in the class befit students over a

longer period. Being several semesters removed from the start of the COVID-19 pandemic, it is now possible to analyze changes implemented during the pandemic and assess their long-term impact on course outcomes and student performance.

1.3. Core Engineering Sequence at the United States Military Academy

The United States Military Academy (USMA) at West Point is a four-year undergraduate institution with the mission to build, educate, train, and inspire 4,400 cadets to be commissioned leaders of character committed to the Army values and ready for a lifetime of service to the Army and nation [42]. Each graduate earns a Bachelor of Science degree. Students have a choice of 36 academic majors, which include ten ABET accredited engineering programs. All non-engineering majors (e.g., history or law) must take a three-course engineering sequence (CES) as a graduation requirement. At present, there are six CESs available to non-engineering majors, which include cyber, environmental, infrastructure, nuclear, robotics, and systems engineering. The environmental engineering CES is typically the most requested by students and each semester teaches over 200 students per graduating cohort. The first of the environmental engineering CES courses, Environmental Science (EV300), is taught during the fall semester of junior year and provides a broad understanding of current global and local environmental issues with a focus on natural ecosystem processes, the effects of pollution on human health, risk assessment, and the environmental effects of energy use, air pollution, global climate change, acid rain, and smog. The second CES course taught during the spring semester of junior year, the focus of this study, is Environmental Engineering Technologies (EV350). This course is described in greater detail in Section 1.4. The third CES course taught fall semester of senior year, Environmental Engineering for Community Development (EV450), is the capstone experience and focuses on clean water, sanitation, and infrastructure challenges in the developing world. In EV450, students assess various technologies (e.g., water or wastewater treatment) and their ability to meet community needs. Each environmental engineering CES course uses traditional lectures, in-class examples, in-class demonstrations, and laboratories to help students attain course outcomes and learning objectives. As an institution, West Point subscribes to an andragogical system, the “Thayer Method.” The Thayer Method requires students to come to class prepared to ask questions and discuss lesson topics, rather than just passively receive a traditional lecture [43].

1.4. Environmental Engineering Technologies Course Description and Teaching Modalities

The second CES course, Environmental Engineering Technologies (EV350), builds on environmental issues introduced in the EV300 introductory environmental science course, while exploring environmental engineering from a unit process and materials balance approach. Environmental topics explored include water transport and quality, drinking water treatment, wastewater treatment, and air pollution transport, quality and control. Due to the high student enrollment, between four and six faculty teach the course each year. There are 40 lessons in the course, including 27 substantive lessons, 2 laboratories, 3 exams, 2 field trips, and 2 lessons designated as engineering design project (EDP) work sessions. The two laboratories required group submissions for a jar test laboratory and a wastewater analysis laboratory. The two field trips incorporated individual reflections based on a trip to the West Point water treatment plant and a trip to the West Point wastewater treatment facility. The course has three homework assignments focused on mass balance and environmental chemistry, water treatment, and air quality and control. The EDP includes biochemical oxygen demand, Streeter Phelps and

dissolved oxygen sag curves in a riverine system, and wastewater treatment plant design. Each of the substantive lessons includes at least one in-class problem to help students learn quantitative concepts and prepare them for problem sets and exams.

Over a four-year period (2019 – 2022), the course leadership implemented a series of modifications, or interventions, to account for changing guidance concerning in-person teaching restrictions throughout the pandemic. Specifically, the course was executed in a traditional in-person format (2019), a fully remote format (2020), a Hyflex format (2021), and a full in-person / hybrid format (2022). The hybrid format used in 2022 differed from the Hyflex format used the previous year by (1) removing the requirement to watch recordings of instruction prior to coming to class, and (2) providing the recordings as resources for students to use as desired. The hybrid format still provided students the opportunity to attend class in person or online as they deemed appropriate for their needs. Regardless of modality selected to attend in person or online, the institution incorporates policies which enforce attendance for all classes. Therefore, this study does not address the impact of the modifications or interventions on class attendance. Instead, the subsequent discussion focuses on impacts on learning which is applicable across all institutions. The changes to teaching modalities, as well as end-of-course survey responses from faculty and students were closely tracked to determine the efficacy of interventions. Further, the course deliberately examined which pandemic interventions could be carried forward (or "bounced forward") beyond the pandemic [27] with the intent of creating flexibility and resiliency in the event of future crises. Therefore, this study explores the efficacy of educational practices used during the pandemic in West Point's high-enrollment Environment Engineering Course to identify which are most advantageous to carry forward post-pandemic.

2. Methods

2.1 Course Modalities and Interventions used through the COVID-19 Pandemic

Figure 1 presents the changes in course teaching and learning modality prior to (2019) and through the COVID-19 pandemic (2022). Several adaptations were immediately implemented in March 2020, when the pandemic was declared by WHO. Specifically, instructors narrated and recorded PowerPoint slides for each lesson, created recordings of all remotely taught classes, used online Kahoot quizzes [44], and created recordings of field trips, laboratories, and in-class exercises. Students were provided recordings of remotely taught classes. Instructors also offered highly flexible remote office hours (i.e., available during any period of the workday, upon request) to increase student engagement. After the 2020 fully remote semester, all recorded material were maintained in a digital library for faculty to access.

