Adaptation to Remote Teaching During Spring 2020 amidst COVID-19: Perspectives of High School Advanced Placement Statistics Teachers

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Abstract

During the Spring 2020 semester, K-12 teachers throughout many parts of the world adapted from face-to-face to online teaching. To better understand these experiences, seven advanced placement (AP) Statistics high school teachers were interviewed following a semi-structured protocol. A collaborative and consensus-driven analysis of transcripts revealed 12 distinct themes. The three most extensively discussed themes appeared to be *assessment* (19.11%), *communication methods* (12.23%), and use of *online instructional approaches* (11.90%). Teachers from schools that did not provide devices to students (i.e., not "one-to-one") tended to report concerns around digital access more frequently (6.87%) and tended to express a more negative sentiment (*Sentiment Mean*=–.09) than teachers at schools that provided devices (5.69%; *Sentiment Mean*=1.35, $p<.01$). These findings highlight issues facing teachers during the transition to remote and online instruction and suggest a need for supporting teachers in developing familiarity with online and remote assessment resources and strategies.

keywords: AP Statistics; online teaching and learning; mixed-methods; COVID-19; teacher perspectives

Introduction

Amidst the outbreak of the COVID-19 pandemic, instructors and students rapidly adapted from a face-to-face instructional format to teaching and learning remotely online (OECD, 2020). The impact on high school students who otherwise would be preparing to take high-stakes standardized exams is unknown yet is thought to affect their educational progress (Kuhfeld & Tarasawa, 2020), in addition to psychologically and financially (Huffman, 2020). In the present investigation, our goals were to better understand the most prevalent factors that influenced instructors' ability to cope or complicated their efforts to do so. Further, we sought to gain insight into the differences in teachers' feelings about these factors, particularly between teachers based on the availability of devices to students. We ultimately aimed to capture a deeper perspective on the experience of teachers during the COVID-19 pandemic.

While current research has so far concentrated on the effects of COVID-19 on students, there is a lack of awareness of how the transition impacted instruction and assessment practices from teachers' perspectives. We were particularly interested in examining teachers' perspectives within the context of advanced placement (AP) courses in the U.S. because doing so may have implications for other advanced high school courses. High school students have the option to enroll in AP courses to receive instruction aligned with a college-level introductory curriculum. At the end of the academic year, students enrolled in AP courses may complete the AP exam, a cumulative exam, and if they receive a satisfactory score, they may be eligible to receive college transfer credit. Given that most AP students are college-bound, we wanted to understand how teachers adapted their instruction to prepare students for the next stage of their academic path. An additional advantage of focusing specifically on teachers of AP courses is that they are preparing students for the same exam, and thus their content is comparable despite differences in instructional practices and contexts. Examining the impact of the pandemic on this context of instruction is thus novel from previous investigations (e.g., Yılmaz et al., 2021) as it may highlight shared and divergent issues in evaluating student learning. In particular, statistics is among one of the continually expanding AP course programs in recent years (College Board, 2020b), possibly due to a growing workforce demand in quantitative methods and data science (Wise, 2020). Though there are several ways of incorporating statistics content into the K-12

curriculum, not all of which directly link it to math content (Usiskin, 2015), it appears to be increasingly a component of standards for math curriculum in the U.S. (Lovett & Lee, 2017). This is also reflected in international assessments such as the Trends in International Mathematics and Science Study (TIMSS), which has some degree of coherence with the math curriculum of participating countries throughout the world (Houang & Schmidt, 2008). In the most recent TIMSS 2019 assessment program, 20% of the Grade 8 mathematics assessment consisted of data and probability content, reflecting an emphasis on foundational statistics skills and knowledge (Mullis et al., 2020). To develop an understanding of the factors that foster resilience and the opportunities to improve instruction of statistics learning in an online environment, it is therefore important to promote awareness and reflect on the experiences of math and statistics educators.

Challenges of Transitioning to Remote Instruction during COVID-19

School closures under normal circumstances are viewed as disruptive to educational progress, and particularly so under emergency circumstances such as natural disasters, violence, and pandemics (Day, 2015; Douglas, 2011; Schweber, 2013). Yet, during the COVID-19 pandemic, relatively few institutions were readily anticipating widespread school closures (Young, 2009). Beginning around mid-March and for the remainder of the 2019-2020 academic year, K-12 teachers and students in the U.S. nevertheless adapted to teaching and learning online in adherence to social distancing practices (OECD, 2020).

Under ideal circumstances, course instruction delivered in either a face-to-face or online remote learning context should not differ. According to *equivalence theory* (Simonson et al., 1999), the quality of students' learning experience between the two modalities should be essentially equivalent if certain key factors are taken into consideration (e.g., the value of learning to students, instructional design, opportunities for students to apply knowledge, students themselves, learning outcomes, etc.). These factors are largely articulated through the perspective of students and provide little guidance on how instructors can promote equivalence between instructional modalities. While instructors may have some ability to control these factors through instructional design, evidence that there is equivalence between instructional modalities remains dubious (Garratt-Reed et al., 2016;

Fonolahi et al., 2014; Paulsen & McCormick, 2020). We thus sought to understand the lived experience, process and decisions of instructors who attempted to establish some equivalence between in-person and online modalities of instruction during a period of rapid transition from in-person to online learning. Rather than focus on *equivalence* – a largely theoretical construct – we instead consider factors that promoted or hindered instructional *continuity*, a more practical aim given the emergency teaching circumstances. Instructional continuity refers to the efforts to maintain a schedule for teaching during and despite disruptions such as those caused by personal (e.g., personal injury or illness or emergency (e.g., weather, public health, etc.) circumstances (Manca & Delfino, 2021). In particular, we sought to identify factors that could threaten the continuity of instruction and assessment practices amidst the transition to remote and online learning during the COVID-19 outbreak in spring 2020. These factors include those related to practical aspects of teaching in an online instructional modality (i.e., communication with students, students' access to digital technology and course material, changes to grading and exam administration) as well as those more specific to the students (i.e., age) and the course (i.e., subject matter, placement). Understanding of these factors in relation to teaching statistics could inform the development of curricula and online instructional practices that are adaptable and aim to address social inequalities laid bare by the pandemic (Borba, 2021). We hoped such knowledge could be used to identify areas where instructors need support in developing effective K-12 online education practices and integrating technology for the sake of student learning, which have previously been identified as knowledge gaps (Carrilo & Flores, 2020; Crompton et al., 2021).

