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Educational Challenges Presented by COVID-19 at Technical Colleges Offering Aviation Maintenance Technology Program

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ORIGINAL

Abstract
In mid-March, many schools in the United States were forced to stop teaching in-person classes and switch to an online format due to the COVID-19 pandemic; as a result, teachers had to quickly implement new technologies and instructional strategies in the classroom. This rapid pandemic response especially affected teachers and students in Aviation Maintenance Technology (AMT) programs around the country as AMT instruction is inherently hands-on in nature. This study conducted semi-structured interviews with 20 FAA Part-147 AMT instructors and administrators from around the country in order to investigate the challenges they faced during the rapid pandemic response and the strategies and technologies they used to address them. In addition to the interview, all participants completed a survey that provided demographic information and expanded on some of the key interview topics. Thematic coding of the interviews and analysis of the data from the surveys was then conducted based on the Resilience Engineering Framework, resulting in the following themes categorizing the schools' responses to COVID: Preemptive Course Adaptation to Pandemic Disruption, Rapid School Response to Pandemic Disruption, Short-Term Course Adjustment to Pandemic Disruption, Long-Term Course Adjustment to Pandemic Disruption, and Challenges Faced by School Regarding Implementation of Course Adjustment. These themes effectively summarize the different phases of the response of the AMT schools to the sudden demands placed on them to adapt their hands-on curriculum to a virtual format. Ultimately, results from this study may help FAA and AMT administrators recognize the need for improved training and increased implementation of technology in the AMT curriculum to better prepare students and instructors in the event of future major disruptions.

Keywords: Aircraft Maintenance Instruction, Resilience Engineering Framework, Rapid Pandemic Response, COVID-19Virtual Learning, Technical Instruction, Two-year Colleges.

1 Introduction

COVID-19, a highly contagious viral disease that caused a global pandemic in early 2020 Petropoulos and Makridakis (2020), led to the closure of schools around the United States to contain its spread. By the end of March 2020, 124,000 schools had been shut down, impacting more than 55.1 million students across the country Young and Donovan (2020). As a result of these closures, schools rushed to transfer their instruction to a virtual learning format for the Spring 2020 semester Almarzooq et al. (2020). However, many schools were challenged by this transition as most of their classes had been taught completely in person until this point.

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As part of the initial pandemic response, many schools closed completely for a short period of time to determine a course of action for the rest of the semester Owusu-Fordjour et al. (2020). During the transitional period before online classes began, students and teachers faced multiple challenges, including varying levels of access to the necessary technologies among students, teachers with limited technology experience, and difficulty in developing virtual learning schedules that students could easily follow. Schools often transitioned to virtual learning by using internet-based educational services and devices like tablets and phones to assist them Basilaia and Kvavadze (2020). These virtual classrooms could be accessed on platforms such as Zoom, Cisco Webex, Google Classroom, Canvas, and Microsoft teams vir (2020). However, teaching labs and hands-on content were difficult to transition to a virtual format due to their inherent interactive nature McQuate. Some instructors chose to stream themselves doing the lab live over the internet and have their students watch and complete assignments regarding what they learned. In other cases, schools delayed lab instruction to a later date, waiting until it was safe for students to return and complete the labs in person.

When faced with such an unexpected challenge as COVID, schools are forced to adapt their instruction rapidly. The Resilience Engineering Framework proposed by Madni and Jackson Madni and Jackson (2011) provides a context for understanding how the organizations, such as schools, are able to adapt to and survive disruptions. This framework describes "external disruptions" as events caused by factors outside of the organization, such as the current global pandemic, that disturb its normal operation. These disruptions are often unpredictable and, hence, difficult to prepare for. In order to avoid catastrophic damage, an organization needs to maintain a supply of resources and have safety procedures in place to address these potential challenges. The conceptual framework for resilience engineering provides an outline for evaluating an organization's ability to rebound from a disruption and consists of four parts: Avoidance, Withstanding, Adaptation To and Recovery From. Avoidance describes the preventive measures that need to be taken to withstand a potential disruption to the system during the remaining phases. This framework also argues that safety, or the system's ability to prevent serious damage when a disruption occurs, is a dynamic characteristic that should be consistently updated so that the system is able to handle new demands. Once the organization is faced with a problem, it is expected to withstand it and absorb the disruption. A critical part of withstanding a problem is being prepared and having the correct resources for handling the situation. To do so effectively, the organization must adapt to the unexpected situation by implementing the procedures they developed to withstand the disruption as well as continue to modify the system as needed. Finally, recovery requires the organization to restore the system to its original state as best as possible though it may face challenges or limitations in doing so. The ability of a system to return to its optimal or operating state depends on its overall resilience. This engineering framework can be applied to a large range of organizations, including higher learning institutions, as engineering, social, and organizational resistance have previously been analyzed using this framework to determine the enablers and barriers faced by the system of higher education Naderpajouh et al. (2018).

This paper applies the Resilience Engineering Framework to the Federal Aviation Administration Part 147 Aircraft Maintenance Technician program to investigate its rapid pandemic response and adaptation of classes to a virtual learning format. There are 178 Part 147 Aircraft Maintenance Technician Schools (AMTS) accredited by the U. S. Federal Aviation Administration (FAA) FAA. These programs are often found at 2-year colleges In order to incorporate an accredited program, the school must go through a 5-step process that includes pre-application, formal application, document compliance, demonstration and inspection, and certification by the FAA r2,Sherman (2006). AMT instruction covers a broad range of topics, including aviation mathematics, FAA regulations, basic electricity, aircraft drawings, and engine inspections and maintenance, broken into 3 levels of instruction avi, AMT (a). Level One classes require knowledge of general principles and instruction by lecture, demonstration, and discussion, but no practical application nor development of manipulative skill. Level Two classes require knowledge of general aviation principles and some demonstration of skill, while Level Three classes require a high degree of practical application and instruction using AMT equipment to simulate a return to service.

These programs are largely hands-on in nature, with course activities focused on teaching students skills like welding, maintaining aircraft hydraulics and electronics, and performing engine and turbine inspections AMT (b). The FAA also requires students to spend a certain amount of time using tools and working on planes before they become certified Aircraft Maintenance Technicians. Furthermore, FAR Section 147.21(e) requires at least 50 percent of the curriculum to be taught in a machine shop or laboratory. As such, these AMT classes were significantly impacted by the nationwide shift to virtual learning.

