2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #32362

Effectiveness of Remote Learning During the COVID-19 Pandemic in Spring 2020: A Survey of Engineering and Computer Science Students

Dr. Rick Hutley, University of the Pacific

Dr. Hutley earned his bachelors degree in computer science from the University of Hatfield, UK, a Masters degree in business administration from Cranfield University in the UK, and his doctorate in education from the University of the Pacific. He is currently the Program Director and Professor of Practice of the Data Science program at the University of the Pacific. His research interests include data science, artificial intelligence, and robotics.

Dr. Rahim Khoie, University of the Pacific

Rahim Khoie received his Ph.D. in Electrical Engineering from University of Pittsburgh, Pennsylvania in 1986. He is presently a professor of electrical and computer engineering at the University of the Pacific in Stockton, California, where he joined in 2002. He is also the director of engineering physics program. His areas of interest include renewable energy, photovoltaics, and semiconductor quantum and nano devices. He has published more than 100 articles in journals, proceedings, and numerous invited presentations at conferences and scientific meetings. He also has received a number of research grants as well as teaching awards. Dr. Khoie has been member of a number of professional societies including ASES, IEEE, ASEE, and SPIE and has served in various chair positions including Pacific's Department of Electrical and Computer Engineering, IEEE Region 6 Student Activities, and ASEE Southwest Section.

Dr. Camilla M. Saviz P.E., University of the Pacific

Camilla Saviz is Professor and Chair of Civil Engineering at the University of the Pacific. She received B.S. and M.S. degrees in Mechanical Engineering from Clarkson University, an M.B.A. from the New York Institute of Technology, and a Ph.D. in Civil and Environmental Engineering from the University of California, Davis. She joined Pacific in 1999 and is a registered Professional Engineer in California.

Dr. Michael Doherty, University of the Pacific

Michael Doherty received a B.S. in Electrical Engineering from the University of Florida, an M.S. in Computer Science from the University of Rhode Island and a Ph.D. in Computer Science from the University of Colorado, Boulder. His experience includes developing simulation and control systems for General Electric. He is currently the Associate Dean of the School of Engineering and Computer Science and an Associate Professor of Computer Science at the University of the Pacific. His research interests include animation, simulation and computer science education.

Effectiveness of Remote Learning During the COVID-19 Pandemic in Spring 2020: A Survey of Engineering and Computer Science Students

Abstract

Like most other universities in the United States, classes and labs at University of the Pacific went fully virtual in March 2020 as a result of the Coronavirus (COVID-19) pandemic. Prior to this event, all classes were taught in face-to-face synchronous mode. At the end of the semester, we administered a survey to students in the School of Engineering and Computer Science asking for feedback on their remote learning experience. In addition to numerical ratings, specific feedback was sought using the following questions:

- What elements of remote delivery were effective/not effective?
- Do you have any specific suggestions for improving delivery of course or lab content in remote environments?
- What elements of the remote environment made it easy to learn/difficult to learn?
- Do you have any specific suggestions that could improve students' ability to learn in remote environments?
- What elements of the remote environment made it easy/difficult to complete your work?
- Do you have any specific suggestions for things that could make it easier for students to complete their work in remote environments?
- Top three factors that affected your learning negatively/positively.

We received 48 responses that included over 400 individual comments. Student demographic data indicated that responses were received from students in all years, although most respondents were seniors.

Responses were analyzed using the ASCE ExCEEd Teaching Model. Comments were coded manually using a spreadsheet and also categorized using MAXQDA qualitative data analysis software and were checked for consistency between the two methods used. Students' comments predominantly addressed appropriate use of technology, student engagement in the class or lab, and structured organization of the material and activities presented synchronously and asynchronously. Findings of the survey were shared with faculty in the School to inform preparation for, and teaching in, Fall 2020.

Survey results, the analysis approach used, and observations are presented in this paper. The ASCE ExCEEd Teaching Model proved to be a valuable framework for cataloging and analyzing over 400 comments provided by students. Analysis of the comments showed that students prefer live classes with recorded lectures for later use together with ample opportunity for office hours and contact and communication with faculty and their peers.

Study Motivation

In the middle of the Spring 2020 semester, University of the Pacific transitioned to remote teaching to prevent the spread of the COVID-19 virus. The announcement was made by the University President on March 11, 2020 (during Spring Break), Spring Break was extended by

one week, and classes resumed on March 23, 2020, but in fully remote mode. With only a week and a half to prepare for remote teaching and learning, this sudden transition created significant challenges for faculty and students.

