Smart Education: Opportunities and Challenges Induced by COVID-19 Pandemic
[A Survey-Based Study]

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Abstract—The viability of online education and comparisons of modes of education have long been a topic in educational study. Due to the COVID-19 pandemic declared in Spring 2020, a stay-at-home order was made in many cities in the United States and other countries, which caused the conversion of university education entirely online right in the middle of a semester. Students have experienced both face-to-face and online instruction in a single semester with almost the same duration. This paper discusses our survey-based study of over 300 students taking a course from the departments in computing and engineering college of a higher education institution in the US, in order to understand the effectiveness of face-to-face and online education through quantitative and qualitative research methods. The familiarity of online resources is relatively high to students and instructors in the computing and engineering disciplines than other disciplines. That technology use itself might be less likely a barrier in the instruction allows us to focus on the effectiveness of teaching and learning. We also offer discussions on the challenges and opportunities of online education that are likely to be a persistent future education option.

Index Terms—COVID-19, Pandemic, Smart education, Survey-based study.

I. INTRODUCTION

The effective modes of education and the comparisons between face-to-face and online educations have long been a topic of educational study. Online courses have been on a steady increase in the past two decades because of its clear benefits such as accessibility to education and flexibility of schedule, especially among adult learners with multiple responsibilities [33]. However, the learning outcome of online has been perceived inferior to face-to-face education, which has been the major set-back of its implementation. Thus, online courses and programs have been mostly limited to outside of formal educational systems and regular programs [6].

COVID-19 is inducing a revolutionary period in education, and online education has been proved to be the only viable option at the time of a pandemic. The global scale and speed of the educational disruption from the COVID-19 epidemic are unparalleled, as the United Nations stated in [31]. For many online educational institutes, this COVID-19 crisis is considered as an opportunity to focus on filling the gap left in conventional face-to-face education. However, the educational responses to the pandemic varies across a country and the world with varied infrastructures and experiences. In April 2020, 272 institutions in 38 states in the US have at least one confirmed case, and over 1,400 colleges and universities have been moved to online instruction [15]. For many countries recognized the importance of online education due to COVID-19 and reacted promptly, such as the United States, China [24] and Saudi Arabia [1]). There are many countries, however, that are not much prepared for online education [2]. [14] remarked that some universities in Australia also have online education only in a few departments. In some developing countries where Internet penetration is low, it is reported that radio, TV broadcast channel, and phone texting are used for education instead of the Internet online education [27]. The extent of online offerings can vary, and some include the implementation of a virtual laboratory learning experience that includes the use of video games, multimedia content, and virtual simulations by generating a general engaging virtual environment [34].

In this study, we explore the perceived effectiveness of face-to-face and online education based on a student survey that was conducted at the end of the Summer semester of 2020 at the School of Computing and Engineering (SCE) at the University of Missouri - Kansas City. Due to COVID-19, a stay-at-home order was implemented right in the middle of a semester in March 2020. Thus, all students experienced both face-to-face and online instruction for the same course for about the same duration within a semester. While we recognize the study is conducted at a special time of the pandemic, we believe it offers a unique perspective to and sheds meaningful insights on educational modes and strategies. The instructors and students of computing and engineering disciplines at an urban university are relatively familiar with Internet technologies and mostly have stable Internet connectivity. Thus the issue of technology readiness may be insignificant, which allows us to focus on the comparison of educational modes. The survey responses allude that online option could be a feasible mode of instruction and learning for formal university education. However, there are some important issues that need to be addressed to be as effective as face-to-face instruction. We also offer the challenges and opportunities for online education for a step forward to smart education.

The rest of the paper is organized as follows. We discuss the prior studies about educational modes in Section II. We

explain our survey study methods in Section III. We discuss the quantitative and qualitative results of the survey in Section IV and Section V, respectively. Guided by the findings, we provide our discussion on the challenges and opportunities of future education in Section VI. Concluding remarks and future work are presented in Section VII.

II. RELATED WORK

The comparisons between face-to-face and online educations have long been a topic of educational study. The article in [33] provides a comprehensive review of pre-COVID-19 research on online learning's with respect to access, cost, and student performance in higher education. As existing studies on college courses typically find negative effects of online delivery on course outcomes, especially for academically less-prepared students. Thus, online courses without strong support to students may worsen educational inequities.