AMT programs are currently allowed to deliver limited training using distance education methods but only with the issuance of the A026 Operations Specification FAA (2015). This requires programs to follow guidance provided by the FAA to develop a distance learning system that includes detailed plans for delivery methods, communication strategies, online system security, and record keeping. The guidance also specifies that distance delivery is only suitable for content normally taught using lecture and written assignments, which does not include most topics requiring instruction at Levels 2 and 3 . While the FAA does provide this mechanism for virtual learning, the lengthy development and approval process and subsequent limited application prevents it from being readily obtainable during an emergency situation such as has been experienced with the restrictions due to COVID. In acknowledgement of this, the FAA issued additional guidance for deviations due to AMT training interruptions almost immediately after the nation was required to stop face-to-face classes in its educational institutions FAA (2012). Options provided in this guidance included expansion of existing distance delivery systems and a fast track issuance of a temporary distance delivery operations specification. However, only 64 of the 89 AMT programs surveyed at the beginning of the pandemic restrictions by the Aviation Technician Education Council indicated that they were using some form of online delivery method in response to the pandemic FAA (2020a). None of the respondents reported using remote instruction for the required hands-on lab activities.

This paper investigates the nature of the rapid pandemic response at AMT schools around the United States using the Resilience Engineering Framework. This paper makes three distinct contributions to aviation maintenance technology education. First, it identifies the challenges that AMT schools around the country faced during the rapid pandemic response as well as the organizational considerations that caused these challenges. Second, it investigates the strategies that instructors employed at different stages as they adapted their courses to virtual learning through interviews. Third, as its primary result, this paper analyzes the mechanisms by which AMT schools around the country can improve the nature of their education and make their curriculum more resilient to improve their response to future disruptions.

1.1 Research questions

Given the hands-on nature of FAA Part 147 aircraft maintenance instruction and the abrupt, rapid pandemic response in Spring 2020 by schools in the United States, Part 147 instructors were forced to quickly adapt their instructional practices in the wake of COVID-19. The goal of this study is to determine the techniques and technologies instructors used to transition to online Part 147 instruction. More specifically, it addresses the following questions:

1. What educational demands were placed on faculty members during the rapid pandemic response?

2. What barriers to adoption and integration of e-learning resources did faculty members and students experience?

3. What strategies did educators employ to most effectively teach students during the rapid transition?

By exploring these research questions, we can better understand how the educational process was impacted by COVID-19 and more effectively identify components of AMT instruction that can be improved to make these programs more resilient. These insights will also aid future work regarding how to implement technology in order to improve education.

2 RESEARCH DESIGN

The research methodology and analysis were conducted using the Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist Tong et al. (2007). A sample of 20 AMT instructors from the United States participated in this study. Semi-structured interviews were conducted to determine the nature of the participant's pandemic response. The responses from these interviews, combined with information from a demographic survey completed by the instructors, were used to identify common themes regarding both the challenges encountered and the overall response.

2.1 Methodology

The study was qualitative in nature, combining an interview and survey section. The purpose of the interview was for instructors to discuss the challenges that they encountered during the rapid pandemic transition due to the COVID-19 crisis and the ways that they used technology to address them. The interview questions were developed by the research team to address the initial research questions, with additional follow-up questions added as needed. The survey covered demographic and educational background information, and was used by the researchers to contextualize and better understand the participant's interview responses. Interview audio recordings were transcribed and then analyzed for relevant themes by two researchers through iterative rounds of coding.

2.2 Participants and Sampling

The participants in this study were identified through collaboration with the Clemson University Center for Workforce Development and the National Center for Autonomous Technologies. Despite this collaboration, the participants were AMT instructors from around the United States. They were selected because all were instructors at technical colleges who supervised and taught FAA Part 147 aircraft maintenance courses that were affected by COVID-19. As such, their experiences and insight into adapting their instruction during the rapid pandemic response were valuable to this study. Participants were purposefully recruited through an email sent by one of the researchers outlining the purpose and nature of the study. A total of 78 instructors were contacted. Of the of 78 instructors contacted, 20 (25.6%) consented to participate. These instructors come from schools around the country and offer a holistic, varied view on the state of AMT education. Interviews were conducted online via Zoom, and all surveys were completed online via Qualtrics. All participants were compensated with a $25 Amazon Gift Card for providing their input. Participants were first interviewed and then asked to complete the online survey (see Appendix B) that covered basic demographic information and questions about their response to the pandemic as an educator. Information obtained from the survey can be seen in Appendix C.

2.3 Data Collection

Regarding the data collection process, all interviews were conducted using a semi-structured format to gain insight into the participants' experiences as instructors during the rapid pandemic response. This interview approach is appropriate as its open-ended nature encourages participants to elaborate on their perspectives and experiences regarding teaching. The interview section consisted of two sections, an interview overview followed by questions related to instructor experiences and challenges. The interviews were conducted by the first author. The interview overview, which was not recorded, consisted of the interviewer informing the participant of their background as a researcher, the nature of the study, and its purpose to determine and characterize the issues and technologies they encountered as instructors during the rapid pandemic response. The instructor-specific questions, which were recorded on the interviewer's laptop, covered topics including the specific courses the instructors taught in the spring and their structure, the general strategies the instructors used to adapt the lab and lecture components of their classes to a virtual format, the specific technologies the instructors used to teach virtually, and the overall challenges they observed and the practices they found to be effective. The first and second authors developed the interview protocol and interview questions in order to effectively address the initial research questions (see Appendix A).

Table 1. Participants' Demographic Information

Factor		**Sample, N=20**
Gender	Male	18 (90%)
	Female	2 (10%)
Experience	Average age	56.55
	Average years teaching at an AMT school	12.375
Class Size	Small (1-20 students)	11
	Medium (21-30 students)	7
	Large (31+ students)	2
Original Class Format	STEM class with lab activities and lectures	11
	STEM class with only lectures	3
	Non-STEM class	1
	Other	5
Technology Use in Education Before Pandemic	Never	0
	Once a week	3
	3 times a week	3
	5 times a week	1
	Once a day	3
	More than once a day	10
Technology Use in Education After Pandemic	Never	1
	Once a week	1
	3 times a week	2
	5 times a week	1
	Once a day	2
	More than once a day	13
Previous Experience Teaching Virtually	Yes	10
	No	10

As previously mentioned, the survey was conducted through Qualtrics, an online surveying tool, with participants being sent a link to complete the survey immediately after the interview qua (2015). Similar to the interview development process, the first and second author developed the survey/demographic questions in order to provide a relevant understanding of the participant's background and teaching experience. Additional survey questions were included based on existing peer-reviewed survey instruments regarding the administration of virtual labs and key considerations for adapting general education in light of COVID-19 Heradio et al. (2016). More specifically, the survey instruments developed by Heradio et. al. for evaluating virtual labs in controls education can be effectively applied to AMT education due to the heavily technical, interactive nature of these labs' source material. The questions in this survey covered topics such as the instructor's technology use before/after the rapid response, the nature of their instruction before the pandemic, and their perceived effect of virtual classes on the student's overall learning (see Appendix B). Moreover, survey results provided the researchers with a background knowledge of their subjects that they could then use to better understand and interpret findings from the interviews.