After March 11, 2020 and throughout the rest of the semester, engineering and computer science faculty held frequent formal and informal virtual meetings to exchange ideas, share resources, and resolve issues collectively. The faculty also created a Canvas Learning Management System site to share information. A discussion board was used to exchange ideas. From these sources and the authors' personal experiences and observations, we identified common challenges facing the faculty and students. These challenges are likely similar to those experienced at numerous other institutions.

Challenges faced by the faculty included:

- Remote teaching platforms: Synchronous class sessions could be held using two services supported by the university: Webex and Zoom. Prior to the shutdown, video conferencing was generally used only for meetings and typically only on rare occasions. Only one program (MS Data Science) had taught classes in remote mode using Webex.
- Class meetings: Although some faculty held classes synchronously, some opted for asynchronous pre-recorded videos, and a few faculty used an intentional flipped course approach. Some faculty also relied upon publicly available (e.g., YouTube) videos.
- Labs: In the absence of any physical laboratory experiment set ups, many faculty opted to emphasize simulation and analysis of data provided to the students.
- Exams and Quizzes: Whether giving open-book or closed book exams, proctoring of exams proved challenging. A few faculty members opted for oral exams which proved to be time consuming and challenging for students who had not experienced this method of examination.
- Delivering all materials electronically: Course materials, quizzes, and exams were typically made available through the Canvas Learning Management System (LMS) although some faculty used other platforms such as Slack and SharePoint. Students uploaded their assignments to Canvas, but some faculty relied on emails. Although all faculty had used Canvas prior to March 2020, many had used it minimally.

Among the challenges facing the students were:

- Attending Remote Classes: Students had to adapt to remote instruction and had to switch among different platforms for different courses.
- Asynchronous Mode: With asynchronous classes, students missed having the ability to ask questions and participate in class discussions in real time.
- Team-based Activities: Students collaborating on lab work and projects requiring teamwork had to adapt from in-person meetings to remote and sometimes asynchronous activities, and in many cases, across time zones.
- Technology: Some students lacked access to reliable computers or internet connectivity.
- Personal: Some students faced difficult family, health, financial, or living situations.

Thrown into the uncharted territory of remote teaching and learning, the experience proved to be less than ideal in spite of everyone's best efforts. While we were cognizant of the issues facing faculty, we needed to better understand the challenges facing students so we could provide

support where needed. To achieve this goal, we administered a survey to our entire student body in the School of Engineering and Computer Science through the school's listserv. The survey instrument was designed to seek students' feedback in the form of numerical ratings of their experiences as well as written comments about effectiveness (and ineffectiveness) of the remote learning environment.

We were particularly interested in learning about actionable elements for the Spring 2020 and Summer 2020 semesters, and in case we faced a fully remote semester in Fall 2020. Indeed, our university – and many universities in California – remained in remote mode for the entirety of the 2020-2021 academic year. The survey was not repeated in Fall 2020 or beyond because in general, the faculty had more time to prepare for teaching in remote mode in Fall 2020. Additionally, in the intervening months, the university had placed better systems in place to support students and faculty.

Survey Instrument

The survey instrument was structured around three broad topics, namely:

- Remote Delivery of Content,
- Remote Learning, and
- Remote Working.

The survey was administered using Google forms. Each section was presented as a separate page and navigation among pages was enabled. Specific questions in each topic area asked students to rate their experience using a five point Likert scale, and then prompted them to identify effective elements, ineffective elements and suggestions for improvement. The questions and format for each topic were similar to reduce cognitive overhead and help students to remain focused. In the final section~~s~~, students were prompted to identify the top three negative factors and top three positive factors relative to their ability to learn effectively in the remote environment.

The survey and the request message sent to students are presented in the Appendix. All survey questions were reviewed by the study authors independently, then as a group, and then shared with the Program Chairs in the School. We were careful to avoid questions that would elicit student responses about specific instructors or specific disciplines. Other than the student's class standing, the survey asked for no personally identifying information so students could be confident that their feedback was anonymous. For this reason and because students take courses taught by faculty in different disciplines across the School, we did not track students' majors.