Math and Statistics Content

While online resources for teaching math and statistics have become increasingly more available (e.g., Tishkovskaya & Lancaster, 2012), there are obvious limitations in guiding, monitoring, evaluating, and providing adequate feedback to students in a fully computer-mediated teaching context (Kebritchi et al., 2017). For statistics education, which itself is a growing area of interest to educators and students given its applicability to understanding important real-world trends (e.g., pandemic-spread; Heyd-Metzuyanim et al., 2021; Kollosche & Meyerhöfer, 2021) in addition to the scholarly and

professional opportunities it affords students (Groth, 2021; Zieffler et al., 2018), there is even less of an understanding of techniques instructors have used to adapt to an online instructional environment (Maciejewski, 2021).

Transitioning high school math and statistics content may be particularly challenging because instructional materials or activities often require visual worked examples (Boaler et al., 2016; Fernandez et al., 2017; Smith et al., 2003; Smith & Ferguson, 2004). Though videos can be an effective way of delivering content (Diwanji et al., 2014), they may not provide the benefit of supporting students as they practice in real-time. Gestures, often inadvertently used by instructors, while conveying mathematical concepts can be highly effective for student learning (Alibali & Nathan, 2012; Rueckert et al., 2017). Such information may not be easily transmitted to students in an online and asynchronous format (Lindgren & Johnson-Glenberg, 2013). Collaborative real-time problem-solving is yet another instructional approach often used in teaching math and related subject matter (Retnowati et al., 2017). In a review of literature on teacher education during the COVID-19 pandemic, Carrillo and Flores (2022) suggest that promoting social interaction in online environments was essential for students' sense of proximity to teachers and peers, engagement, and learning. In an online and asynchronous teaching environment, on top of having strong content knowledge, math and statistics instructors may either need to adapt techniques to promote social interactions and need to possess the requisite technical skills to leverage technology to do so. Nevertheless, some have even argued that the rapid transition to online learning may be a productive catalyst for reimagining and improving math and statistics education (Kossybayeva et al., 2022).

Advanced Placement Courses

Throughout the United States, AP courses offer high school students the opportunity to study college-level curriculum for an academic year. Students enrolled in AP coursework prepare to complete a cumulative AP exam at the end of the spring semester. Depending on whether students receive a satisfactory grade (typically a score of 3 or greater out of 5 points), they may be eligible for college credit equivalent to a semester's coursework in the subject area. As of 2021, AP exams scores were recognized as college credit transfer eligible by over 60 institutions throughout the world, in addition

to 2000 institutions within the U.S. (College Board, 2021). Under normal circumstances, AP Statistics may be challenging to teach due to the emphasis of the course on conceptual understanding and active problem-solving (Haines, 2015). Yet, during the 2019-2020 academic year, teachers of AP courses faced additional specific and unanticipated challenges. The AP exam is a standardized test administered only once annually on the same day and at the same time. Typically, it is administered in-person, however, in Spring 2020, the exam was administered remotely online with all students initially completing the exam at the same time. In addition, the format for each exam was shortened from about 3 hours to 45 minutes (College Board, 2020a). Some have also been critical of the logistical demands placed on students in terms of dealing with issues such as intermittent internet connectivity, incompatible web browsers, and submission errors (Galczynski, 2020).

The AP Statistics exam also covered modified content with new question types. The scope of the content became less expansive as a result of removing certain topics (e.g., chi-square test, regression inference) from the material on the exam (Chu, 2020). As such, AP teachers also had to prepare students to take a considerably different exam than previous years, in terms of the format, logistics of administration, and content.

Compared to students enrolled in college and university, grade school students and teachers faced additional challenges. Though recently published studies have examined the impact of the COVID-19 pandemic on teaching and learning (e.g., Cutri et al., 2020; Crawford et al., 2020; Johnson et al., 2020; Kozimor, 2020; Rapanta et al., 2020), many of these studies examine college students. Models of online teaching have already been developed and utilized within college courses for decades (e.g., Garfield & Everson, 2009; Mills & Raju, 2011; Tudor, 2006). Unlike primary and secondary grade school students, college students have likely already developed greater autonomy over their learning (Bangser, 2008; Ratelle et al., 2007). Thus, they may be better prepared to continue learning even during the disruptions like the COVID-19 pandemic that necessitates remote and online learning. By contrast, high school students are generally accustomed to routines created by the school or their teachers (Conley, 2007; Rehn et al., 2016). Some evidence also suggests that differences in instructional modalities may be less salient for adult learners than for youth (Bernard et al., 2004). Unlike adult education, primary and secondary school education tends to involve more

hands-on, collaborative, and interactive learning activities (Kumi–Yeboah et al., 2018; Sublett, & Chang 2019), which are difficult to implement in remote learning contexts.

Challenges for Teachers during the Transition

Limited Opportunities to Communicate with Students

Communication may be among the most obvious challenges that emerged during the transition to online remote learning amidst COVID-19. Clausen et al. (2020) administered a survey to 44 middle and high school teachers in the midwestern U.S. to inquire about their experiences communicating with students. Teachers reported being unsuccessful in contacting 59% of students at-risk for failure due to a lack of homework completion. Teachers and students in conventional K-12 education settings are accustomed to seeing each other on a frequent, if not daily basis. These contexts for teaching help to develop a rapport that encourages students to approach teachers if they have questions or need help learning a particular topic. In an online remote learning context, students and teachers have fewer opportunities to communicate with one another, particularly in asynchronous online learning environments. For K-12 instructors especially, their students may be less accustomed to the expectations of responsibility and self-regulated learning required to contact teachers when in need, and otherwise self-manage coursework and deadlines.