There are efforts to make a learning framework adaptive to individual's needs. The authors in [9] proposed a novel deep reinforcement learning framework that adaptively provides exercises to students, recommending non-mastered exercise problems to address the immediate weakness of students. That is to gradually increase the difficulty level of exercise problems to keep the students engaged. A Workshop reported in [32] attempted to tackle issues of motivating and evaluating students of large scale online courses using crowd-sourcing. In the Report in [16], 45 studies have been summarized on K-12 and higher education students to see the effects of Face-to-face, blended and fully online courses and they found positive effects of fully online and blended format on learning outcome. A recent study in [4] assessed the satisfaction of Ghanaian international students in China with the massive online learning in higher educational institutions in Beijing during Spring 2020. They found students were generally satisfied with the online courses, but the problems of cost and bandwidth of the Internet connectivity were significant challenges to some students.

In this study, we uniquely explore the perceived comparison between face-to-face and online education from computing and engineering students at an urban university in the United States in Spring 2020. As a stay-at-home order due to COVID-19 was implemented right in the middle of a semester, all students experienced both face-to-face and online instruction for the same course for about same duration within a semester. This timely and unique study on the important topic of education would enhance the understanding of challenges and opportunities of educational modes and guide the direction of future smart education strategies.

III. SURVEY STUDY METHODS AND DATA

The study population was the students taking courses from departments (4 disciplines) at School of Computing and Engineering at the University of Missouri – Kansas City during the semester of spring 2020. The survey solicitation was sent out by emails from a school administrative staff and a reminder email was sent by class instructors. The survey
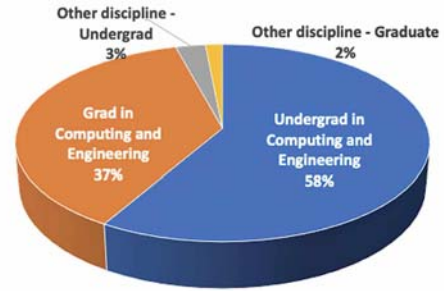

Fig. 1. Participants Characteristics

was open up to two months, but most of the participants responded within two weeks of the initial invitation which was during and after the final exam week in May 2020. All 334 survey results were collected in spring 2020, where 260 participants fully completed the survey, and the remaining 74 responses were partially completed skipping some questions. The survey response was voluntary, and the data is collected only after informed consent. The research protocol was officially exempted by our university's Institutional Review Board (IRB). We have used the Qualtrics online survey tool, where participants respond to the questions anonymously through a web link in the invitation email. 90% of participants completed the responses within 11 minutes. The survey questionnaire included 33 Likert scale questions, sorted into 4 to 8 dimensions or factors. One question was about the participants' group, either undergraduate or graduate and the last question was an open-ended one on suggestions and comments about online education. For the open-ended question, we have conducted a qualitative study with the comments using ATLAS.ti 8, an analytic data platform for organizing and interpreting unstructured qualitative data.

Out of the responses, 58.40% (n = 153) identified themselves as undergraduate students in Computing and Engineering; 37.40% (n = 98) as graduate students in Computing and Engineering; 2.67% (n = 7) as undergraduate students in other disciplines; and 1.53% (n = 4) graduate students in other disciplines, as depicted in Figure 1.

IV. QUANTITATIVE STUDY RESULTS

In this section, we present the notable survey results out of the 33 questions, due to the space limitation. We first discuss the survey results on the Internet connectivity and the level of comfort about the learning management system (LMS) and online video platform (Zoom) that were used for their online education.