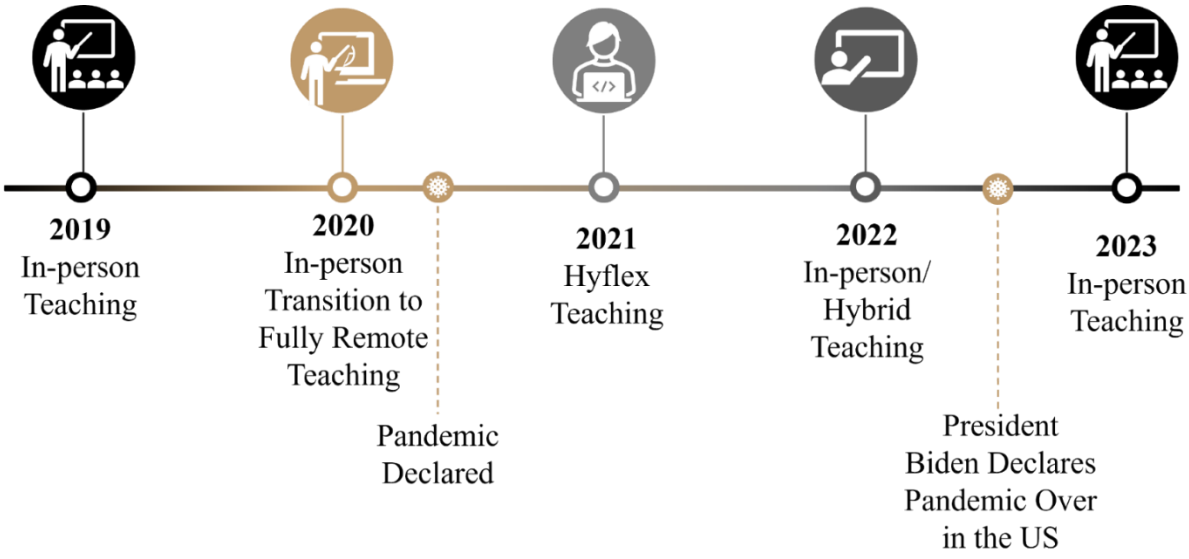

Figure 1. Timeline and Modalities of Environmental Engineering Technologies (EV350) Course Offerings. The upper portion of the figure shows the offerings and modality. The bottom portion of the figure shows the year of examination, as well as the declaration of the pandemic in March 2020 and the declared end of the pandemic by U.S. President Biden in September 2022 [48]. Of note, at the time of this study there are varying opinions concerning when the pandemic has ended, or if it is still on-going.

During the Hyflex semester (2021), institutional restrictions required students to attend a synchronous portion of class instruction; however, students were allowed to choose their modality of this synchronous instruction, either remote or in-person. Enabling flexibility for students to select their modality required instructors to simultaneously integrate remote and in-person students for each lesson. Those students attending remotely were counted as present and were required to keep their cameras on in order to engender heightened attention and engagement with the instructor. In support of the flipped classroom andragogy, narrated PowerPoint slide shows (hereafter referred to as narrated slideshows) were provided to students prior to synchronous lecture periods to prepare for class. After the lesson was complete, students were able view a recorded version of the lesson via Blackboard (BB) Connect. The Hyflex semester also required students to take field trips asynchronously though recorded tours of treatment facilities.

In spring 2022, the course returned to in-person only offerings, while retaining virtually administered pre-recorded field trips. The course director also deliberately continued several other pandemic adaptations, to include providing access to narrated slideshows and recordings of labs, lessons, and in-class demonstrations. Narrated slideshows were available for all lessons and provided information to students on how to complete in-class problems. Faculty could view the slideshows at any time to prepare for their lesson, while students could only view them after the lesson to reinforce concepts presented in class. Therefore, the narrated slideshows were no longer a preparation activity and transitioned to use as an optional review tool. Faculty also had access to recorded lessons previously created during the Hyflex semester, which could help each prepare for classes. The video recordings of the field trips were used as asynchronous lessons for the students to see the application of concepts covered in class. The lab recordings were used by

faculty to prepare for lab and by the students who could not attend lab in person, otherwise all laboratory periods were conducted in person.

2.1.1. Narrated Slideshows

Narrated slideshows were prepared by the course director and shared across all sections. Narrated slideshows were provided to students during the Remote semester (2020), Hyflex semester (2021), and the in-person / Hybrid semester (2022). In 2020 and 2021, students were required to view the narrated slideshows as part of their classroom preparation. To keep students engaged during the narrated slideshow, students could earn instructor points by answering questions embedded in the slideshow and by self-reporting completion of watching the entire narrated slideshow. Recent research has shown that use of recorded lectures requiring student engagement throughout the recording enables higher levels of attention than online instruction [45]. Giving students access to narrated slideshows before class also allowed them to follow along during synchronous lectures and have more complete notes.

2.1.2. Virtual Laboratories and Field Trips

At the start of the pandemic, all laboratories and field trips transitioned from in-person to virtual experiences. This approach used through the 2021 Hyflex offering. In 2022, the laboratories transitioned back to in-person experiences; however, students that were absent from a lab were provided with pre-recorded videos from 2020 and 2021. The field trips to the local drinking water treatment plant and the local wastewater treatment plant remained virtual experiences for the students. Literature regarding the effectiveness of virtual field trips in lieu of in-person field trips provided justification for maintaining the intervention post-pandemic [46, 47].

2.2. Qualitative and Quantitative Data Analyzed

To determine the impact of different modalities, this study combines qualitative data from end-of-course surveys provided to both faculty and students with quantitative data of student performance on homework assignments, laboratories, and examinations. The results from four surveys were evaluated. During the 2022 course offering, two surveys were administered to students, and one was administered to faculty. The first survey was administered to students (n = 175) which evaluated their perceptions regarding the utility and effectiveness of remote resources and modalities. Table 1 contains the list of questions in this analysis. The second survey was completed by faculty (n = 6) which qualitatively addressed both the utility and perceived impact of remote resources for faculty and the students. The questions associated with this survey are shown in Table 2. The third survey was the institutional-level end-of-course survey administered to students at the end of each semester with several questions applicable to the change in modalities from 2019 through 2022 (n = 83). Table 3 provides clarity on the institutional questions asked. The fourth survey provides the end of course survey questions with responses collected each year (n ranging from 116 to 177 responses each year). Table 4 contains questions specific to the course. The combined list of questions shown in Table 3 and 4 incorporate institutional questions evaluated across all courses down to individual questions per course to enable longitudinal analysis of questions related to attainment of course outcomes. Surveys were voluntary and responses for each survey were collected based on a Likert scale (1 to 5) with 5 being most preferred.

For quantitative data analysis, all major graded events (homeworks, laboratories, and examinations) for 2019 and 2022 were analyzed to identify differences in student performance during the different modalities of teaching. Statistical tests incorporated to assess performance on different graded events include t-tests and ANOVA tests. Determining if changes in modality yielded statistically different results were reflected with (1) p-values less than 0.05, (2) t-stat greater than or equal to t-critical, or (3) F-value greater than or equal to F-critical. P-values greater than 0.05, t-stat less than t-critical, or F-value less than F-critical characterized compared populations as statistically similar.

Table 1. Survey 1 questions to qualitatively evaluate student opinions regarding in-person and hybrid modalities.