Issues of Digital Access

Access to the internet and digital technology was a key factor affecting communication between teachers and students during COVID-19. Cutri et al. (2020) studied self-perceptions of readiness of college faculty for teaching online during the pandemic and found that although instructors felt a sense of camaraderie with students given the circumstances, such feelings were undermined by challenges in assessing students' access to online resources (i.e., digital access). By at least one estimate, approximately 15% of households within the U.S. were without access to the internet around the onset of the COVID-19 pandemic in Spring 2020 (Pew Research, 2020 March). Students from low-income or other underserved groups are especially likely to be affected by a lack of digital access (Pew Research, 2020 September; Reich, 2020). Many stakeholders were concerned about the quality of instruction and students falling behind (Pew Research, 2020 April; Quezada et al., 2020).

Some schools may attempt to fill this gap by providing a device to each student enrolled for academic learning outside the traditional classroom (i.e., "one-to-one" policy). Lei and Zhao (2008) found that students largely used their school-provided devices at home for a variety of academic purposes and gained technology proficiency as a result of having a device readily available to them. Lowther et al. (2012) found that students enrolled at schools were more motivated to use laptops for learning. One-to-one policies may not only provide the resources to access course materials in an online remote learning environment but may also support students' digital literacy in learning in a computer-mediated context. Criticisms of "one-to-one" policies often point out that students may not fully use the device to its greatest potential for learning (Harper & Milman, 2016) and it could result in non-academic device use (Selwyn et al., 2017).

Despite the impact of the COVID-19 pandemic, few recent studies have considered the impact of one-to-one policies on student learning, nor the scope of its implementation even though it is thought to affect a large percentage of K-12 schools. By some estimates, as of early May 2020, approximately 65% of school districts (drawn from a sample representing roughly 11% of all public schools) provided personal devices to students, though not necessarily on a one-to-one basis (Malkus & Christensen, 2020).

Grading and Exam Preparation

Assessment is regarded as an essential aspect of instruction and serves as a means to adapt it to meet students' learning needs (Raje & Stitzel, 2020). Research conducted before the pandemic suggests that academic misconduct occurred less frequently online as opposed to face-to-face instructional contexts (Stuber-McEwen et al., 2009). Yet, other factors aside from the instructional modality could be driving this effect, including students' age or intentions for taking courses online (e.g., seeking credential or licensure; Eaton, 2020). Though concerns around academic integrity appear minimal when stacked against concerns over physical and emotional health and well-being, they were valid concerns shared by instructors of degree-seeking students who recognized that implementing a paper-based assessment online was insufficient given the change in circumstances (Jamieson, 2020).

Research Aims

In light of these circumstances, our aims were to understand (1) AP Statistics teachers' experiences and how they adapted to online instruction; (2) what types of sentiments were implied when describing specific issues; and (3) how sentiment towards specific issues differed between teachers based on whether or not the schools provided devices to students for remote learning. To address these research aims, we analyzed responses from AP Statistics teachers during a semi-structured interview and applied a mixed-methods approach to capture aspects of the teachers' experience providing instruction to students during a crisis that drastically affected the instructional format and continuity. The study is therefore novel for at least two reasons. First, because we chose to focus on AP Statistics for the reasons outlined previously and given that it is an under-researched context. Second, the study is novel because we sought to use a rich corpus of text to determine whether it was possible to unobtrusively detect differences in the feelings expressed by the interviewees when describing a particular topic that might otherwise go unnoticed using only a conventional content analysis of text. The findings from this study could be useful for systematically gauging difficulties in instruction and assessment practices and better prepare teachers for emergency teaching during crises.

Based on transcripts of semi-structured interviews with teachers, the research questions guiding this investigation include the following:

- **RQ1**: What themes emerge across the interviews?
- **RQ2**: **(a)** How frequently do the themes occur across the interviews? **(b)** What are the most prevalent themes? (**c**) How does the prevalence of these themes differ between teachers who taught at a school with a one-to-one device policy or not?
- **RQ3**: **(a)** To what extent were each of the themes described in a more positive or negative manner? **(b)** Did the description of themes differ based on whether teachers taught at a school with a one-to-one device policy or not?

We hoped to capture an in-depth perspective on the experience of AP Statistics teachers during the COVID-19 pandemic, particularly concerning complex themes, common ideas, and emotional content across question topics, as well as the prevalence of these different themes (**RQ1**). We anticipated that some of the themes related to concrete aspects of teaching (e.g., planning,

communicating, grading, or assessment) would be most prevalent (**RQ2**). We also expected that themes that posed some of the greatest challenges to teachers would receive more negative sentiment scores and further anticipated that teachers from schools that did not have a one-to-one device policy would respond more negatively towards themes specific to the use of technology (**RQ3**).

Methods

Interview transcripts were analyzed across two phases. The first phase involved a qualitative content analysis of the transcripts of the teachers' responses (Hsieh & Shannon, 2005) that was conducted collaboratively (see Cornish et al., 2013; Weston et al., 2001). The second phase involved text mining of the same transcript data (Meyer et al., 2008) and was specifically concerned with extracting prominent topics, sentiment via word choice, and common connections between concepts.

Participants

The interviewees were seven high school teachers of AP Statistics in schools located in northern Indiana. All instructors (5 male, 2 female) had at least five or more years of experience teaching math or statistics courses to high school students. Teachers were involved in an ongoing study conducted within the research lab and were thus recruited from a convenience sample.

Transcript Data

After stemming and removal of stop words, the text corpus containing responses from teachers comprised 59,268 words (vocabulary size of 1,981) with the average length per interviewee being 8,466.86 words (average vocabulary size of 662.43 per interviewee).

Procedures

Semi-structured Interviews

The interviews with teachers were conducted between May 26 and August 10, 2020, using the Zoom video conference platform. Each interview lasted between 30-45 minutes. Before the interview questions were posed, the interviewees consented and were informed that the sessions were recorded for transcript purposes only and that identifying information would be removed from the transcripts before analysis. For each interview, a series of nine main questions were posed by the interviewer to

each teacher in a largely fixed order. Depending on the thoroughness of the teachers' responses and the time constraints, additional planned follow-up questions were posed to the teachers. Appendix A in Supplemental Materials provides details about the interview script. Supplemental Materisl can be found in the online repository associated with this project, along with additional information about the study procedures (Ober et al., 2021).