Due to the COVID-19 pandemic, the study had to be conducted entirely virtually. Thus, all interviews were conducted between the participants and the researcher over the teleconferencing platform Zoom, with the researcher sending the participant a link to join the call at least 12 hours before the start of the interview Video (2019). Each interview was conducted only once and was audio recorded with no additional notes taken by the researcher. Although the semi-structured interviews followed the protocol developed by the researchers at the beginning of the study, participants were encouraged to freely speak about their experiences and deviate from the questions as needed. Furthermore, probing or follow-up questions that were not part of the interview guide were supplied by the interviewer as needed based on the responses given by the participant to the initial questions. All audio recordings and survey responses were stored in an encrypted and password protected database on a secure university server that could only be accessed by the primary investigator and the members of the research team.

2.4 Data Analysis

All surveys were transcribed using the service provided by GoTranscript got. Then, thematic analysis was conducted on the transcribed data, with two researchers conducting iterative rounds of category generation and coding.

2.4.1 Initial Category Generation

To generate categories for the interview dataset, three randomly selected interview transcripts were analyzed by both researchers. They read these interviews separately, with each individually generating several categories describing the participants' responses. Then, the two researchers discussed the categories they had developed. These codes were then compiled, resulting in 34 categories describing the themes in the data.

Next, three more interview transcripts were randomly selected and analyzed as part of the pilot analysis process. They were coded by both researchers using the previously developed 34 categories, with each independently adding any new codes as needed and noting those they deemed redundant or not useful. The two researchers subsequently discussed the codes that they used to categorize the second group of interviews, and the original codebook was then refined, resulting in 30 formal categories describing the major themes found in the data. Each of these categories was formally defined to ensure agreement by both researchers. The codes generated through this iterative coding process are as follows: Asynchronous Lecture, Best Practices, Course Structure Adjustment, Biggest Challenge, Course Name, Course Structure, Desired Resources, FAA Challenges, Face to Face, Hands On, High-level Labs, In-Person Class/Labs, Lab Challenges, Lab Adjustment, Lecture Challenges, Lecture Adjustment, Low-level Labs, Safety Student Challenges, Student Engagement Negative, Student Engagement Positive, Support, Synchronous Lecture, Technologies Used, Technology Accessibility, Previous Technology Use, Technology Challenges, Testing, and Transition.

After two rounds of initial category generation and pilot coding, both researchers independently coded the entire data set of 20 interviews based on the 30 categories they had generated, assigning the appropriate codes to each instructor response. This qualitative analysis process was conducted based on the research guidelines in Braun and Clarke Braun and Clarke (2013). The two researchers met to compare their responses, discussing any disagreements until they reached 100% consensus. Inter-rater reliability between the two researchers, calculated using Krippendoff's c-Alpha-binary method iRR, was 0.922.

3 Results

Applying the Resilience Engineering Framework to the interview data resulted in the following five themes describing the response of AMT schools to disruptions like COVID-19: Overall Course Structure of Part-147 AMT Instruction, Preemptive Course Adaptation to Pandemic Disruption, Rapid School Response to Pandemic Disruption, Short-Term Course Adjustment to Pandemic Disruption, and Long-Term Course Adjustment to Pandemic Disruption. Course Structure is defined as the characteristics or general attributes of the AMT course/curriculum. Preemptive Course Adaptation, which is consistent with the Anticipation phase of the Resilience Engineering Framework, includes the practices that the school employed prior to the pandemic to preemptively adjust to the move to virtual learning. Rapid Response, corresponding to the Withstanding phase of the Resilience Engineering Framework, reflects the beginning of the pandemic when most schools scrambled to transition or find a temporary solution to the disruption that they faced. Short-Term Adjustment, consistent with the Adaption To Phase, includes the strategies that schools used to complete the semester as they reformatted as much of their program as they could to a distance learning format. Long-Term Adjustment, consistent with the Recovery From phase of the Resilience Engineering Framework, includes the strategies or general changes to the AMT curriculum that schools plan to make their programs more resilient and suited for virtual instruction in the future. Furthermore, most schools around the country encountered a variety of challenges during the pandemic response, and these issues are also included in their respective themes.

These themes provide a comprehensive understanding of the rapid pandemic response as they cover specific educational demands that educators encountered, the evolving strategies that they used to respond over time, and the different challenges and disadvantages related to these strategies that they encountered over time.

3.1 Overall Course Structure of Part-147 AMT Instruction

During the interviews, the instructors consistently discussed the practices they employed to adapt to virtual AMT education, focusing on the key characteristics regarding the course organizational infrastructure, complexity, and overall function. These recurring concepts that describe normal AMT instruction before the pandemic are defined as Course Structure. They commented on the general structure of their programs, ranging from such general descriptions as "We'd like to do the lecture, reinforce it with the lab, go to the next lecture, reinforce it with the lab, go to the next lecture, and so on," (Participant 1) to specific credit-hour breakdowns as explained by Participant 8, who indicated that "the theory or lecture component of the airframe program is about 289 hours and then the lab component is 461 hours."

Because Part-147 instruction is heavily lab and technical skill-focused, instructors also elaborated on the overall nature of AMT lab instruction, with many expressing that one of the most crucial aspects of their program was that instruction was hands-on, providing students with the opportunity to interact with relevant equipment: "Our kind of student is here for that reason – they want to physically go down and touch that plane and torque bolt. They want to physically go down there and pull a panel off the plane" (Participant 18). Other instructors explained that all AMT programs are focused around teaching "hands-on manipulative skills that the student is supposed to acquire while they're in school, so they can be utilized on the job" (Participant 13).