As in Figure 2, the majority of the students used used residential WiFi for their online education. Regarding the Internet bandwidth at students' residents, about the majority responded to have sufficient bandwidth, but there were about 4% of students who said Frequent problems, inconvenient (n = 9) or Very inconvenient (n = 2), and the majority of the
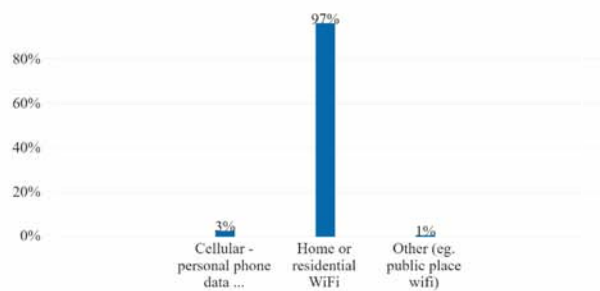
Fig. 2. Responses to Q: What is your main Internet connectivity at home for online learning?

Fig. 3. Responses to Q: Do you have a sufficient Internet bandwidth for online education?

students used residential WiFi for their online education as seen in Figure 3.

The comfort level of the LMS and video platform were very high for most of the students. The LMS Canvas system has been used for a few years in UMKC. The majority, 94% of the students – 55% of the students - very comfortable, 39% of students - moderately comfortable – responded comfortable with the LMS, as shown in Figure 4. Once the classes turned into online, most of classes used Zoom as a video platform for synchronous classes. Even though most of students haven't used it much before the pandemic, the majority, 82% of students found it comfortable, as shown in Figure 5.

The response result about the overall comparison between face-to-face and online is shown in Figure 6. Even though more than 60% of students responded that face-to-face instruction is superior, close to 40% of students responded either online is superior or about the same as face-to-face. Figure 7 shows the perceived satisfaction between face-to-face and online learning. About half of the students responded either the same or online-superior and the other half of the students responded with face-to-face superior. Notably, about 40% of students said the perceived learning outcome is about the same, even though higher percentage of students responded face-to-face learning (44%) is either somewhat superior or superior to online one (14%), as in Figure 8. The face-to-face instruction was perceived clearly superior to online with respect to the student-to-student interactions and learning outcome. Over 70% of students responded that face-to-face learning is either somewhat superior or superior to online one, as shown in Figure 10. The responses to the question about support for students with different learning styles were pretty close between the two, with a slight preference for face-to-face learning, as in Figure 11. Overall, while face-to-face learning is still preferred for the learning experience and satisfaction, the online option was very close to the level of equivalence.

Online instruction was responded to be superior to face-to-face one in several aspects. Online is superior in terms of scheduling flexibility, as seen in Figure 9. About 55% of students responded that online learning is somewhat superior or superior to face-to-face one, and about 22% of students said it is about the same between the two. About 55% of
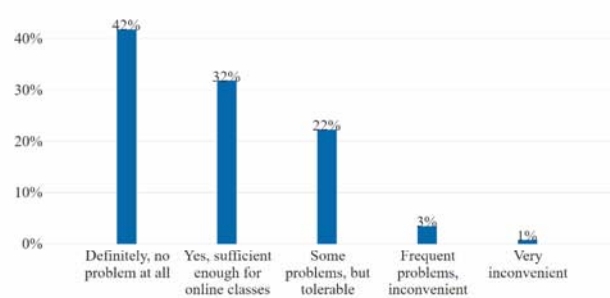
students responded that online learning is somewhat superior or superior to face-to-face one, with respect to the ability of students to Work at their own pace, and about 30% of students said it is about the same between the two, as shown in Figure 12. When synchronous online lectures were given as well as its recordings, the majority of the students (over 68%) replayed the videos taking advantage of the online content available, as shown in Figure 13.

V. QUALITATIVE STUDY RESULTS

Using grounded theory approaches [8, 20, 23], we developed codes with the constant comparison technique and identified patterns of themes in the open-ended question for comments or suggestions. Specifically, participants' answers were analyzed inductively, using a combination of open coding of identifying relevant themes line-by-line as well as focused coding of searching for specific themes to group them into categories. The final set of codes included both pre-existing codes drawn from the closed-ended questions and emergent codes during the open-coding or in vivo process [3, 5]. Once a stable categorization of codes was produced, comments were coded in the second round of focused coding, and codes were entered manually into ATLAS.ti 8. These focused codes form the basis of the analysis found below, with representative excerpts used to illustrate the categories. These qualitative analyses show insightful perspectives that were not pertinent in quantitative analyses.