Transcript Preparation

After the interviews were completed, automatically generated transcripts were downloaded from the Zoom platform and prepared for analysis. Preparation involved removing timestamp information, truncating the transcript so that only the dialogue surrounding the questions was included, removing identifiable information, and tagging each interviewer question and interviewee response to the respective question from the interview script to allow for comparison of questions across interviews. With the de-identified and formatted transcripts, two researchers reviewed each for the quality of the text against a video recording of the interview to correct for transcription error, speaker misattributions, and to include necessary punctuation to indicate breaks for interpretability.

Content Analysis to Identify Themes

Following the procedure outlined by Cornish et al. (2001), a preliminary codebook containing themes presumed to be prevalent was created. The cleaned transcript documents were coded collaboratively using the CATMA (v.6; Meister et al., 2019) online text annotation software. A group of five researchers convened to begin coding the transcripts regularly between June and September 2020. During the first meeting, the researchers were trained in using the annotation software, and to ensure consistency in the application of coding, the researchers collectively practiced coding sections of a transcript. Each researcher was then tasked with coding the interviewee's responses within at least two transcripts so that each was coded twice by different researchers. The researchers then met weekly to review the codes applied to transcripts and resolve discrepancies in the application of codes through consensus. The interviews were then coded holistically, with themes examined across responses to different questions (see Appendix B in Supplemental Materials for the codebook with a final list of themes; see Ober et al., 2021). After reviewing the codes for four out of the seven

transcripts, no new themes were created, thus suggesting that saturation of themes with the text corpus had been achieved (Guest et al., 2020).

Text Mining for Sentiment Analysis

We subsequently conducted a text mining analysis, which consisted of two analytic procedures. First, we examined the descriptives of the most frequent words and phrases that appeared in the text overall. Second, we conducted a sentiment analysis of the teachers' responses (see Table 1). This analysis was conducted to examine variation in teachers' sentiment scores based on both the different themes derived from the previous analysis, and whether they taught at a school with a one-to-one device policy. Complementing more conventional analyses conducted to derive themes from the text, sentiment analysis such as that used in the present study is an increasingly popular approach to understand affective qualities of responses that appear in text data (Cunningham-Nelson et al., 2020).

Additional data cleaning steps were taken to prepare the transcripts for text mining. All the comments from an interviewer were removed from the transcripts. Stop words were removed using a lexicon based on System for the Mechanical Analysis and Retrieval of Text (SMART) word list (Salton, 1971). Text mining analyses were subsequently performed in the *R* statistical computing environment (R Core Team, 2020) using the *hunspell* and *stringi* packages for the handling of misspelled words, and the *tidytext* package to examine the most prevalent themes derived from the content analysis. Subsequently, sentiment analysis was performed using the *textdata* package. Using the AFINN lexicon (Nielsen, 2011), we derived a value indicating the extent to which certain words carried a positive or negative sentiment. The AFINN lexicon consists of English words rated for valence with an integer between –5 (very negative sentiment) and +5 (very positive sentiment). For example, a word within the AFINN lexicon will have a greater positive value to indicate a more positive sentiment (e.g., "outstanding", "superb", etc.) as opposed to a word carrying a bleak or hostile connotation. An average sentiment score was derived for each teacher based on a sum of their sentiment word scores to indicate an overall average of the sentiment conveyed during the interview. While we note that the sample size used for this analysis is relatively small (N=7), past research on

sentiment analysis of text failed to find a clear connection between sample size an accuracy with respect to manually labeled sentiment scores (Hartmann et al., 2019).

Results

The results of the qualitative analysis are presented first, followed by the findings from the text mining procedures.

Content Analysis

We extracted and summarized common themes from the interviews using a qualitative analysis with the agreement of themes achieved through group consensus. Table 1 provides a list of the twelve distinct themes, along with examples, and the number of words and percent of the overall corpus the theme occupied (**RQ1**).

Table 1. Themes and exemplary text for each theme derived from the content analysis sorted from greatest to the smallest coverage

	Theme	Word Count (Total)	% Coverage (Total)	% Coverage (not 1:1)	% Coverage (1:1)	Unedited Example Text
1	Assessment	11329	19.11%	21.39%	18.37%	"You know, I ended up, like, I tried to do testing with them and what I ended up doing is I took the test that I had already created and kind of gave it to them as assignment, but did not give them the answers, obviously. So I probably picked up that it was a test. And I could definitely tell there was cheating going on because people will turn in exactly the same which clearly you know they're going to do the same if they get it right, but then they would get it wrong, and it would just be totally wrong."
2	Communication Methods	7250	12.23%	13.51%	11.84%	"I would send you know email either just from my school email, I will send it through Schoology, I would send it through InfiniteCampus, which is what we use for grading, I can send it through that. And it wouldn't matter how I would send it. The kids just don't bother to check."
3	Online Instructional Approaches	7054	11.90%	14.05%	10.95%	"..., put them into groups, which was great because they were still in their same seating chart groups and so they talk freely and comfortably with each other. And I was very confident that that was one of the best parts about the online instruction was the, the group work that they were still able to do even through Zoom."
4	Productivity	6442	10.87%	8.74%	12.93%	"So the assignments, not every student was doing them. And so they lightened the load to hopefully encourage more be getting done and be less of a burden on the students was the thought process."
5	Motivation	4584	7.73%	5.33%	9.81%	"My AP Stats class, I had about 80% did a pretty decent job of continuing with the work and putting in their best effort"
6	Grading	4581	7.73%	7.79%	8.06%	"... there was a lot of effort based assignments, where as long as they did it and show that they had a core idea of the concept I'd give them five out of five points."
7	Online Teaching Resources	4381	7.39%	11.78%	4.58%	"But I found that EdPuzzle, which is an awesome program where you can take any video that you have or a teaching video you make. You can chop it up and put the questions in there and you can make it so students can't skip through and I will be doing some of that just to have a sense of how many kids are actually watching the video. There's all kinds of analytics with that. They'll tell you how many times they've watched segments or parts of the video and who took the quiz and how