In addition to stressing the generally hands-on nature of AMT instruction, a clear delineation between the different types of labs in the Part-147 curriculum emerged, with the labs being grouped into either low-level or high-level labs. Low-level labs usually fall under Level 1 Part-147 course guidelines and tend to be theory or lecture-heavy, as they include components corresponding to the general education courses. As Participant 6 explained, "Aerodynamics labs, those were very– They were a little less hands-on and a bit more theory and principle-based". This view was supported by Participant 12 who expressed that the lab components for the paperwork/research courses involved "level one projects [that] don't require physical hands on too much. It's mostly working with the aircraft manuals and load manuals and things like that." On the other hand, high-level labs require extensive hands-on work by the student and heavy aircraft-related equipment, usually falling under Level 2 or 3 Part-147 guidelines. Participant 12 explains that these labs often involve working on an airplane as students complete activities like "disassemble, inspect, and reassemble a magneto and perform the internal timing of that magneto and then test it, and of course, to install a magneto on an engine and time it to the engine."

While AMT schools around the country developed a plan to adjust their course instruction to a virtual format during the rapid pandemic response, to actually implement this new learning plan, programs had to obtain approval from their local FAA office, an issue for many schools; as Participant 14 explained, "With most part 147 schools, there's not a lot of technology incorporated because of the type work it is and because we're so bound by the FAA who has been so reluctant to allow anything online." Obtaining this approval to adapt instruction to the pandemic was an issue for many instructors because of such factors as the lack of uniformity in FAA guidance; according to Participant 16, "One of the biggest frustrations is the inconsistency from flight safety office to flight safety office because the principal maintenance inspectors have such control over what we do, they really can dictate a lot of it and a lot of it, it's an opinion-based more than anything else" In addition FAA was seen as guided by outdated policies as Participant 17 explained, saying "We will get there someday, but not when the FAA is still living in the 1960s or the early 1970s which is when part 147 was written" (Participant 17). Ultimately the FAA dictates the nature of AMT instruction, both before and after the pandemic. Therefore, this organization can act as a barrier to instructors adjusting their course structure to fit a virtual format in light of this and any other disruption.

The common themes regarding course structure and system attributes were further supported by results from the survey. Of the instructors surveyed, 55% taught a STEM course with a lab and lecture component, 15% a STEM course with only a lecture component, and 5% taught non-stem courses. The instructors who responded "Other" to the survey were all in administrative roles and did not directly teach classes during the spring semester. Survey results regarding original course structure can be seen in Table I.

3.2 Preemptive Course Adaptation to Pandemic Disruption

During the rapid pandemic response, all AMT course instruction could no longer continue to be taught in person. In response, instructors adapted at least some portion of their course to synchronous or asynchronous instruction using technology. During the interviews, instructors commented on whether they had previous experience using technology for education before the pandemic. They were specifically asked to elaborate on the technologies that they used as well as how they used them. These practices that instructors employed to make their teaching more robust and to quickly adjust to virtual education are defined as Preemptive Course Adaptation.

Technology use among instructors before the rapid pandemic response varied, with some indicating that they used technology infrequently in the classroom, stating "it was pretty rare. In fact, I would hardly ever use Blackboard except to post PowerPoints and things of that nature. I typically wouldn't even use it to grade. . . . We really didn't use any sort of computerized technologies in the classroom" (Participant 4). Others responded that they discouraged their students from using technology in the class, saying "we do not want students in lab taking notes on a computer. . . . In several of the classes, we are actually prohibiting in-class tablet and laptop use" (Participant 11).

However, instructors at other schools used technology frequently; according to Participant 2, for example, "We use it on a daily basis. Every student is assigned a laptop computer in the program." Furthermore, some had begun implementing several distance learning technologies in their face-to-face class that they would use more extensively in the response to the pandemic: "I had been planning for us to go more to a digital type campus. I've been very instrumental in creating a digital type environment because I felt like that was where the program needed to go. I had already created a SharePoint site with all of our manuals, and all of our interactions and documents, and forms and training stuff for our students and for our instructors. It was an easier lead probably for us than it was for a lot of folks" (Participant 3).

These trends with some instructors not utilizing technology, while others proactively adapting their course to suit a virtual learning environment can be seen in the survey data as well. Of the 20 instructors, 10 had never taught a class in a virtual format, while the other 10 had used some form of virtual instruction before the pandemic. Instructor technology habits before the move to remote learning can be seen in Table I.

3.3 Rapid School Response to Pandemic Disruption

In light of the disruption caused by COVID-19, schools across the country were forced to decide if and how they would continue teaching AMT classes if they were not going to be able to do so in-person. This period of the rapid pandemic response when schools were tasked with instantly responding to an external disruption and developing a transitional plan is referred to as Rapid Response.

When instructors were asked about the actions that they and their school took immediately after the announcement that classes could not be held face-to-face for the foreseeable future, many initially commented on the status of their course at the time of the rapid response, primarily focusing on the need to complete the lab components of their classes. As Participant 2 explained, "In the case of ignition systems, that's a combined course of which lecture was, let's say it was a 75-hour course, and lecture was 25 hours, and lab was the remainder. I'd only taught 10 hours of the lab." On the other hand, some instructors had more work left regarding the lecture component. For example, Participant 1 explains, "when we broke down and had to do the restriction, we only had about six or eight hours of lab remaining. The rest of it was all lecture."

Furthermore, many schools took immediate action during the rapid response and put classes on break or extended current spring breaks so that instructors would have time to adapt to a new format. For example, Participant 6's institution gave its faculty one more week after spring break "with no class at all in order for the instructors to move to online. They gave us a week to get started." Not only did this break period provide teachers with time to prepare lessons using new technology - "I had never really used voice-over PowerPoints. . . . What I did was the week after we decided to resume classes distance, I gave my students a week off. I said I need a week to get ahead of you" (Participant 11) - but AMT schools around the country also used this period to provide teachers with formal guidance and training about how to respond to this disruption effectively. This support during the rapid pandemic response included providing instructors with training seminars on the various virtual educational tools; for example, Participant 6 indicated that "We have a department on campus called Center for Teaching Excellence. . . . They did a lot to push out to everybody like, 'Here's all of the things available to you as a teacher in order to offer a digital-based or an online-based instruction.'" In addition, schools passed along overarching directives from the FAA to teachers about how they could go about further adjusting their classes; as Participant 10 explained, "We did receive oversight through the school and we were all provided the information that was provided from the FAA for 147 schools. We knew what the rules of engagement were." This support provided to instructors in combination with any strategies instructors employed during the initial transition phase characterizes how instructors were able to address the challenges of adapting their classes to a virtual format.

3.4 Short-Term Course Adjustment to Pandemic Disruption

After the initial pandemic response when instructors were compelled to rapidly acclimate to new distance learning technologies, they adapted their lesson plans and adjusted protocols for the teaching of the lecture and lab components of their courses. These strategies and this reconfigured format that they used in their classes for the rest of the semester are referred to Short-Term Adjustment.