Number	Questions
1	Did you watch any recordings of previous lessons (recordings of voiced over lecture slides) because you were unable to attend class during your regular class period due to illness, field trip, or any other reason causing you to be absent?
2	If you did watch the recordings of previous lessons due to absences, how many videos did you watch?
3	Did you watch any recordings of previous lessons (recordings of voiced over lecture slides) as a means to review material covered in classes you attended?
4	If you did watch the recordings of previous lessons to review material covered in classes you attended, how many videos did you watch?
5	If you watched a recording of a previous lesson, how beneficial was the recording?
6	Would you recommend recordings of previous lessons (recordings of voiced over lecture slides) be available for future classes?
7	How many times throughout the semester did your instructor remind you about the availability of the recordings of previous lessons (recordings of voiced over lecture slides)?
8	Did you feel you received an equally meaningful experience by attending the field trips remotely versus being in person?
9	How well did the requirement to fill out blanks on the diagrams of the two plants (Lusk Drinking Water Treatment Plant and Target Hill Wastewater Treatment Plant) keep you engaged throughout the field trip recording?
10	How much did you enjoy the field trip video recordings?
11	Video recordings were available for the jar test lab (after the lab was complete) and the wastewater lab (before the lab occurred). Did you watch either of these videos?
12	If you watched a recording of the jar test and/or wastewater laboratory exercise, how beneficial was the recording?
13	When would you prefer to have the jar test and wastewater laboratory exercises?
14	How meaningful and developmental were the laboratory experiences?
15	Did your instructor make use of a shared file (e.g., PowerPoint) or program (e.g., OneNote) for group work?
16	If your instructor did make use of a shared file or program, how useful was that tool to enhance learning and engagement?
17	After a class period where a Kahoot quiz was used, did you access the in-class Kahoot quiz to review concepts covered during class?
18	Class slides for all lessons were available for Cadets in Blackboard for Term 21-22. Did you have a copy of the class slides before class based on what was made available in the previous term?
19	If you did have a copy of the slides, how useful were they in helping to follow along during class?

Table 1 (continued). Survey 1 questions to qualitatively evaluate student opinions regarding in-person and hybrid modalities.

Number	Questions
20	If EV350 was offered during the summer term, would you be interested in taking the course during the summer instead of during the academic year?
21	Is there anything else you would like to recommend or share for instructor consideration regarding sustaining student resource availability based upon material created during COVID? Examples would be wonderful!

Table 2. Survey 2 questions to qualitatively evaluate faculty opinions regarding in-person and hybrid modalities.

Number	Questions
1	How many videos (recordings of voiced over lecture slides) did you watch in preparation for class over the semester?
2	On a scale of 1 to 5, how useful were the recordings of voiced over lecture slides?
3	Recording of voiced over lecture slides were available to students for each class after the lesson was taught. How many office hour sessions did you spend with students reteaching material covered in class versus answering specific homework or design questions.
4	How often did you remind your students about the recorded lectures available on Blackboard for their review of material?
5	Did you watch any of the in-class demonstration recordings in preparation for class?
6	Did you watch any of the laboratory exercise recordings in preparation for lab?
7	Did you watch the field trip recordings?
8	How many times did you teach your class from a remote location due to weather, quarantine, or any other reason for not being in person for class?
9	How many times did you have your class taught by another faculty member due to absence as a result of weather, quarantine, or any other reason for not being in person for class?
10	How many times did you provide additional instruction (office hours) in person?
11	How many times did you provide additional instruction (office hours) remotely?
12	Did you feel there was any loss of message delivery or quality of additional instruction when proving additional instruction remotely?
13	Is there anything else you would like to mention about efficiencies you gained due to material created during COVID? Examples would be wonderful!

Table 3. Survey 3 questions derived from institution level as part of the annual end of course survey to qualitatively evaluate student opinions on a variety of areas.

Number	Questions
1	This instructor encouraged students to be responsible for their own learning.
2	This instructor used effective techniques for learning, both in class and for out-of-class assignments.
3	My instructor cared about my learning in this course.
4	My instructor demonstrated respect for cadets as individuals.
5	My fellow students contributed to my learning in this course.
6	My motivation to learn and to continue learning has increased because of this course.
7	My personal schedule allows me enough time to reflect on the material I have learned in class.

Table 3 (continued). Survey 3 questions derived from institution level as part of the annual end of course survey to qualitatively evaluate student opinions on a variety of areas.

Number	Questions
8	My personal schedule allows me enough time to adequately prepare for my optimum academic performance.
9	This instructor stimulated my thinking.
10	In this course, my critical thinking ability increased.
11	The homework assignments, papers, and projects in this course could be completed within the USMA time guideline of a 2:1 ratio of out-of-class time versus in-class time.
12	The classroom environment (e.g., desk setup, boards, technology, lights, etc.) had a positive impact on my ability to learn.
13	In this course, my ability to think creatively and take intellectual risks increased.
14	This instructor encouraged students to think creatively and take intellectual risks.

Table 4. Survey 4 questions incorporate end of course survey questions applicable to the specific course of instruction to evaluate course outcomes (Likert Scale, 1 to 5).

Number	Questions
15	I can design engineered systems to solve fundamental environmental problems in drinking water, wastewater, and air pollution.
16	I can develop models for analyzing environmental problems by applying basic mathematics and science.
17	I can apply the environmental engineering design process to an environmental problem in order to safeguard the environment and protect human health.
18	I can assess infrastructure through laboratory experimentation and site surveys.

3. Results and Discussion

3.1. Use and Efficacy of Narrated slideshow Presentations and Recorded Classes

In 2022, the narrated slideshows were no longer required as part of lesson preparation; however, students were provided with the narrated slideshows to review material after the lesson. Instructors continually reminded students about the availability of the narrated slideshows throughout the semester as confirmed by 85% of surveyed students. These resources developed during COVID are particularly beneficial for students to review more difficult problems. 67.7% of students self-reported they watched a narrated slideshow to review material covered in a class they attended with 84.1% indicating they watched more than one narrated slideshow to gain better understanding of the material (see Figure 2). The narrated slideshows also serve as a resource for students who missed class. 67.7% of respondents stated that they watched recordings of lessons missed due to absences. However, slightly less than 20% replied they did not watch any of the narrated slideshows despite being absent from class. 12.9% selected not applicable as they did not miss any class. For those that were absent, 79.1% watched more than one video which tangentially indicates the perceived value of these resources by the students. Regardless of the student's motivation to view the narrated slideshows, 93.5% of students recommended these resources should be available for future classes with 100% of the students who watched the narrated slideshows rating them as somewhat to very beneficial (see Figure 3).