						they did. That that's a really powerful tool, instead of just doing a video out there and not really knowing who's watching it or if it's effective"
8	Digital access	3571	6.03%	6.87%	5.69%	"Now as far as Internet availability. I know that it was a major problem. And if we heard ...or not a major problem, but it was an issue and our superintendent communicated a lot with us about if we found a student that did not have some sort of WIFI or Internet capabilities to let them know. And they would, they had a program and I didn't have to find a whole lot of information about it because all my students were fine."
9	Preparation for Online Teaching	2925	4.94%	4.58%	5.41%	"What we weren't set up real well for is just the daily, you know, we're okay with twice a semester, that's no big deal. You can get away with just posting some things that are just review. You don't even have to teach live necessarily don't even have to record a video, necessarily, but now you know we had to think through, Okay, what's the best way to still teach."
10	Feedback	2841	4.79%	3.60%	5.86%	"... but online the contact is way less so encouraging them to do their work. Is difficult. So also, there was, there were students that were working hard and they were just frustrated because they had questions and they would ask me, but it wasn't immediate feedback and we'd have to send two or three emails back and forth."
11	Teacher-student Relationship	1800	3.04%	1.00%	4.65%	"I think what's difficult about the e-learning. It could be happening, but since you don't see it every day, just like any other relationship if you're not in it everyday, you start to lose a little bit of the trust in the relationship. And you really have to like Make sure that your read on, let's say non communication is Well, correct, as you know, far as, you know, it may be not communicated, but they could be doing the work and doing quite fine or you could have the other end where I'm not seeing a login. I need a little bit More just to Know which side of the coin, that is, you know, kind of thing."
12	Personal / Teaching Philosophy	953	1.61%	1.36%	1.86%	"...from the outgo I was of the mindset that I didn't want to hurt people during this experience because … I don't, you know? We weren't given a lot of guidance."

Most of the teachers reported receiving *little to no experience teaching fully online*. Some schools or math departments had provided professional development specifically for online teaching during the pandemic, which in some departments was facilitated voluntarily by other teachers. At least one teacher noted that the *collegiality of "teachers helping teachers"* made circumstances more tolerable. In other cases, teachers had developed experience teaching online for a short-term period through "make-up" days, which had been designed specifically in the event of a short-term natural disaster (e.g., snowstorm) or unexpected event. No teachers reported any type of pandemic plan for long-term online teaching. Only one teacher had experience adjunct teaching college students online and described drawing from that experience.

The teachers were asked to describe how they adapted to *delivering instruction online* and *communicating with students* regularly. All except one teacher stated that they decided to provide instruction asynchronously, out of concern over issues in scheduling, sleep habits, and internet access. At least one teacher described some of the challenges in teaching math or statistics remotely given a

preference towards handwritten formulas and proofs while explaining and the difficulties adapting with an equation editing software.

Issues around communication also tended to bring up the theme of *feedback*, particularly the inadequacy of providing online feedback to students, as well as evaluating student learning. All of the teachers raised concerns around *cheating* in an online learning environment, noting that there was little in the way of preventing students from sharing answers to homework assignments, let alone tests. Some of the teachers, however, noted that assessment of student learning to demonstrate mastery of the subject matter was less of a concern since the course had entered a *review phase* in preparation for the AP exam either shortly before or after the transition to online remote teaching took place in mid-March. Thus, some teachers noted that concerns around teaching new material were considerably less of an issue compared with other non-AP classes they were teaching.

When asked about preparing students for the AP exam considering the exam changes, most of the teachers expressed that they simply did not know the concerns students might have felt given that communication with them was infrequent. Even so, at least one teacher noted that several students had difficulty in taking the AP exam online due to technical issues in mid-May and were in the process of rescheduling a make-up exam with the College Board.

Text Mining

Descriptives

Additional information about themes could be revealed by considering the most frequent words and phrases within the text. Some of the most frequently occurring words related to the practical aspects of teaching, including a focus on students, time, and effort (e.g., real, try, hard). For more details, see Appendix C in Supplemental Materials.

Thematic Coverage

We subsequently examined the percentage of coverage of coded themes within the text across all seven interviews (**RQ2a**). Table 1 shows the word count for each of the 12 themes, along with the percentage of coverage. Percent coverage is derived based on the count of words within the theme divided by the total number of words within text identified with themes. If sections of the transcript

were not coded under a particular theme, they were not considered in the percent coverage estimate reported; however, if a word appears multiple times (i.e., non-unique), they are counted towards the total words used in deriving the percent coverage. Based on the percent coverage estimates (**RQ2b**), the most prevalent general themes were *assessment* (19.11%), *communication* (12.23%), *online instructional approaches* (11.90%), and *productivity* (10.87%).

Differences based on "One-to-One" status. All teachers expressed concern about the equity of digital access amongst students and most acknowledged this as a motivator for asynchronous instruction. Four of the seven teachers explained that the school had a "one-to-one" policy for providing an electronic device (e.g., laptop or tablet) to students for academic purposes. The remaining three of the seven teachers indicated their school did not have such a policy. We attempted to control for the transcript length for each teacher by dividing the word count for each theme per teacher by the total number of coded words on a teacher's transcript. Those teachers from schools that did not provide devices to students tended to report concerns around digital access more (6.87%) than those at schools which provided devices (5.69%). We also wanted to determine whether the difference was significant between the two groups and thus conducted a t-test of proportions. Though this difference was not statistically significant, likely due in part to the small sample size (N=7) and thus low statistical power, it did appear to produce a small effect, $t(5)=.29$, $p=.79$, $d=.25$.

Recognizing that such a policy could create considerable differences that could affect instruction provided by teachers, we further examined whether other differences in the coverage of themes could emerge based on whether the school had a one-to-one policy (**RQ2c**). Table 1 also shows the thematic coverage between teachers who taught at a school with a one-to-one device policy for other themes, in addition to the theme of digital access. While the relative frequency of themes between the two groups of teachers is comparable, several key differences emerge. The themes of *assessment* (one-to-one: 18.37%; not one-to-one: 21.39%; $t(5)=.25$, $p=.82$, $d=.19$), *communication* (one-to-one: 11.84%; not one-to-one: 13.51%; $t(5)=.27$, $p=.80$, $d=.20$), and *online instructional approaches* (one-to-one: 10.95%; not one-to-one: 14.05%; $t(5)=.88$, $p=.44$, $d=.72$) were among the most frequently discussed topics among both groups.