Given the multifaceted nature of AMT instruction, instructors employed a variety of adjustment strategies. On a general level, their first change involved modifying the overall structure of the course to suit an online format. To do so, instructors employed strategies like only teaching material that was not hands on; for example, as Participant 8 explained, "We went to a remote instruction or online instruction and we did both synchronous and asynchronous. We were only delivering the theory components." Others moved all material to another virtual format: "I just set everything up in a [Canvas] module, where there was a lecture with videos and one-dimensional pictures and so forth, and then along the way, you did a lab assignment, which was that you'd have to go into various manuals or textbooks, to determine the outcome or answer to the questions, and then there were quizzes" (Participant 7).

Instructors also employed specific strategies to adapt the lecture and lab components of class individually. For the lecture adjustments, teachers employed various strategies and technologies that mimicked the lecture environment of a normal classroom, saying, for example, "we took our classroom lecture format and put it into Teams. Then we had a distance learning virtual classroom setup where the students all had laptops already. They would log into Teams and we would use the video camera portion, and we would conduct class and the lecture in that regard. Then, practical demonstrations, I would do on camera" (Participant 10). Lecturing in a virtual format also required teachers to reconfigure the way that they spoke to and engaged their class; as Participant 1 explained, "It changed the way I taught. I would lecture for a few minutes to stop and ask a series of questions and lecture for a few minutes. I would have to pick different students, the ones that I know typically were the ones that would struggle."Furthermore, in conjunction with these strategies, teachers either shared lecture material with their students synchronously or asynchronously. Synchronous lectures occurred in real time between the instructor and the students over a teleconferencing platform; for Participant 3, "It was always in person, it was always a live lecture. The instructor would log in at the time of the class and he would make contact with everybody through the cameras." Asynchronous lectures, on the other hand, involved recorded videos usually posted to a hub where students could watch them at their own pace; as Participant 4 explained, "they would record [the lectures]. Then I would give the recording to our IT Department and then they would link it to our Blackboard page so then the students could stream it from our website and they could watch it any time they wanted to."

Instructors also had varied approaches to lab courses, with varying adjustments depending on the content and level of the lab, with low-level labs being adapted to a virtual format. According to Participant 3, "we converted all of our level one and level two labs that did not require a hands-on component into Microsoft Forms. My instructors were very diligent in switching that format so that the students could interact with the instructor through Microsoft Forms and do questions and answers and research and fill out project material." This strategy was used more frequently and more completely with these labs than the high-level labs; as Participant 15 explained, "Some of them that are to a level three, I've been able to have them do partially online so that when we meet again, I'll be able to pick up where they left off and say, 'Okay. Now, here's the airplane. Now go out to the airplane and finish the process.'"

However, the most common strategy employed by instructors to teach labs, especially high-level labs, was to bring students back to school at a later date when it was deemed safe by the school; according to Participant 16, "in June, we brought back our students for a two-week intensive lab setting. They were on campus for two weeks for four hours a day and they did nothing but their level three labs" (Participant 16). Moreover, these high-level labs were often required to be taught in person by the FAA, meaning they had to be completed at a later date because "the level three labs, the return to service labs, almost all the sheet metal labs are at that level and because they were at that level, I was not able to do anything towards doing them online. They require an in-person" (Participant 15). Although these labs were completed in person, schools conducted them with extra consideration for safety and social distancing in an effort to prevent the spread of COVID-19; as Participant 4 explained, "We had like an open shop that was set up with social distancing and spacing and disinfecting and all that, but then they would leave, and then we would have class."

While most instructors were able to adapt their lecture instruction despite these limitations necessitated by the pandemic, they still encountered many issues regarding the ability to relay information effectively: "When you're sitting at a computer, you don't know what to do with yourself because you're used to articulating, and there's a tendency to go into a monotone voice, like you're reciting into a microphone, a recorder, or something" (Participant 20) They also were unable to monitor their students' engagement and understanding of course material: "The biggest issue was the fact during the lecture you never knew who really understood it and who didn't understand it without going through" (Participant 1). Moreover, instructors explained that students were easily distracted from virtual lecture because, for example, "you got families trying to cook dinner that kind of stuff. There were a lot of distractions in a lot of the students' homes, which didn't aid them in being able to concentrate fully" (Participant 10). Instructors who adjusted lab instructions by delaying them to a later date when students could return to campus frequently encountered issues with student retention due to the break in time between lectures and resumption of labs: “We had some people that took three or four times as long as if they had gone from the class to the shop to do the project because their either retention or their attitude or any one of the possible things that makes you not pay attention or not remember, could have kicked in” (Participant 17).

Apart from the lab components that were completed in person, all course reconfiguration was centered around or dependent on various technologies. The technology was used by AMT instructors for lectures was Zoom as explained by Participant 4 who said, “that’s what I do now, to host, basically, lectures,” while for labs Participant 3 “discovered a program called EveryCircuit. . . .They could build the electronic circuits on their computer screen rather than build them live with actual components.” In addition, this participant also reflected on the change in the way exams were administered, saying “I converted all of our [quizzes] to electronic forms using Microsoft Forms to where the exercises and the labs and the quizzes and testing can be rated automatically” (Participant 3). The different technologies and ways that instructors used these technologies were found throughout all aspects of the reconfiguration process as instructors concentrated their efforts for addressing the challenge of distance learning.

Both students and teachers had issues implementing and adapting to new technologies. Because AMT instruction is an inherently applied discipline, students had issues adapting to virtual classes as this mode of instruction was very different from what they had registered for, saying “the biggest hurdle for these kinds of programs is that we’re talking about students who chose to go to a program that is so heavy with hands-on skills, that the idea of doing it in an online setting is just not something that – Those two things don’t fit” (Participant 6). Furthermore, many instructors did not have experience with the technologies needed for virtual instruction: “For some instructors, they came into it extremely challenged, just having learned things like PowerPoint and presentation skills and things like that” (Participant 3).Furthermore, both students and teachers sometimes lacked access to the necessary technologies for virtual instruction, especially students, many of whom lacked the equipment or proper connection to engage in classes conducted over the internet: “We did run into some challenges with some of the students that were on cellular plans and they were getting metered by the end of the first week or so” (Participant 20).

3.5 Long-Term Course Adjustment to Pandemic Disruption

All interviews were conducted with participants in late June and early July, approximately four months after the rapid transition that instructors responded to in March. As such, instructors were able to evaluate some of the strategies that they used to Anticipate, Absorb, and Adapt to the pandemic disruption. Any new practices or tools that instructors have begun to implement or wish to implement in their AMT instruction in order to make the overall educational process more resilient to future disruptions are defined as Long-Term Adjustment.