A. Positive or Satisfactory Responses about Online Courses

There were a number of students comments that were satisfactory or positive about online courses. Some examples are shown below. Note that we don't use any pseudonyms for the comments, as all quotations are from different participants.

"I've actually been very happy with the way everything turned out– that's the benefit of being in computer science because most of the instructors already have a 90% online course."

"All good"

"Online is fine"

"Offer more online classes for those in the SCE program. I wish more classes were offered online as I live so far away."
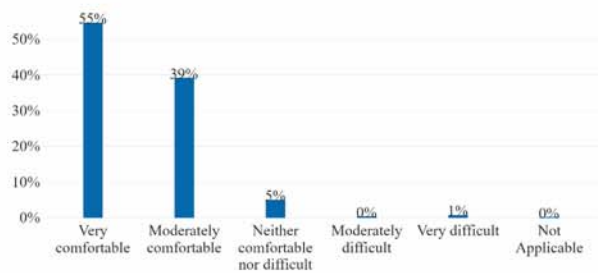
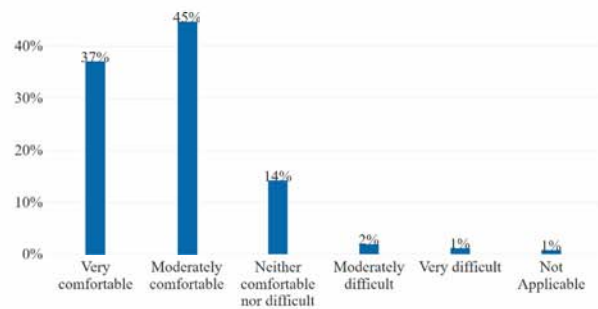Fig. 4. Technical comfort level with Canvas

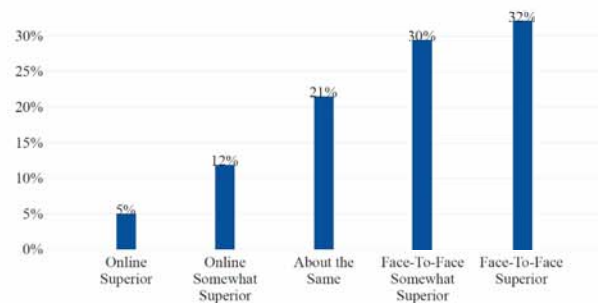Fig. 5. Technical comfort level with Zoom

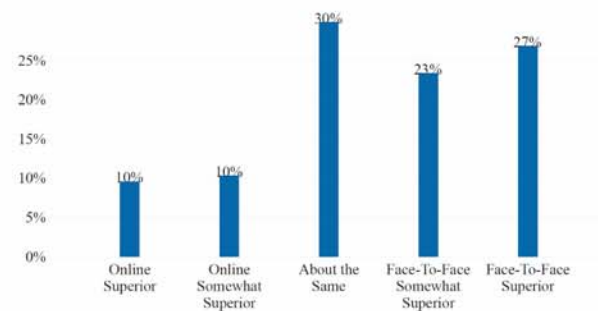Fig. 6. Online And Face-To-Face Courses Overall Comparison

Fig. 7. About Perceived Student Satisfaction in Online and Face-To-Face Courses
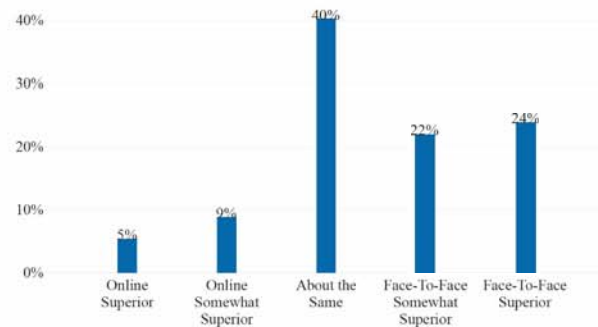