While none of the differences were statistically significant, likely due to the small sample size of teachers, several differences produced very large effect size estimates. Teachers in one-to-one schools tended to discuss concerns around *productivity* (both their own and that of their students) more often (12.93%) than teachers from schools that did not have a one-to-one policy (8.74%), $t(5)=-2.05$, $p=.10$, $d=-1.48$. Teachers from schools with a one-to-one policy also tended to refer to *students' motivation* or lack thereof (9.81%) more often than their counterparts (5.33%), $t(5)=-1.60$, $p=.19$, $d=1.06$. On the other hand, teachers from schools without a one-to-one policy tended to discuss different types of *online resources* considerably more frequently (11.78%) than teachers from schools with a one-to-one policy (4.58%), $t(5)=2.45$, $p=.08$, $d=1.97$. While generalizing from such a small sample is tenuous, these differences present an intriguing contrast.

Sentiment Analysis

After examining the emergent themes in the transcripts of the interviews, we considered the affective qualities of the teachers' responses. We conducted a sentiment analysis of the interview transcripts to examine differences in teachers' sentiment scores based on themes discussed (**RQ3a**) and whether they taught at a school with a one-to-one device policy (**RQ3b**). The sentiment score for words across all transcripts ranged between –3 (more negative) and 3 (more positive). Teachers largely conveyed neutral to slightly positive sentiment (*Mean*=.14, *SD*=1.88) when discussing the themes.

Sentiment Analysis of Themes. It is also worth considering differences based on which themes were discussed. Thus, we next examined the distribution of sentiment scores of words used that were related to each theme. Table 2 shows the mean sentiment score per theme. Note that the number of words corresponds to the words used to describe each theme and which also appeared in the AFINN lexicon. Figure 1 shows the sentiment score distribution across each of the qualitatively coded themes with a left skew on the x-axis corresponding with more pleasant word choice when describing issues related to a theme and a right skew corresponding with more negative word choice.

The teachers generally appeared to use more positive words when discussing online teaching resources (e.g., *effective*, *wonderful*, *easy*). In contrast, words used to describe the communication methods were overall relatively neutral, consisting of a mixture of more positive (e.g., *responsive*,

helpful, cool, encourage) and some more negative words (e.g., *difficult, frustrate*). Interestingly, while assessment was one of the most prevalent themes discussed, it also appeared to be among the most negative. Some of the most common AFINN words used when speaking about the topic included: *cheat, wrong, clear, difficult, hard*. This may reflect the inadequacy of resources available to teachers to administer and prepare students for assessment in a fully remote and online context.

Table 2. Mean and standard deviation for each theme's sentiment score (sorted most positive to most negative)

Theme	N_{words}	*Mean*	*SD*
Online teaching resources	61	1.54	1.66
Digital access	54	0.74	1.92
Preparation for online teaching	45	0.69	2.07
Teacher-student relationship	36	0.64	1.44
Online instructional approaches	97	0.56	1.72
Motivation	117	0.16	1.59
Communication methods	118	0.09	1.67
Grading	69	-0.03	1.81
Productivity	111	-0.06	1.71
Feedback	69	-0.32	1.45
Assessment	193	-0.42	2.18
Personal philosophy	27	-0.44	2.04
Fall Semester Teaching	13	-0.46	1.85

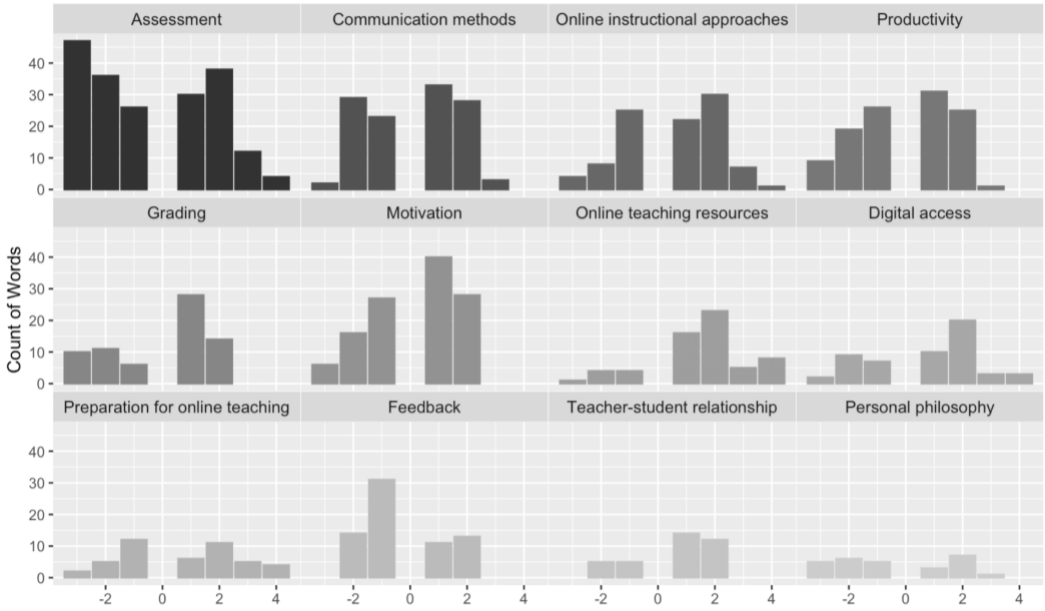

Figure 1. Frequency of words (x-axis) plotted over AFINN word valence (x-axis) for each overarching theme extracted from teacher transcripts. (arranged row-wise from most prevalent to the least prevalent theme)

Differences based on "One-to-One" status. We next examined differences in average sentiment scores based on whether teachers taught at schools with or without a one-to-one policy. Table 3 shows the average sentiment score based on the status of the one-to-one policy. Note that sample sizes shown in Table 3 reflect the total number of AFINN words used (not the number of teachers) in deriving the average sentiment score for that group. Averaging the mean sentiment score overall of

coded responses revealed that teachers in schools that were *not* one-to-one tended to express a more positive sentiment (*Mean*=.37, *SD*=1.96) overall than teachers from one-to-one schools (*Mean*=.03, *SD*=1.83), and this effect was significant, $t(995)=2.62$, $p=.008$, $d=.18$.