When asked about the changes the AMT instructors were planning to incorporate into their overall instruction in light of the challenges of the pandemic, many expressed their interest in integrating technology more fully and effectively into the overall course structure: “We’re trying to incorporate more of that just, because these students–that’s technology that grabs their attention and they like it. We’re using that on a small scale. I’d like more of my faculty to be utilizing that as well” (Participant 18). Furthermore, teachers who were once resistant to using technology in the class have begun to change their perspective; for example Participant 20 indicated that “now, we have an implementation plan that we are formulating where in the classroom we will start to allow some of those devices when we’ve got Canvas up to a level that we believe is to our satisfaction and content.”

Although instructors were able to adapt a large portion of their lecture instruction to a virtual learning format, many labs had to be completed in person because of their intensive, hands-on nature. When asked about the resources that would be useful for effectively teaching labs in a virtual format, instructors had an extensive wish list, ranging from specific existing simulation software currently used by aviation companies– “Let’s say that you want to teach landing gear, Boeing can project a holograph of, say, a 777 landing gear and students can put on special goggles that allows them to not only see but then they can go ahead and remove the wheels, service the strut, etcetera, on this holograph" (Participant 2)–to general, large-scale technologies–"I want digitally modeled aircraft. I want virtual reality digitally modeled aircraft so that I can have students actually mess around with things using a digital model" (Participant 15). A commonality observed among all the resources desired by instructors was their wish for virtual reality or simulation technology to help teach labs in the future: "I like the VR world that's coming out around now and the enhanced VR. . . . If we could have that, some of these other subject areas that are currently done hands-on could be accomplished virtually" (Participant 13).

While teachers expressed interest in adapting higher-level labs to a virtual format at some point, they frequently mentioned that the existing simulation and VR technologies for this kind of instruction were too expensive or proprietary: "It would have been nice if we had the ability to do some virtual labs, but unfortunately I don't know of any technology out there other than what Boeing has that would allow us to do that… but it's astronomically expensive" (Participant 2).

Some of the trends observed throughout the interview process, such as changes in the way that instructors use technology, are also seen in the survey data. In general, it can be seen that instructors made more frequent use of technology on a daily basis for education after the rapid pandemic response relative to before as shown in Table I.

4 DISCUSSION

Many schools around the country found themselves scrambling in March to adapt whatever components of their curriculum they could to a virtual format. This situation was especially true for AMT instructors as their course curriculum was designed by the FAA to be almost entirely hands-on. To explore this pedagogical change, this study examined the educational demands placed on AMT educators, the specific strategies that they employed to address these demands, and the challenges that they encountered when trying to implement these strategies.

4.1 Educational Demands Placed on Educators at the Onset of the Pandemic Disruption

An external disruption is a condition or an event caused by factors (e.g., random phenomena, input transients) outside of a system Madni and Jackson (2011), like the global COVID-19 pandemic. AMT schools around the country, like all organizations, were forced to respond to this disruption or risk being closed down. To complete instruction for the Spring 2020 semester, most AMT schools adopted a virtual education strategy whereby they used technology to teach whatever components of lecture and lab that they could. Instructor response to the pandemic was not uniform. In many cases, the manner in which an instructor adjusted their instruction was dependent on the type of course and how much content had completed at the time of the rapid pandemic response in March. Courses that were classified as Level 3 Return to Service Labs, however, were blocked from being adjusted to a virtual format by the FAA.

On the other hand, most instructors were granted permission by their respective local FAA offices to transfer most lectures and Level 1 and 2 labs to a virtual format. As such, educators were tasked with the challenge of transitioning their hands-on AMT instruction to an online format that was engaging and effective for students in a short period of time. Although some instructors had experience using distance learning technologies and made frequent use of virtual tools, the majority of instructors had no prior experience teaching a course virtually. This lack of anticipation for the sudden need to transition classes to a distance learning format left schools scrambling to train teachers on the necessary technologies and develop a plan of action for the rest of the semester. Instructors were often provided support in the form of training seminars and extended breaks so that they could have more time. However, this attempt to rapidly adjust courses to a virtual format was taxing on both teachers and students: teachers often spent far longer developing virtual lessons than they normally would have, and the student's quality of learning was generally negatively impacted, as perceived by instructors. These findings are consistent with previous research regarding the ability of teachers to integrate new technology into their curriculum; teachers have been found to experience issues using tools like smart whiteboards or electronic tablets effectively without formal training or time to get acclimated to the tool Al-Faki and Khamis (2014).

The disruption caused by the pandemic and the sudden need to transition all learning to an online format was not expected by AMT instructors around the country. As such, when the pandemic happened, most instructors were not prepared for the educational demands of fundamentally altering their teaching methods. Had there been more ongoing technical training and frequent use of technology in everyday class activities, the overall AMT curriculum would have been more resilient, better preparing teachers to effectively address and prepare for the educational demands placed on them at the onset of the pandemic. These suggestions are not novel, as it has previously been suggested that using a virtual learning environment can have a high efficacy, but requires a baseline level of computer literacy on the part of the student and the educator Piccoli et al. (2001). In the case of this pandemic, both teachers and students did not have the foresight to establish this literacy before it was too late.

4.2 Strategies Used To Effectively Implement Adaptive Virtual Learning Strategies

During the rapid transition to adapt to COVID-19 restrictions and regulations, instructors had to find new ways to effectively teach their students. Some instructors, due to the hands-on requirements of their classes, brought students back to learn in person. If instructors were allowed to bring students back to in-person labs, safety precautions, such as wearing face masks, social distancing and diligent cleaning, were enforced to keep students and instructors safe and healthy and prevent the spread of illness.

Most instructors had to make a quick transition to online learning for both their lab and lecture courses. Educators completed virtual lectures in either a synchronous or asynchronous fashion. Instructors who taught their classes synchronously found that they could effectively keep their students engaged by lecturing, asking questions and including in-class activities. By interacting with students during their virtual class time, they were aware of who was actively paying attention and who was not. These classes met on video conference platforms such as Zoom and used PowerPoints to present information and engage with students using programs like Kahoot. Previous cognitive research suggests that these virtual formats are effective for engaging students as they allow teachers to offer support and feedback personally in real time, meaning they are more likely to maintain student engagement and morale Semradova and Hubackova (2013).