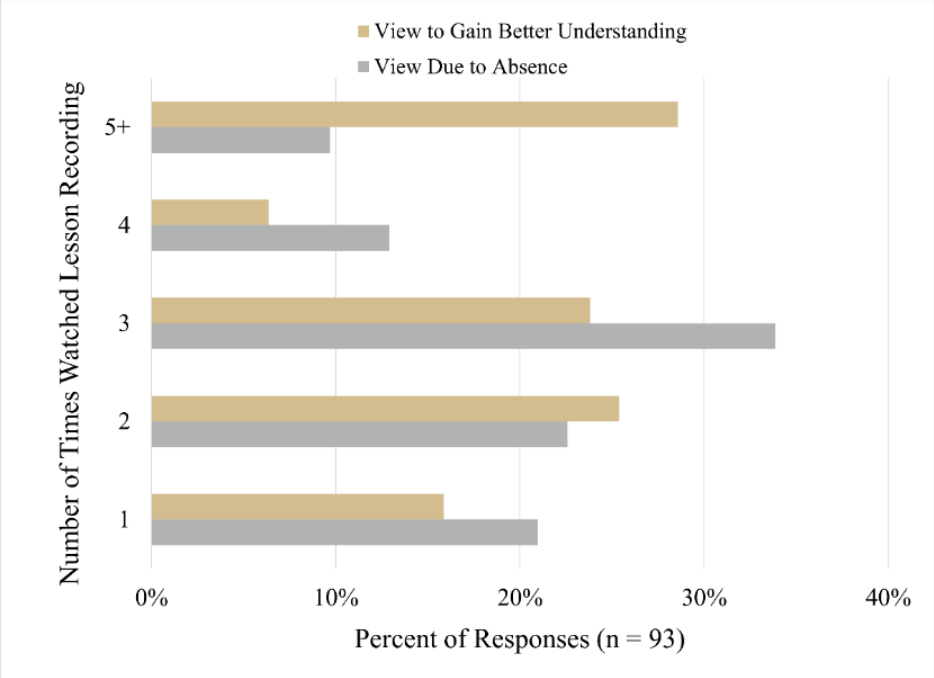

Figure 2. Student use of narrated slideshows in 2022 demonstrating the potential value for maintaining access to these resources for future students.

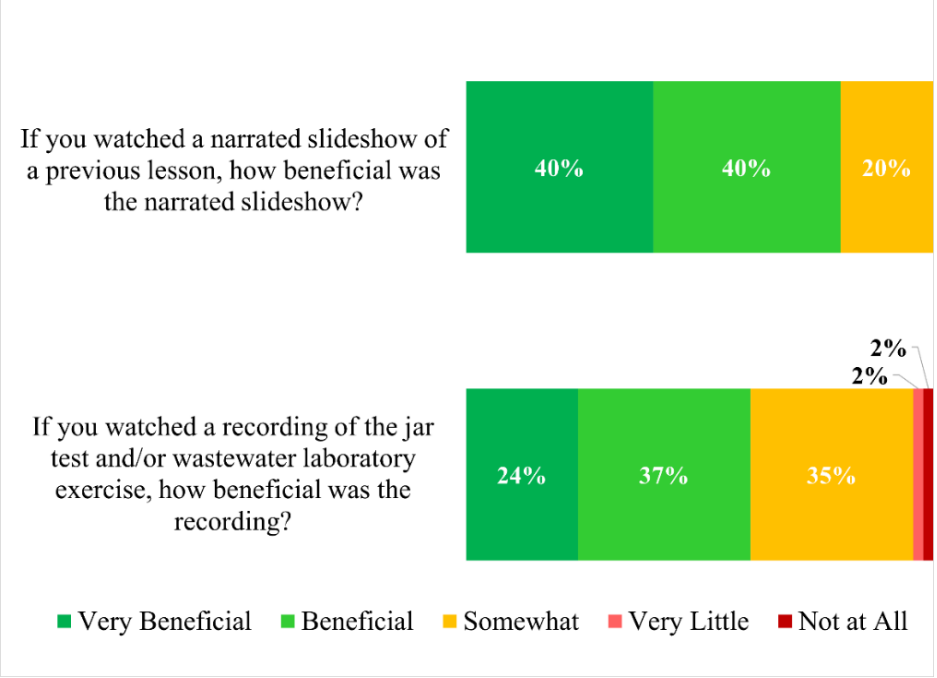

Figure 3. Perceptions on utility of resources and select experiences available for student learning.

The perceived value of the narrated slideshows was highlighted during the standard end of course surveys from 2020, 2021, and 2022 in which students responded to questions to provide sustains and improves for the course. There were no specific questions regarding how the students felt about the narrated slideshows. As students reflected on sustains and improves from

the course, numerous students provided comments specific to the narrated slideshows without being prompted. In 2020, 15.3% of respondents (21 of 137) affirmed the positive significant impact of the narrated slideshows. The two areas identified for improvement from 4 and 5 respondents respectively included shortening the narrated slideshow length and ensuring that instructors did not repeat the material taught in the slideshows during class. In so doing, the instructors reduced the student's perceived value of watching the narrated slideshows because they were getting the same material repeated when attending class. In 2021, 26.15% of respondents (34 of 130) used the opportunity to share positive comments regarding the utility of the narrated slideshows with one student stating, "The PowerPoint videos the night before each lesson were extremely helpful to my learning during this class and I hope they keep them for the next courses to come." With enhanced guidance for the instructors to ensure that they did not repeat what was taught during the narrated slideshows, there was only one comment for improvement received in this area. There were seven comments mentioning the narrated slideshows were too long with an average length of 50 minutes. In 2022, even though there was no longer a requirement to view the narrated slideshows, 19.48% of respondents (15 of 77) positively mentioned the value of these resources with no negative comments regarding the slideshows.

When the narrated slideshows are incorporated properly, students value the ability to participate in more problem-solving which strengthens their understanding of the material and additional benefits. If narrated slideshows are provided and required for students to view prior to class, students should arrive to class better prepared for the lesson. However, faculty must ensure that they do not repeat what was in the narrated slideshows as this has multiple negative impacts such as students feeling the preparation time is unnecessary and repetitive. As a result, students may lose their motivation to view the videos. The instructor also misses out on the opportunity to go deeper into the material as the student should already have the background understanding based on watching the narrated slideshows.