Fig. 8. About Learning Outcomes in Online Education Compared To Face-To-Face
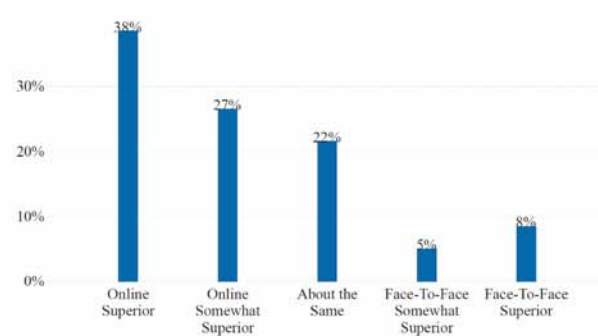

Fig. 9. About Scheduling Flexibility For Students

"I honestly preferred online, the switch from in-person to online literally made no difference to me, especially in my computer classes. If anything, I learned even more and caught on way better."

"Provide more online classes after the pandemic is over."

"SCE SHOULD DEFINITELY OFFER MORE ONLINE COURSES."

"my experiences are both good and bad for online just as in person, it all depends on the material and instructor and how well their able to teach with the tools they have."

""No much difficulty, lectures feel the same in class or through zoom"

"I don't mind the online classes that much. It allows me to focus on lectures and have the ability to go back and watch."

B. It Depends on the Instructor

On the other hand, some comments indicate, it is a more of an instructor (probably teaching style and engagement with students) than the mode of education that makes a difference.

"It depends on the instructor for the course. Some professors made the transition to online learning almost seamlessly and other professors less so."

"Some teachers have suffered greatly from the switch to online courses."

"Historically, instructors have been terrible about consistently using Canvas/LMS to show a calendar of assignments/exams and posting resources. This semester, my classes were mostly good about it but I imagine many courses suffered
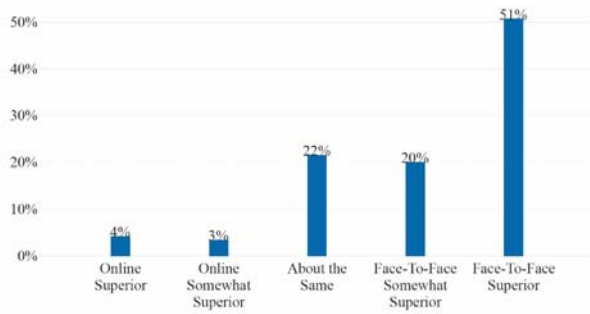
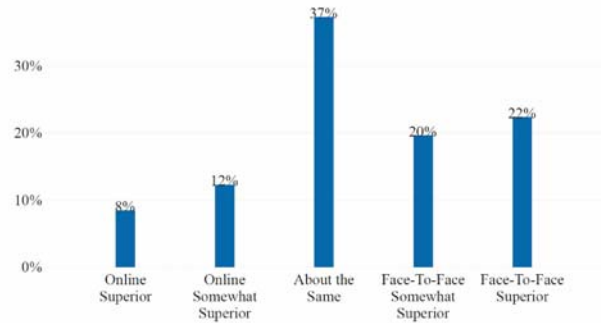Fig. 10. About Student-To-Student Interactions

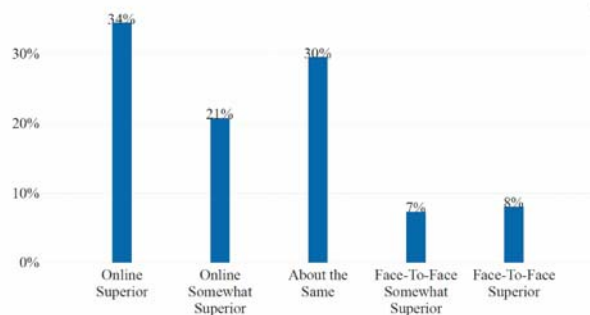Fig. 11. About Support For Students With Different Learning Styles

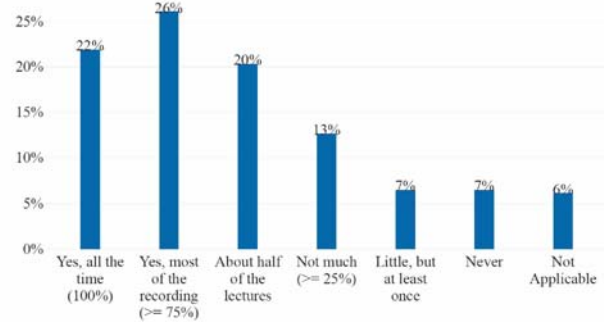Fig. 12. About Ability of Students to Work at Their Own Pace

Fig. 13. When the synchronous online instruction is given, did you still watch the recording of the lecture?