Some teachers chose to carry out lecture asynchronously. These instructors uploaded their course materials to platforms such as Canvas, Microsoft Teams, Blackboard, or Google Classroom, where students would have access to various learning materials, including PowerPoint presentations, pre-recorded videos, textbooks or other worksheets. Instructors who taught asynchronously found it easy to keep track of their students because they could see when students logged on, watched videos, and completed assignments. A trend that has been commonly observed among professors who shift from teaching in-person courses to asynchronous courses is that they assume a “managerial” role that requires attention to detail, meaning they devote more time to individualized student monitoring and making necessary course adjustments based on student performance Al-Faki and Khamis (2014). Students also seemed to like this method as they could work at their own pace. However, instructors who taught asynchronously found that keeping students engaged was difficult; since students lacked a specific structure, they would log on to the learning platform infrequently and had trouble completing assignments on time. Furthermore, instructors had no way of knowing how attentive students were being when they watched videos.

Many instructors mentioned that they would like to implement two aspects in the future to improve their virtual classes: a face-to-face component and increased use of virtual reality or simulation technology. Several instructors plan to move to a synchronous format and include video lectures and labs if they cannot return to in-person instruction. Others have decided to keep their curriculum online but plan to include a virtual office hour to meet with students over video conference to give them an opportunity to ask questions. In addition, instructors plan to improve their classes by integrating virtual reality or online aircraft simulation programs. Although some aircraft-relevant virtual reality technology and online simulation tools are currently available, these programs are prohibitively expensive for 2-year technical colleges to afford. This highlights the need for more, accessible virtual learning tools suited for AMT education.

4.3 Barriers to Adoption of Adaptive Virtual Learning Strategies

Once instructors developed a plan for teaching their lectures and labs virtually, they were still faced with several barriers that impacted how effectively they were able to execute these labs. One of the main barriers to adaptation that instructors encountered was the FAA, which is the governing body for all AMT instruction and as such must approve any changes that schools make to their programs. Many instructors indicated this issue, saying that although they wanted to incorporate more virtual learning technologies and practices in their curriculum, the FAA was largely against these changes, allowing only some low-level labs and lectures to be taught virtually. The FAA developed Part 147 AMT instruction in the 1960s, and has been hesitant to change or adjust its policies since then r1. To develop a resilient system that is able to support its students and teachers when future disruptions occur, it is important that the FAA treats safety as a “dynamic characteristic” and make changes to its curriculum that encourage the use of distance learning technologies for more aspects of AMT instruction. The generally negative views expressed by interview participants about the reluctance of the FAA to adapt to a virtual learning format are only partially consistent with previous studies of the FAA. A case study conducted in 2002 with 42 FAA employees found that most professionals “believe the FAA organization and its immediate managers are generally supportive of distance education and training professionals,” but these same surveys also indicate that the FAA has a “negative impact on the trainers’ ability to perform and to plan quality distance education and training programs” Watts (2002).

In an effort to mitigate this negative impact, formal recommendations from the Aviation Technician Education Council have been submitted in response to a Notice of Proposed Rulemaking that would revise and update FAA Part 147 FAA (2020b). Recommendations include removing curriculum and instruction requirements from Part 147 and allowing programs to move towards performance-based instruction based on proposed certification standards. Adapting the rule to include this broader language could allow Part 147 programs to work towards more innovative instructional technologies such as virtual learning.

Instructors also faced several barriers in delivering their lectures. Teachers observed that students were generally less engaged with a lecture in a virtual format like Zoom or Microsoft Teams. During virtual lectures, students became easily distracted by disturbances at their home, did not show up to class, or would engage in inappropriate activities like cooking food or playing games while using the software. These issues are consistent with observations of student mental health during the COVID-19 pandemic, as researchers observed that students tend to be less focused and engaged with school during the time of the pandemic and virtual learning Chandasiri (2020). Furthermore, when teachers lectured, they found that it was difficult to gauge whether students understood the material as well as they could in an in-person lecture.

In addition to these issues regarding student engagement, both teachers and students encountered technological issues. Some students lacked the resources needed to participate in lectures, and as previously mentioned, some teachers did not have enough experience using the technology. These issues with virtual lectures can be attributed to the lack of preparation and guidelines provided to students and teachers about how to interact with technology. Since students were not prepared for AMT classes to become virtual when this rapid shift occurred, many were not able to interact with this new instructional method properly and had engagement issues. These findings are consistent with previously observed challenges when implementing distance learning as instructors must consider and practice skills such as time management, collaboration, and awareness in a virtual learning environment in addition to any challenges inherent in using technology Kimball (2002).

To develop a more resilient system in the future, AMT programs should make greater use of technology in all lecture activities. This will train both students and instructors on how best to interact with and use these technologies, resulting in an improved educational experience should another disruption occur.

4.4 Study Limitations

There were several limitations regarding the design and execution of the study. Despite the large number of AMT educators contacted to participate in this study, only 20 consented. Although these 20 instructors still provided deep, varied insights into the challenges that they faced during the pandemic, this sample may not be representative of all AMT instructors. Future interview and surveys with instructors across different age, experience, location, gender, and race demographics are required to provide the most accurate understanding of AMT education possible. Additionally, this study was conducted between May and July of 2020. In the time since then, schools around the country have resumed instruction in various ways, with some schools remaining completely virtual, some having class completely in person, and some adapting a hybrid model. Future research should be done in a longitudinal with the instructors from this study in order to learn about how they have since adapted their classes and any new challenges they face. Finally, this study was conducted during the COVID-19 pandemic. Although all interviews and surveys were able to be performed virtually, this lack of a face-to-face interaction may have prevented the participant from feeling at ease and speaking as freely as they may have if the study was in person. One advantage to doing the study virtually, however, was the fact that interviews and surveys could be conducted with people around the country who would normally not be able to meet in person, ultimately allowing the researchers to study a broader group of AMT educators.

5 CONCLUSION AND FUTURE WORK

Ultimately, AMT schools were not fully prepared to transition to completely virtual education as the situation required them to do so in March. As explained by the Resilience Engineering Framework, strong organizations treat safety as a dynamic property and continually work to innovate and change aspects of their systems to anticipate and more effectively respond to the challenges they may face. Although some AMT schools were able to integrate technology into their curriculum before the pandemic, most programs around the country used technology sparsely. As such, these schools had to scramble to rapidly adjust whatever aspects of their course that they could to a virtual format by learning and implementing new educational technologies. Often, this rapid transition to virtual learning was not completely effective as teachers had difficulty learning the technology and getting students to interact effectively with the new format. In the future, it is important that virtual learning technologies are utilized more frequently in the overall AMT curriculum and that a revised FAA Part 147 considers these needs. Not only will this serve to train instructors on how to most effectively use these technologies to teach, but it will also help students understand how to properly use virtual learning tools to improve their overall understanding of the course material. This adoption of technology can serve to make AMT schools around the country more resilient and better prepared to handle another rapid transition to remote learning if needed.