3.2. Transition of In-person Laboratories and Field Trips to Asynchronous Virtual Laboratories and Field Trips

Although laboratories were in-person in spring 2022, 24 of the 92 student respondents stated they watched at least one of the laboratory recordings and 20 students took time to watch recordings of both laboratories. Figure 3 shows that 96% of respondents who watched a recording of one of the laboratory exercises felt that viewing the video was beneficial. Of the 44 students who watched at least one lab recording, 61% found the videos beneficial or very beneficial. Field trips remained asynchronous virtual events for three primary reasons which included eliminating the coordination requirement for on-site visits, reclaiming the additional time spent by instructors during preparation and execution, and reclaiming the additional time spent by students in traveling to and from the field trips.

The standard end of course surveys captured the perceived value of the asynchronous labs and field trips from 2020, 2021, and 2022. In 2020, students mentioned "the labs and guided tours help bring course concepts alive and transfer the academic portion into something real and exciting." In 2021, the positive comments about the value and utility of the lab and field trip recordings almost doubled. In 2022, three students noted they would rather attend field trips in person. However, the opportunity to attend the field trips remotely resulted in 83.7% of

respondents expressing perceived value in the asynchronous modality. The method used to keep students attentive during the entirety of the video included filling out an information sheet regarding what was stated during the video for key processes discussed. 92.5% of students felt this format kept them engaged with 57.6% of students selecting a response that they enjoyed, very much enjoyed, or "oh my goodness, everyone should watch!" (8.7%). One student's survey response summarized the intended outcome superbly, stating "the virtual field trips in this course greatly contributed to my understanding and confidence in what I was learning and what it looks like in real life."

3.3. Faculty Perceptions of Modalities Used & Efficiencies Gained through Interventions

The narrated slideshows developed during 2019 found utility in subsequent semesters for a variety of applications. Instructors had the opportunity to see how the course director presented material. Three of the five faculty responding to the survey (60%) indicated they watched at least one narrated slideshow prior to class for preparation purposes.

Recordings of laboratory exercises, in-class demonstrations, and virtual field trips provide significant opportunities and efficiencies for faculty, students, and the conduct of the course across modalities. Having recorded material available, allowed faculty to easily review and prepare for in-class demonstrations and laboratories. 80% of faculty viewed the in-class demonstration videos to set the conditions for successful execution of the demonstrations in class. The same percentage of the faculty also viewed recordings of laboratory exercises prior to conducting them in person in 2022. In the event of student absences, recordings of these events were available to allow students to not miss out on the learning afforded through viewing. The virtual field trips created in 2020 enabled asynchronous field trips in future semester reducing faculty requirements to travel to and from the field trip location, thereby reducing preparation time and execution time. Additionally, the virtual field trips provide redundancy in the event of inclement weather or availability conflicts regarding desired field trip dates with the water treatment plant or wastewater treatment plant operators. In order to keep students engaged and validate viewing of the entire virtual field trip, each student completed a reflection with questions asked associated with the discussion presented at various points during the field trip. All faculty surveyed noted they watched the asynchronous field trip videos to support further discussions in class.

Recordings of lessons taught during 2019 and 2020 also served as resources for faculty. The ability to view these recordings provided faculty insight regarding questions students have in previous lecture periods. There is also an opportunity to better understand where students struggled to grasp key concepts. Viewing the recordings of the lessons taught also provides faculty with an example of how to teach remotely for those that may not have had that experience. Section sizes at West Point are 18 students. Remote teaching may allow for some students to join other classes remotely. Similarly, if a faculty member is unable to teach in-person (e.g., inclement weather, conference participation), they may shift to remote teaching. 60% of responding faculty taught remotely instead of asking another instructor to substitute in-person. Anecdotally, one instructor asked their students if they would like an in-person substitute or have them teach remotely more than once over the course of the semester due to conferences and other conflicts. Each time, the class was unanimous in wanting their instructor to teach

remotely as the students have familiarity with that style of instruction and the established atmosphere.

The narrated slideshows and recordings of the lessons also provide a resource for students who may have missed the lesson or had trouble with concepts. Providing either one or both resources to students enables them to reengage with the material at their own pace and frequency. This opportunity for the students reduces the demand on faculty to "reteach" lesson material during office hours leading to increased efficiency for faculty. In order to ensure students knew of these resources, all faculty reminded students of the availability of recorded lectures a minimum of three times over the course of the semester (the majority over 5 times). Because of the additional resource, in-person office hour requirements were reduced. 60% of instructors surveyed stated that they spent no more than two office hour sessions covering material already on the narrated slideshows or recording of the lessons over the entire semester. Instead, office hours centered on answering questions about the problems sets or term design project. Additional efficiencies regarding office hours involved the ability to conduct remote office hours via Microsoft Teams. A mix of in-person or remote office hours is now standard practice. Remote office hours increased faculty availability and flexibility while reducing student transit time. There is a point of caution with the higher ease of access which is that students may reach faculty at any point in the day; therefore, faculty must set clear boundaries to protect their own time for class preparation, research, family, and other endeavors.

3.4. Student Performance on Graded Events

Student performance on graded events was used to quantitatively assess the impact of varying teaching modalities. Figure 4 shows mean values of mid-term exams, final exams, and the end-of-course average over the four-year span. Overlapping error bars show 95% confidence intervals and depict statistical similarity in student performance for most events – very few statistically significant differences were identified despite varying teaching modalities. The first notable statistically significant relationship was observed in performance on exams in 2019 (in-person) and 2020 (fully remote). In 2020, student performance on exams 1 and 2 was statistically lower than the 2019 offering (both p values >> 0.05). In 2020, exams 1 and 2 were offered in-person prior to the pandemic-induced shift to fully-remote. The statistically lower performance on exams 1 and 2 in 2020 was counterbalanced by a statistically higher performance (p value >> 0.05) on exam 3 and the final exam, both of which were taken remotely. The reasons for statistically lower performance on exams 1 and 2 in 2020 may be attributed to a change in weighting of multiple-choice problems (from 3 points to 4 points each) between the 2019 and 2020 course offering. However, student performance on exams 1 and 2 rebounded to 2019 levels in both 2021 and 2022 (i.e., there was no statistically significant difference in performance between 2019, 2021, and 2022) suggesting that other variables may have impacted pre-pandemic student performance in 2020. In 2020, exam 3 was the first to occur during pandemic fully remote conditions. The statistically significant increase in performance on exam 3 and the final exam in 2020 is likely attributed to several factors associated with the shift to fully remote. First, students at West Point have many competing military and athletic requirements, all of which were eliminated when students shifted to learning remotely from home. Second, faculty deliberately elected to provide students with more flexibility and leniency when completing graded events. Some students found themselves in unstable home environments during the pandemic or had poor internet connections. Correspondingly, some students were afforded extra

time or resources, which may have ultimately increased scores. Third, the final exam format changed in 2020 relative to 2019. In 2019, the final exam was a cumulative 3.5-hour event consisting of a mix of multiple-choice questions (17) and calculation questions (11). In 2020, the final exam was executed asynchronously via BlackBoard and consisted of a truncated number of questions that were executed over a 24-hour period, which created a scenario for students to score significantly higher than the previous year.