Fig. 14. Word Cloud from an Open Comment Question

from a lack of online engagement the same way that in-person classes do."

C. About Audio and Video Quality

Some suggestions were about audio and (asynchronous) video quality like the followings. *"student's volume control is not in their hands in case of zoom, it is difficult to hear with that huge volume. so it is better to modify or use any other tool for synchronous lectures."*

"I need one-on-one Question and answer with my professors. I need something like office hours so I can request assistance with the professors."

D. Security and Privacy Concerns

There were a few security and privacy related remarks as below.

"The video proctoring of exams I STRONGLY dislike. I think it's an incredible invasion of privacy and we should NOT be required to use video cameras."

"Proctorio is making getting grades really difficult, since the exam pattern using that tool is very intense and makes me really nervous."

"Proctorio caused many classmates extensive grief during high-stakes testing."

E. Equity Issue

There were a couple of remarks about the Internet access issue.

" One thing I mention is that perhaps a professor for his or her particular class could do a mass survey for the students BEFORE classes begin, which could ask certain questions about their internet bandwidth, quality of home environment (to do work and listen to potential lectures) and etc."

"I don't think online learning is fair to students who have no internet access or their own computer or students who live in a household with many other people. I didn't have trouble

but I don't think it's fair while there are students who aren't able to participate under these conditions."

"Proctorio is the worst and if your internet connection is not great (like mine) it will kick you out of an online exam which is STRESSFUL"

VI. Opportunities and Challenges

Online education is not a particular option anymore. It is a default option in Fall 2020, at least, while some in-person educations are offered as a special case. In this section, we discuss the opportunities and challenges that online education is bringing.

A. Opportunities

A number of benefits of digital technologies and online education would help enable and enhance the learning experiences.

1) Acceptance of Online Education and Easier Access of Education: The level of faculty acceptance of online instruction used to be low and only slowly increasing over the years [33]. Youtube or the popularity of MOOC have been changing the way people learn, but mainly in the informal educations. However, online education proved to be the only viable option for even formal education during this COVID-19 pandemic. Clearly, online makes education accessible from anywhere as long as the Internet is available. Recorded videos allow students to replay later and learn at their own pace. Students who live far away, work full-time while being parents of young children, or whose physical condition does not allow travel to a classroom can still learn and participate in the class, review the material anytime, and many times.

2) Availability of Rich and Diverse Online Tools for Education: There are a number of features available for online meetings that can be utilized for student engagements online. The technologies for online meetings have rapidly evolved in recent years, allowing rich and diverse features that can emulate various kinds of activities of real meetings. For instance, *Breakout room* feature can be used to mimic small group discussion settings in a classroom. *Breakout room* feature can also be used to minimize the noise the exam related troubleshooting when multiple proctors are available. *QnA* feature makes it easy to follow up and follow through each question during an online class session. Social engagement features like *reactions of thumb-up or clapping, physical response mimicking features like quick polling (yes, no) and raising hands* are available that can make the class more interactive, they can only be actively utilized when the teacher actively encourages, and facilitate their use.

Many physical classroom activities like a show of hands for polling and students' verbal questions can be facilitated by technology. To gather students' input interactively, cloud-based collaborating tools where many people can write or contribute to a discussion simultaneously. There are cloud-based collaborative engagement tools that can be used either synchronously (eg. chats, QnA features of online meetings, online polling [17] and brainstorming [10] tools) or asynchronously (discussion boards of LMS platforms, team messaging platforms) that can take input from students in the format of short responses or writing. Some introverted students may find it more comfortable with writing questions and responses than speaking in a class. Such technology-assisted student engagement could be easier to scale to large classes and be utilized for face-to-face instruction too. Teachers' competency, encouragement and use of engagement features would be important for students to actively engage in the class meeting activities.