Furthermore, this need for improving organizational resiliency can be expanded beyond the aviation community. All schools and organizations should strive to better integrate technology and virtual communication into their work in order to better prepare members to adjust to future disruptions like the COVID-19 pandemic. As technology continues to become an integral part of all aspects of daily life, it is crucial that organizations embrace these innovations in order to be best prepared to adapt to new, unique challenges.

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Appendix A: Semi-structured interview guide

Course Structure

1. What courses did you teach during the Spring 2020 semester?
    (a) What was the general structure/content of those classes, as in how much of the class was lab, and how much was lecture?

Adjustment and Challenges

1. How did you adjust teaching the lecture component of your course during the remote transition phase?
    (a) What were some of the biggest challenges that you faced when trying to teach/administer lectures remotely?
2. How did you adjust teaching all of your lab-based activities during the remote transition phase?
    (a) What were some of the biggest challenges that you faced when trying to teach/administer labs remotely?
3. How did you use technology in education before the move to remote learning? How heavily did your school and your class utilize technology?
4. How did you use technology in education after the move to remote learning?
    (a) What were the specific technologies that you used?
    (b) What did you like most about the technologies that you used for virtual instruction?
    (c) What were some issues you encountered regarding the technologies that you used for virtual instruction?

5. How did you continue teaching all of your virtual courses during the remote transition phase?

Overall

1. What resources, if any, did your school provide you with to assist you in teaching after the move to remote learning?
2. What were the two biggest challenges that you faced when trying to teach students remotely?
3. How did you adjust your instruction/administration of these lab courses to manage these challenges that you face - what strategies did you use?
4. What resources would have helped you to more effectively teach lab courses remotely?
5. What other suggestions or strategies do you have to help with the instruction of lab courses remotely?
    (a) What are some strategies that you/your school used for the transition that you are particularly proud of?

Appendix B:Survey guide

1. Participant Number (Number provided by researcher)
2. Year of Birth
3. Gender
4. How many years have you been a lab instructor at a technical college? (Numeric entry)
5. On average, how large would you say your class sizes are? (select one)
    (a) Small (10-20 students)
    (b) Medium (21 - 30 students)
    (c) Large (31-49 students)
    (d) Very Large (50 students or more))
6. Following the outbreak of COVID-19, what format were your spring 2020 classes delivered? (check all that apply)
    (a) I taught at least one course synchronously (students met with me at a specified time, using virtual meeting software).
    (b) I taught at least one course asynchronously (content for the course, such as videos or slide decks, was uploaded for students to view at any time).
    (c) At least one course used a combination of synchronous and asynchronous formats.
    (d) Other (explain)
7. What types of courses did you teach during the spring 2020 semester (select all that apply)?
    (a) STEM class with lab-based activities AND lectures
    (b) STEM class with ONLY lab-based activities
    (c) STEM class with ONLY lectures
    (d) Non-STEM class
    (e) Other (explain)
8. Have you ever taught a class virtually before the move to remote learning?

(a) Yes
(b) No

9. How frequently did you use technology in education BEFORE the move to remote learning?
   (a) Never
   (b) Once a week
   (c) 3 times a week
   (d) 5 times a week
   (e) Once a day
   (f) More than once a day
10. How frequently did you use technology in education AFTER the move to remote learning?
   (a) Never
   (b) Once a week
   (c) 3 times a week
   (d) 5 times a week
   (e) Once a day
   (f) More than once a day
11. If you taught any courses that had a lab-based component, how would you describe the way those labs were conducted BEFORE the move to distance to learning? (select all that apply)
   (a) Hands-on labs where students interacted with physical materials to perform experiments or tasks
   (b) Virtual labs where students only interacted with a virtual, simulated environment to perform experiments or tasks
   (c) Other (explain)
12. Which aspects of the teaching experience were most challenging for you, AFTER the move to distance to learning ? (select all that apply)
   (a) Reliable/stable internet connection issues
   (b) Students not attending class
   (c) Students attending but not participating in class
   (d) Lack of a quiet or private place to teach class virtually
   (e) Confusion about how to use the video conference software or application for class
   (f) Trying to deliver planned content for a face-to-face class through an online format
   (g) Lack of closed captioning for video or transcripts for audio materials
   (h) Access to assistive technology hardware
   (i) Access to assistive technology software
   (j) Issues related to testing students (i.e., proctoring, time on tests)
   (k) Other (explain)
13. What aspects of teaching/administering remote or virtual labs were challenging to you? (select all that apply)

(a) Reliable/stable internet connection issues
(b) Students not completing labs
(c) Inability to talk with students and explain lab components to them
(d) Lack of materials or resources to teach students

14. How greatly do you believe the quality of the student's learning in your OVERALL classes were impacted by moving to an online format? (select one)
    (a) Very negatively impacted
    (b) Slightly negatively impacted
    (c) Not impacted
    (d) Slightly positively impacted
    (e) Very positively impacted

15. How greatly do you believe the quality of the student's learning in LAB-BASED classes were impacted by moving to an online format? (select one)
    (a) Very negatively impacted
    (b) Slightly negatively impacted
    (c) Not impacted
    (d) Slightly positively impacted
    (e) Very positively impacted

Appendix C: Additional Survey Results

Factor		Sample, N=20
Course Delivery After Pandemic	At least one synchronous course	5
	At least one asynchronous course	10
	At least one hybrid course	3
	Other	7
Original Lab Format	Hands-on labs	18
	Virtual labs	0
	Other	2
Teaching Challenges After Pandemic	Stable internet connection	8
	Students not attending class	8
	Students not participating in class	11
	Lack of private place to teach	0
	Confusion over software	3
	Face-to-face nature of content	7
	Lack of closed captioning	0
	Access to assistive hardware	0
	Access to assistive software	4
	Testing student issues	4
	Other	5
Lab Challenges After Pandemic	Stable internet connection	5
	Students not completing labs	7
	Inability to talk with students	6
	Lack of teaching materials	5
Perceived Impact of Pandemic on Overall Instruction	Very negative impact	4
	Slightly negative impact	13
	No impact	2
	Slightly positive impact	3
	Very positive impact	0
Perceived Impact of Pandemic on Lab Instruction	Very negative impact	6
	Slightly negative impact	7
	No impact	6
	Slightly positive impact	7
	Very positive impact	7