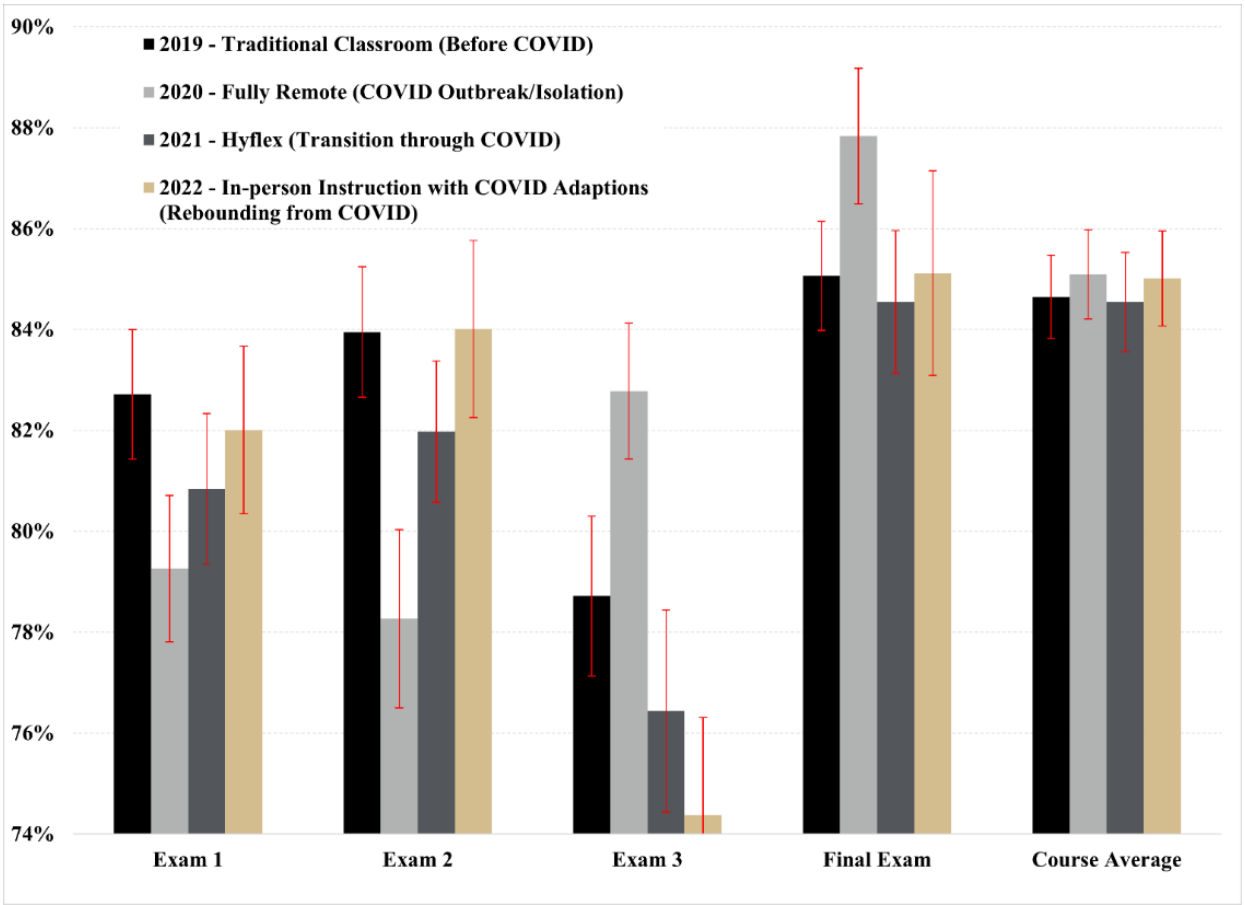

Figure 4. Comparison of student performance on examinations and the course average across four teaching modalities (2019 – 2022). Mean values are depicted and error bars represent the 95% confidence intervals. The number of students surveyed varied slightly by year: 2019 (n = 225 students); 2020 (n = 190); 2021 (n = 215); 2022 (n = 175).

A second notable comparison is observed in the statistically similar final course averages between 2019 and 2022. The final average across all semesters is statistically similar (p value >> 0.05) with a range of 0.17% difference in 95% confidence intervals. This result suggests that student performance was unaffected by the varying teaching modalities implemented throughout the four-year span examined.

Measurement of student performance via graded assignments is largely considered an essential aspect of assessing and evaluating the effectiveness of educational interventions [30, 32] and is a required component in continuous improvement schemes by some accreditors (e.g., ABET).

Unfortunately, grades alone likely underrepresent student learning and aptitude [34, 35] and can result in a diminution in student learning [36]. The COVID19 pandemic resulted in four interventions in EV350, which were continued in post-pandemic face-to-face semesters. Throughout the four years evaluated, the computation of the final course grade remained consistent. Course assessment revealed that these improvements did not result in higher post-pandemic student grades (Figure 4). However, formative assessment (subjective) results (Figure 2 and 3) demonstrated that these course improvements provided substantial benefits to students and faculty that were not captured by student grades. This finding supports the notion that educators must consider formative assessment and be careful not to overemphasize grades when evaluating the effectiveness of learning interventions and other course improvements [30].

3.5. Key Take-Aways

The impact of different modalities did not yield variations in the course average across the four years evaluated. Nevertheless, the value of the resources available for students was denoted through the survey results from both students and faculty. Therefore, the authors recommend the following key take-aways for consideration and implementation.