B. Technology-Enhanced Teaching and Learning

In addition to the use of the aforementioned features, a mixed-mode of asynchronous video and live class (either synchronous online or in-person class after this pandemic is over) could be more commonly used to enhance the classroom experience, with the available technology platform. A flipped classroom model flips the traditional class time and homework where students learn at home via online lectures, and instructors use class time for questions and answers, and instructor-guided practice or project work. This model enables teachers to use class time for more than delivering traditional lectures. However, how to use the class time would need some deliberate planning, not to use it for repeating the lectures [7].

1) Institutions' Investment and Support for Online Education: Online education preparedness became the top priority of educational systems at this moment. Many administrators in the higher education are recognizing this special moment as an opportunity to equip their professor for instructional excellence and to survive and thrive in the current and future education.

For instance, our university, the University of Missouri - Kansas City has been offering, so-called 'PROFF' course over this Summer 2020 that offers professional learning for faculty to prepare for a Fall semester by sharing ideas among the faculty members across various disciplines [28]. As for a larger scale instruction program support in response to the COVID-19 impact, the recent initiative of the National Association of System Heads (NASH) will offer a special 25-week program [26] on effective teaching practices and online strategies, in partnership with the Association of College and University Educators (ACUE) [25]. That program encompasses over 63 universities of the four university systems in the United States.

C. Proliferation of Digital Learning Materials and Quality

More and more education contents are being and will be made available for Fall 2020. More 3D AR/VR content for educations are going to be produced and available in the near future. Thanks to the editability and reproducibility of digital materials, the quality of education will continue to improve at a faster rate. Once the contents are made, they can be reused and edited easily to improve the learning experience, and flipped classroom practices would be made more common in the future.

1) More Reflections and Discussions on Teaching and Education Quality: This pandemic gives a special opportunity for instructors to carefully reflect upon their teaching quality

and ways to improve them. As discussed in the qualitative study section, Section V, the experiences of online education of the same instructor is not much different from its face-to-face one. Thus the quality and attention of the instructor could be a possibly more important factor than a mode of education. Abundant discussions are floating around about online education during this pandemic that brings up increasing attention and promote further discussions. This heightened attention might improve the teaching strategies and eventually, the quality of overall education in a relatively short time.

D. Challenges

Here we discuss the challenges of online education and offer some suggestions when possible.

1) Resources Required for Online Education and Digital Divide: The investment for online instruction is necessary not only for being able to offer the basic educational service but also is regarded as a path forward for future competitiveness and success. The institutions are taking the intense pressure of the rapid shift and improvement that require lots of financial, managerial, and training resources. Schools have to invest in educational platforms, software and instructor training. This would reveal another kind of digital equity gaps across the institutions and countries. Furthermore, the fundamental requirement is the Internet infrastructure of the region/country and digital access devices of instructors and students. In some developing countries, where most of the students do not have Internet access, TV channels are used for public educations [29].

2) Rapid Cultural Shift and Learning Curve: Online education preparedness and instructional excellence have become the top priority of all educational systems at this moment. The investment for online instruction is not only for being able to offer the basic educational service but also is regarded as a path forward for future competitiveness and success. Even with resources available, it takes time and guidance for instructors to master online educational tools and platforms. In addition, depending on disciplines and topics of education, instructors who are not familiar with technologies would have to spend a significantly varying amount of time and effort. However, once the familiarity of the tools set in the instructors and the digital contents is generated, that would be a significant cultural change in education, which is not likely to be reversed back. The digital educational materials can be easily reproduced and updated to be reused, and instructors will continue to use the technical skills learned.

3) Learning Assessment: One of the main challenges of online courses is that it is difficult to truly assess students' learning. Particularly, the integrity of proctored in-class exams is hard to be replaced online. During the temporary pandemic situation in Spring 2020, learning outcome expectations were toned down in many cases, and the amount of workload and type of assessment was not as strict in regular times.