Table 3. Mean and standard deviation for each teacher's sentiment score and per "one-to-one" school policy status (arranged with the most prevalent theme at the top and least prevalent theme at the bottom)

	Not "One-to-One"			"One-to-One"					
Theme	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*t*	*p*	*d*
Assessment	78	-0.05	2.29	115	-0.67	2.08	**1.91** ˙	**0.058**	**0.29**
Communication methods	25	1.08	1.50	93	-0.17	1.63	**3.64 ****	**0.001**	**0.78**
Online instructional approaches	45	0.53	1.69	52	0.58	1.76	-0.12	0.901	-0.03
Productivity	28	0.54	1.57	83	-0.27	1.72	**2.27 ***	**0.027**	**0.48**
Grading	17	0.29	1.76	52	-0.13	1.84	0.86	0.396	0.24
Motivation	20	0.05	1.61	97	0.19	1.60	-0.34	0.733	-0.08
Online teaching resources	29	1.93	1.60	32	1.19	1.65	**1.78** ˙	**0.080**	**0.46**
Digital access	23	-0.09	2.17	31	1.35	1.47	**-2.75 ****	**0.009**	**-0.80**
Preparation for online teaching	13	0.46	1.98	32	0.78	2.12	-0.48	0.636	-0.15
Feedback	12	0.00	1.81	57	-0.39	1.37	0.70	0.497	0.27
Teacher-student relationship	3	0.67	1.53	33	0.64	1.45	0.03	0.976	0.02
Personal philosophy	12	-0.42	1.93	15	-0.47	2.20	0.06	0.950	0.02

** $p < .01$, * $p < .05$, ˙ $p < .10$

There were also some apparent differences in the content of teachers' responses coded for certain themes. There appeared to be a difference between the two groups with a large effect of sentiment concerning *communication methods* ($t(116)=3.64$, $p<.01$). The estimate of Cohen's *d* (*d*=.78) indicates this is a large effect. Teachers from schools without a "one-to-one" policy expressing more positive sentiment via word choice when discussing communication methods (*Mean*=1.08) compared with teachers from schools that did provide devices to students (*Mean*=–.17). There was also a significant difference between the two groups in the sentiment scores for the theme of *productivity* ($t(109)=2.27$, $p<.05$), with Cohen's *d* suggesting this effect is moderate (*d*=.48). The words used by teachers who were not from "one-to-one" schools tended to be more positive (*Mean*=.54) than teachers from "one-to-one" schools (*Mean*=–.27) when discussing the theme of productivity. By contrast, teachers from schools without a "one-to-one" policy conveyed much more negative sentiment via word choice (*Mean*=–.09) when discussing issues around *digital access* ($t(52)=-2.75$, $p<.01$) and the digital divide compared with teachers at schools with a "one-to-one" policy (*Mean*=1.35). Cohen's *d* indicates this effect is large (*d*=–.80). Though differences between the two groups were not statistically significant ($t(59)=1.78$, $p=.08$), there appeared to be a moderate effect of differences based on *online teaching resources* (*d*=.46) with teachers who were not from

"one-to-one" schools expressing more positive sentiment (*Mean*=1.93) than their counterparts (*Mean*=1.19). There was also a small and non-significant effect of differences between groups in discussing the theme of *assessment* ($t(191)=1.91$, $p = .06$, $d=.29$). Teachers who were not from "one-to-one" schools tended to select words that expressed slightly less negative sentiment (*Mean*=–.05) than teachers from "one–to–one" schools (*Mean*=–.67).

Discussion

These findings highlight prevalent issues facing AP Statistics teachers amidst the initial outbreak of the COVID-19 pandemic in Spring 2020 and provide insight into the decisions made while striving towards instructional continuity and access. Some may feel the need to prepare for a future that will still require some online instruction or even a quick shift to a fully online format (Black et al., 2020; Esposito & Principi, 2020; Tesar, 2020). Based on the issues described by teachers, it seems unlikely that equivalence between instructional modalities is attainable in emergency teaching circumstances such as the initial outbreak of the COVID-19 pandemic. There is some current discussion of advocacy for supporting pre-and in-service professional development for teaching online (Cutri et al., 2020; Hartshorne et al., 2020; Van Nuland et al., 2020), particularly by leveraging home and community resources, and which center applications of educational technologies on addressing students' interests and needs (Baran & Al Zoubi, 2020; Richmond et al., 2020). While statistics education is a prominent component of the K-12 math curriculum within the U.S. (Lovett & Lee, 2017; Scheaffer & Jacobbe, 2014) and internationally (Houang & Schmidt, 2008; Mullis et al., 2020), and extensive research has been conducted on teaching statistics online to undergraduate and graduate students for more than a decade (Mills & Raju, 2011), the teaching of statistics through an online and remote instruction to K-12 students is still greatly under-examined (Yang, 2017). The present findings provide information not only for better preparation in the face of future emergencies that necessitate remote teaching (Crompton et al., 2021) but also to meet the growing demand for K-12 online educators (Moore-Adams et al., 2016), particularly those skilled in online math and statistics pedagogical practices.

Our analysis revealed 12 distinct themes, spanning some of the practical aspects of teaching (e.g., communication, assessment, instructional approaches, online teaching resources, grading) as

well as the socio-emotional and interpersonal aspects (e.g., motivation, feedback, teacher-student relationship). We found that *assessments* (both in-class and the AP exam), *communication* with students, adopting *online instructional approaches*, *productivity*, and *motivation* were among the five most discussed issues. Considering the challenges of administering assessments remotely online, it is hardly surprising that this would be a prominent topic. The pandemic created numerous difficulties in delivering instruction, but moreover, created many barriers to adequately assessing student learning (Adedoyin & Soykan, 2020; Lake & Olson, 2020). Due to other factors that could influence scores on classroom assessments (e.g., student engagement, test anxiety, etc.), it may be difficult to evaluate the impact on student learning (Middleton, 2020). Academic integrity was a recurring issue related to the theme of assessment and indeed undermine efforts to gather accurate information about student progress (Dicks et al., 2020). Some have proposed using assessment systems to provide a rich source of information about student learning within a response-to-intervention framework (Wyse et al., 2020). Difficulties in communicating with students was yet another factor cited often by the teachers. Each teacher described instances where either they or a colleague had students enrolled in their class that simply did not respond at all. Communication with students has been identified as a crucial factor that influences the success of online learning (Garbe et al., 2020; Kollalpitiya et al., 2020).