- Effectively archive all narrated slideshows and video recording made during the pandemic for future use. Be deliberate in placement of the archives for ease of access by new instructors and course directors. This active archiving of the resources made during COVID ensures that the time spent to create the narrated slideshows continues to provide a consistent return on investment of time for both faculty and students. In the current Spring 2025 semester, students are actively using the videos as a resource for enhanced learning.
- Allow additional tools for learning and teaching supported by making narrated slideshows available for faculty and students. Even if the narrated slideshows are not required as preparation for class, the authors strongly recommend that these resources are made available for students.
- Employ the use of recordings of field trips to minimize resource requirement and maximize student appreciation for the connection between course material and local employment of those technologies.

4. Conclusions

Most programs quickly adopted engaging online activities to educate students during the COVID-19 pandemic. Four interventions were continued in post-pandemic face-to-face semesters in EV350. Evaluation of these interventions in the post pandemic classroom revealed that they had limited influence on students' graded assignments. It is argued that educators must consider subjective assessment data for analysis of innovative teaching interventions because grades alone likely underrepresent student learning and the effectiveness of the classroom environment.

References

[1] D. Cucinotta and M. Vanelli, "WHO Declares COVID-19 a Pandemic," *Acta Bio Medica: Atenei Parmensis*, vol. 91, no. 1, p. 157, 2020.

[2] R. Scherer, F. Siddiq, S. K. Howard, and J. Tondeur, "The More Experienced, the Better Prepared? New Evidence on the Relation between Teachers' Experience and Their Readiness for Online Teaching and Learning," *Computers in Human Behavior*, vol. 139 (February), p. 107530, 2023. https://doi.org/10.1016/j.chb.2022.107530.

[3] C. Damşa, M. Langford, D. Uehara, and R. Scherer, "Teachers' Agency and Online Education in Times of Crisis," *Computers in Human Behavior*, vol. 121 (August), p. 106793, 2021. https://doi.org/10.1016/j.chb.2021.106793.

[4] "Faculty Readiness to Begin Fully Remote Teaching." [Online]. Available: https://er.educause.edu/blogs/2020/3/faculty-readiness-to-begin-fully-remote-teaching. [Accessed January 9, 2023].

[5] K. A. Weeden and B. Cornwell, "The Small-World Network of College Classes: Implications for Epidemic Spread on a University Campus," *Sociological Science*, vol. 7, pp. 222–241, 2020.

[6] S. Rashid and S. S. Yadav, "Impact of Covid-19 Pandemic on Higher Education and Research," *Indian Journal of Human Development*, vol. 14, no. 2, pp. 340–343, 2020.

[7] P. Sahu, "Closure of Universities Due to Coronavirus Disease 2019 (COVID-19): Impact on Education and Mental Health of Students and Academic Staff," *Cureus*, vol. 12, no. 4, 2020.

[8] "COVID-19 Educational Disruption and Response | UNESCO," [Online]. Available: https://www.unesco.org/en/articles/covid-19-educational-disruption-and-response. [Accessed January 6, 2023].

[9] L-A. Ewing, "Rethinking Higher Education Post COVID-19," In *The Future of Service Post-COVID-19 Pandemic Volume 1*, Singapore: Springer, 2021. pp. 37-54.

[10] J. DeVaney, G. Shimshon, M. Rascoff, and J. Maggioncalda, "Higher Ed Needs a Long-Term Plan for Virtual Learning," *Harvard Business Review*, May 5, 2020. https://hbr.org/2020/05/higher-ed-needs-a-long-term-plan-for-virtual-learning.

[11] A. P. Kelly and R. Columbus, "College in the Time of Coronavirus: Challenges Facing American Higher Education," 2020.

[12] A. D. Dumford and A. L. Miller, "Online Learning in Higher Education: Exploring Advantages and Disadvantages for Engagement," *Journal of Computing in Higher Education*, vol. 30, no. 3, pp. 452–465, 2018.

[13] L. S. Neuwirth, S. Jović, and B. R. Mukherji, "Reimagining Higher Education during and Post-COVID-19: Challenges and Opportunities," *Journal of Adult and Continuing Education*, vol. 27, no. 2, pp. 141–156, 2021.

[14] Á. Benito, K. D. Yenisey, K. Khanna, M. F. Masis, R. M. Monge, M. A. Tugtan, L. D. V. Araya, and R. Vig, "Changes That Should Remain in Higher Education Post COVID-19: A Mixed-Methods Analysis of the Experiences at Three Universities," *Higher Learning Research Communications*, vol. 11, p. 4, 2021.

[15] D. Turnbull, R. Chugh, and J. Luck, "Transitioning to E-Learning during the COVID-19 Pandemic: How Have Higher Education Institutions Responded to the Challenge?" *Education and Information Technologies*, vol. 26, no. 5, pp. 6401–6419, 2021.

[16] B. Attallah, "Post COVID-19 Higher Education Empowered by Virtual Worlds and Applications," Seventh International Conference on Information Technology Trends