Practices that instructors typically used in Spring 2020 as an alternative of an in-class exam include a take-home exam, computerized multiple-choice questions, or an exam proctored through zoom, and/or using a proctoring software. However, it is easy for students to get away from proctoring during an online exam, and the use of proctoring technology could be bandwidth demanding and may seem intimidating and intrusive, as discussed in Section V. Many K-12 school districts in the US did not enforce any coursework, and no assessment and grading were in the last quarter of the 2019-2020 school year [22]. More robust assessment strategies would be in need for an online education to be considered as rigorous as a face-to-face version.

4) Engagement and Inclusiveness: The general educational topic of engagement and inclusiveness has become more challenging in an online setting. With limited visual views and non-verbal cues, and the lack of personal moments with an instructor before and after classes, it could be more difficult for students, especially introverts, to build a personal rapport with an instructor or to ask questions, especially during synchronous/live classes.

Fortunately, more and more technological platforms are being developed and utilized. Synchronous platforms like quick polling, brain-storming, and commenting on slides or video discussion boards,

Ultimate responsibility and effectiveness, however, would be mainly on the shoulder of an instructor. Setting the tone of inclusiveness and such encouragement from the beginning of the course and encouraging and facilitating students' engagement throughout the course conduct would make a big difference. Rather than an introvert or extrovert, it will be recognized as an online classroom management skill that is expected of an instructor.

5) Laboratory exercises and hands-on training: Some topics and exercises of education, such as laboratory experiments, are difficult to practice online. For instance, hands-on chemical or electronic circuit experiments, especially when they require large, expensive equipment, can be conducted by students. Even when the materials are delivered and available at students' hands, handling the unexpected or troubleshooting (e.g. IoT sensor malfunction) becomes a lot more challenging than the cases in class as teachers cannot perform any troubleshooting test themselves. Some training and lessons like musical, dance, or athletic performances require a teacher three-dimensional observation than a flat two-dimensional screen can provide. Also, assisting an individual student for any trouble during a class would interfere with all the rest of students' activity. To overcome the limitations of 2D images/video lessons, 3D Augmented Reality, and Virtual Reality tools are gaining its momentum for training of hands-on 3D physical materials or medical experiments [11, 30]. We expect that 3D AR/VR educational contents are going to be greatly produced and popularly utilized in the near future.

6) Online fatigue: As the number of meetings and the duration of our time spent online get increased, online fatigue becomes an issue as well [12]. We are on video meetings more than ever before, since the COVID-19 pandemic hit, and many people are finding it more exhausting than a face-to-face meeting. The reasons could include those video meetings give

the feeling of being watched by everyone and require more energy to process non-verbal expressions than a face-to-face meeting [12]. In addition, according to a study in [21], silence in a video meeting creates a negative view on the people. As we recognize the fatigue, pacing online meetings as possible would be helpful.

E. Additional Tips for Online Teaching

Instructors around the world are working hard to prepare for more successful online teaching for this Fall. Even if the instruction might be planned for an in-person setting at the moment, instructors should be ready for any situational changes during the semester as we have experienced in Spring 2020. Most preparations would be about getting familiar with the university offered educational platforms and other useful online tools. Additional suggestions about details of classroom experience like preparing a good microphone and frontal LED ring light that could help the online videos and classes less distracting [13, 28].

For students, the general attributes and skills of a successful learner are all the more important in online learning. They include persistence, effective time-management skills, effective and appropriate communication skills, basic technical skills reading and writing skills motivation and independence and a good study environment [18, 19].

VII. CONCLUSIONS AND FUTURE WORK

In April 2020, around 1400 U.S. institutions moved classes online in response to the COVID-19 [15], which showed us that online education would be an undeniable future either as its own or as an available hybrid option with a face-to-face version. In this paper, we have conducted mixed methods research that involves collecting, analyzing, and interpreting quantitative and qualitative data from the survey from students who took classes at the School of Computing and Engineering of the University of Missouri - Kansas City to see the perspective and comfort level from their side. Considering different aspects, it can easily be said students have adopted online education pretty easily, but there still might be a number of issues that can be addressed relatively easily, as well as necessary steps that can be taken to resolve them. Strategies could help for continued online sessions in the future, including the immediate fall semester. As future work, we plan to include and compare the surveys from the instructors' perspective to understand a more holistic perception of the online education experience.

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