Socio-emotional aspects of teaching and learning were also quite prominent. Motivation was often described as an alternative explanation for the challenges in connecting with students during periods of remote online instruction. Teachers conveyed how difficult it was to keep students motivated amid the crisis while also expressing that they themselves felt pressure to remain productive despite finding that increasingly challenging while managing other duties in their home environment. Both themes speak to the general fatigue that teachers and students likely faced while coping (Carpenter et al., 2020; Carter et al., 2020). Even so, the teachers described efforts amongst themselves to collaborate and support each other in providing training and resources for using online tools for teaching (e.g., Borup et al., 2020).

We were also interested in how sentiment could be expressed through word choice. Several of the teachers expressed frustration because they did not feel adequately prepared to teach students, and these differences appear to have driven variability in expressed sentiment between teachers. When

examining differences based on themes, we anticipated that themes that posed some of the greatest challenges to teachers would receive more negative average sentiment scores. This generally seemed true, at least descriptively. For example, the topic of assessment was a concern that teachers appeared to use more negative words in describing.

One factor which we felt could influence teachers' experience during the transition was the extent to which schools provided technology resources directly to students. Though we did find differences in overall sentiment scores between teachers based on whether schools had a one-to-one device policy, the difference in means suggested that teachers from schools without the device policy were generally more positive in their word choice. However, we cannot be certain that other factors might also explain these differences. For example, individual differences in sentiment scores have been documented concerning certain demographic factors (Diaz et al., 2018; Kiritchenko & Mohammad, 2018; Thelwall, 2018). Since the two groups of teachers are not matched on key demographic factors, any differences found between groups may be confounded by existing individual differences rather than the type of school they are teaching within. Particularly given the small sample size and that this analysis does not account for such individual differences, we caution against generalizing this effect.

Teachers from schools without a one-to-one device policy conveyed slightly more positive sentiment when discussing issues around productivity and online instructional resources. While it is difficult to know what factors could be driving this effect beyond individual differences in speaking styles and conversational tone, it exposes the possibility that teachers at schools without a one-to-one device policy received more autonomy in developing their instruction to suit students' needs and access to technology. Critics of "one-to-one" device policies may point out that such policies do not guarantee students are willing to use the devices solely for academic purposes (Selwyn et al., 2017) or even at all (Crichton et al., 2012). However, when discussing the theme of digital access, teachers from schools without a one-to-one device policy tended to convey significantly more negative sentiment. Ensuring equitable access to the Internet and online learning resources used for instructional purposes is necessary for promoting instructional continuity (Bacher-Hicks et al., 2020; Reimers et al., 2020).

Implications

The present findings demonstrate critical areas of instruction that need to be addressed for teachers to support students such as those enrolled in AP Statistics in the event future semesters require a swift transition from face-to-face to online teaching. These findings could inform the development of instruments for systematically studying difficulties encountered by teachers during emergency teaching. Based on the responses, two critical areas appear to warrant further consideration. First, nearly all of the teachers (except for one who had taught college courses online) expressed that they had no formal experience or professional development teaching K-12 instruction online. Professional development opportunities – even for experienced teachers – could help to ease the transition to online instruction should it be necessary for the future for prolonged periods. Second, all the teachers expressed concern in administering assessments online because tests would not be a valid reflection of students' knowledge, students simply wouldn't complete the tests, students may be inclined to cheat, or a combination of these and other reasons. There is a need for online assessment resources and strategies that could help teachers in trying to gauge student progress in a manner that is adapted to the online and remote instructional modality. Understanding these prevalent themes may help in developing measures that allow for long-term and larger-scale surveying of the impact of the COVID-19 pandemic and subsequent factors on instruction and students' educational progress.

Limitations

Despite the practical implications of these findings, there are several limitations to the current study. The present study focuses on teachers of AP Statistics and thus it may be difficult to generalize the findings even to teachers of non-AP high school math and statistics courses. Several of the teachers themselves drew such comparisons with other courses, noting that their instruction for AP courses had already shifted to focus primarily on review in anticipation of the AP exam. The generalizability of the findings is threatened by the small sample size (N=7) recruited via a convenience sample. While the transcripts reflect the teachers' in-depth perspectives on their instructional experiences during the Spring 2020 semester, this is only a small snapshot of high school teachers.

Further work should consider whether variation in teachers' experience echoes that of students. Particularly given that issues surrounding communication were a prevalent theme it would be helpful to further understand what issues teachers faced when trying to connect with students mapped onto students' own experiences. For example, did students struggle to communicate with teachers due to issues of digital access, family circumstances, or lack of motivation? Forming an understanding from both teacher and student perspectives could help identify more effective means to intervene and provide student support in the event of future prolonged periods of online instruction. These limitations notwithstanding, we believe these findings help to forge an awareness of the factors that teachers faced during the initial onset of the COVID-19 pandemic.

Conclusion

While the context surrounding the COVID-19 pandemic is presently unfolding, it can sometimes feel challenging to understand what the future may hold for K-12 teaching and learning contexts. We attempted to gauge AP Statistics teachers' experiences transitioning from face-to-face to online and remote instruction during this time. We conducted interviews with seven AP Statistics teachers following a semi-structured protocol. Analysis revealed 12 distinct themes, with *assessment*, *communication methods*, and using *online instructional approaches* among the three most prevalent themes. Teachers from schools that did not provide devices to students tended to report concerns around digital access slightly more frequently than teachers at schools that provided devices. The findings may point to a gap in necessary support for teachers in developing familiarity with online teaching resources and strategies and the need for guidance on applying online and remote assessment resources and practices. These findings may inform future practices that address instructional needs and promote continuity in online and remote learning contexts, even in the face of emergency teaching.

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