(ITT), Abu Dhabi, United Arab Emirates, pp. 161–164, 2020. IEEE. doi: 10.1109/ITT51279.2020.9320772.
[17] B. R. Wooldridge, K-A. Byun, Z. Pei, J. Hong, and K. R. Swimberghe, "Educational Risk: Lessons Learned during the COVID-19 Pandemic," *Marketing Education Review*, vol. 31, no. 4, pp. 340–351, 2021.
[18] C. Q. Linvill, B. M. Wallen, A. R. Pfluger, and M. A. Butkus, "Incorporation of Best Practices in Environmental Engineering Education to Maximize Student Engagement and Instructor Efficiency," *American Society for Engineering Education, 2021 ASEE St. Lawrence Section Conference Paper,* 2021. https://peer.asee.org/38299.
[19] M. A. Camilleri, "Evaluating Service Quality and Performance of Higher Education Institutions: A Systematic Review and a Post-COVID-19 Outlook," *International Journal of Quality and Service Sciences*, vol. 13, no. 2, pp. 268–281, 2021.
[20] B. Beatty, "Transitioning to an Online World: Using HyFlex Courses to Bridge the Gap," In EdMedia + Innovate Learning Proceedings, Vancouver, Canada, 2701–6. Association for the Advancement of Computing in Education (AACE), 2007.
[21] B. Beatty, "Hybrid Courses with Flexible Participation: The HyFlex Course Design," In *Practical Applications and Experiences in K-20 Blended Learning Environments*, 153–77. IGI global, 2014.
[22] L. Trail, S. Fields, and N. Caukin, "Finding Flexibility with HyFlex: Teaching in the Digital Age," *International Journal of the Whole Child*, vol. 5, no. 2, pp. 22–26, 2020.
[23] M. Leijon and B. Lundgren, "Connecting Physical and Virtual Spaces in a HyFlex Pedagogic Model with a Focus on Teacher Interaction," *Journal of Learning Spaces*, vol. 8, no. 1, 2019.[24] H. Al-Samarraie, A. Shamsuddin, and A. I. Alzahrani, "A flipped classroom model in higher education: a review of the evidence across disciplines," *Education Tech Research Dev*, vol. 68, pp. 1017-1051, 2020.
[25] G. Heilporn and S. Lakhal, "Converting a Graduate-Level Course into a HyFlex Modality: What Are Effective Engagement Strategies?" *The International Journal of Management Education*, vol. 19, no. 1, pp. 100454, 2021.
[26] C. Rapanta, L. Botturi, P. Goodyear, L. Guàrdia, and M. Koole, "Balancing Technology, Pedagogy and the New Normal: Post-Pandemic Challenges for Higher Education," *Postdigital Science and Education*, vol. 3, no. 3, pp. 715–742, 2021.
[27] M. R. Read, B. M. Wallen, A. R. Pfluger, and M. A. Butkus, "Applying Resilience Theory to 'Bounce Forward'from COVID-19 for Environmental Engineering Programs," In Conference Proceedings, *2021 American Society for Engineering Education Virtual Annual Conference*. https://peer.asee.org/36694, 2021.
[28] *Financial Times*, "Arundhati Roy: 'The Pandemic Is a Portal' | Free to Read," April 3, 2020.
[29] M. A. Peters, F. Rizvi, G. McCulloch, P. Gibbs, R. Gorur, M. Hong, Y. Hwang, L. Zipin, M. Brennan, and S. Robertson, "Reimagining the New Pedagogical Possibilities for Universities Post-Covid-19: An EPAT Collective Project," *Educational Philosophy and Theory*, vol. 54, no. 6, pp. 717–760, 2022.
[30] R. Lynch and J. Hennessy, "Learning to Earn? The Role of Performance Grades in Higher Education," *Studies in Higher Education*, vol. 42, no. 9, pp. 1750–1763, 2017.
[31] K. Chamberlin, M. Yasué, and I-C. A. Chiang, "The Impact of Grades on Student Motivation," *Active Learning in Higher Education*, 2018.

[32] D. R. Sadler, "Interpretations of Criteria-based Assessment and Grading in Higher Education," *Assessment & Evaluation in Higher Education*, vol. 30, no. 2, pp. 175–194, 2005.
[33] "Accreditation | ABET." [Online]. Available: https://www.abet.org/accreditation/. [Accessed February 23, 2023].
[34] K. Schwab, B. Moseley, and D. Dustin, "Grading Grades as a Measure of Student Learning," *SCHOLE: A Journal of Leisure Studies and Recreation Education*, vol. 33, no. 2, pp. 87–95, 2018.
[35] P. T. Knight, "Summative Assessment in Higher Education: Practices in Disarray," *Studies in Higher Education*, vol. 27, no. 3, pp. 275–286, 2002.
[36] C. Pulfrey, C. Buchs, and F. Butera, "Why Grades Engender Performance-Avoidance Goals: The Mediating Role of Autonomous Motivation," *Journal of Educational Psychology*, vol. 103, no. 3, p. 683, 2011.
[37] S. A. Eveslage, E. C. Wilson, and G. H. Dye, "BEST PRACTICES: Good Practices in End-of-Course Surveys for Online Master's Programs," *The Journal of Continuing Higher Education*, vol. 55, no. 3, pp. 24–30, 2007.
[38] J. Moss and G. Hendry, "Use of Electronic Surveys in Course Evaluation," *British Journal of Educational Technology*, vol. 33, no. 5, pp. 583–592, 2002.
[39] S. Watt, C. Simpson, C. McKillop, and V. Nunn, "Electronic Course Surveys: Does Automating Feedback and Reporting Give Better Results?" *Assessment & Evaluation in Higher Education*, vol. 27, no. 4, pp. 325–337, 2002.
[40] J. C. Wise, S. H. Lee, T. Litzinger, R. M. Marra, and B. Palmer, "A Report on a Four-Year Longitudinal Study of Intellectual Development of Engineering Undergraduates," *Journal of Adult Development*, vol. 11, pp. 103–110, 2004.
[41] S. Sheppard, C. Atman, R. Stevens, L. Fleming, R. Streveler, R. Adams, and T. Barker, "Studying the Engineering Experience: Design of a Longitudinal Study," *ASEE Annual Conference Proceedings*, 13091-13105, 2004.
[42] "United States Military Academy West Point." n.d. Accessed January 6, 2023. https://www.westpoint.edu/.
[43] A. E. Shell, "The Thayer Method of Instruction at the United States Military Academy: A Modest History and a Modern Personal Account." *PRIMUS*, vol. 12, no. 1, pp. 27–38, 2002. https://doi.org/10.1080/10511970208984015.
[44] "Make Your Students the Hosts of Their Own Learning Experiences." Kahoot! [Online]. Available: https://kahoot.com/schools-u/. [Accessed January 6, 2023].
[45] C-H. Lin, W-H. Wu, and T-N. Lee, "Using an Online Learning Platform to Show Students' Achievements and Attention in the Video Lecture and Online Practice Learning Environments," *Educational Technology & Society*, vol. 25, no. 1, pp. 155–165, 2022.
[46] M. Puhek, M. Perše, and A. Šorgo, "Comparison between a Real Field Trip and a Virtual Field Trip in a Nature Preserve: Knowledge Gained in Biology and Ecology," *Journal of Baltic Science Education*, vol. 11, no. 2, p. 164, 2012.
[47] C. Mead, S. Buxner, G. Bruce, W. Taylor, S. Semken, and A. D. Anbar, "Immersive, Interactive Virtual Field Trips Promote Science Learning," *Journal of Geoscience Education*, vol. 67, no. 2, pp. 131–142, 2019.
[48] "Biden Declared the Pandemic 'over.' His Covid Team Says It's More Complicated. - POLITICO." [Online]. Available: https://www.politico.com/news/2022/09/19/biden-pandemic-over-covid-team-response-00057649. [Accessed January 6, 2023].