Analysis of Numerical Results

We received 48 responses, a response rate of approximately 7% of the 720 students in the School of Engineering and Computer Science. Fig. 1 shows the class standing of the survey respondents. Students in freshman and sophomore classes represent about 19% of respondents. The majority of respondents, roughly 70%, were juniors and seniors. Because personal information was not gathered, there is no definitive way to elicit reasons for the difference in response rates among academic years. However, in general, seniors tend to be more connected

to the School and faculty, and therefore are often more likely to take action when requested. Note that the percentages add to greater than 100% because some students identified more than one class standing. Although we would have preferred a higher response rate, the survey responses represented feedback from across the School and analysis of the comments revealed many commonalities among the students' experiences.

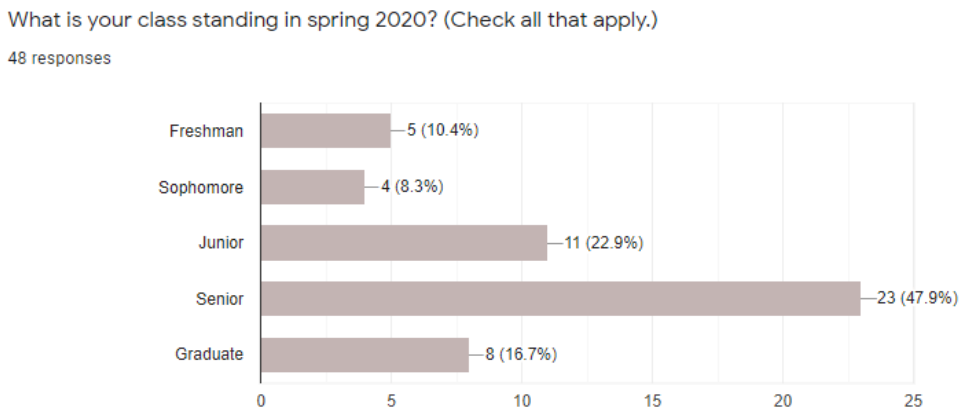

Fig. 1. Class standing of survey respondents

Results of students' ratings on *instructors' delivery* of the courses and labs are shown in Fig. 2. Likert scale ratings ranged from 1 (poor experience) to 5 (great experience). Combining scores of 4 and 5 as "positive experience" and 1 and 2 as "negative experience," the majority of the respondents (56%) found their experience positive compared to 15% who found the experience negative. Thirty percent rated the experience as a score of 3, considered to be neutral. The fact that almost 85% found the experience to be neutral or positive was important because negative feedback could not be easily dismissed as coming from disgruntled students.

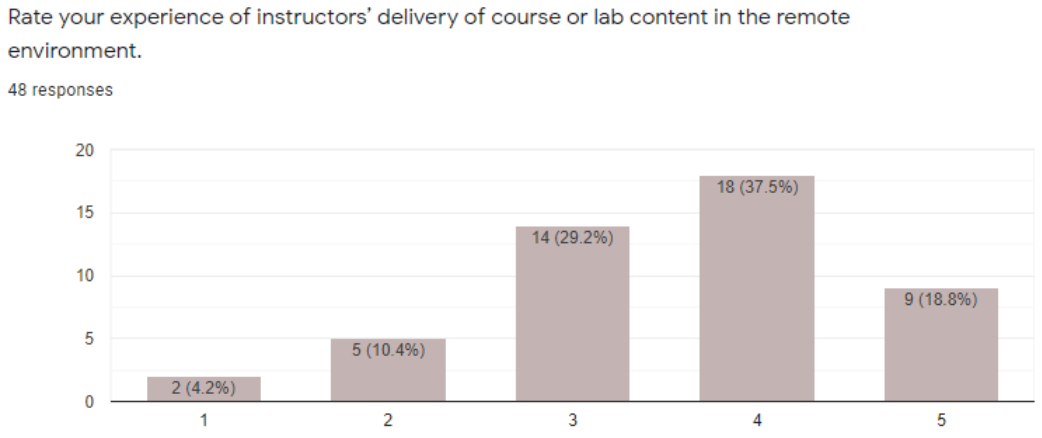

Fig. 2. Ratings of instructors' delivery of courses and labs in remote environment.

Using a similar approach on the question of the students' *ability to learn* in the remote environment, 52% of respondents reported a positive experience compared to 21% reporting a negative experience (Fig. 3). Finally, as shown in Fig. 4, a large majority of respondents (67%)

rated their *ability to complete* their work positively, compared to 12% who felt they were not able to complete their course assignments and exams effectively in the remote environment.

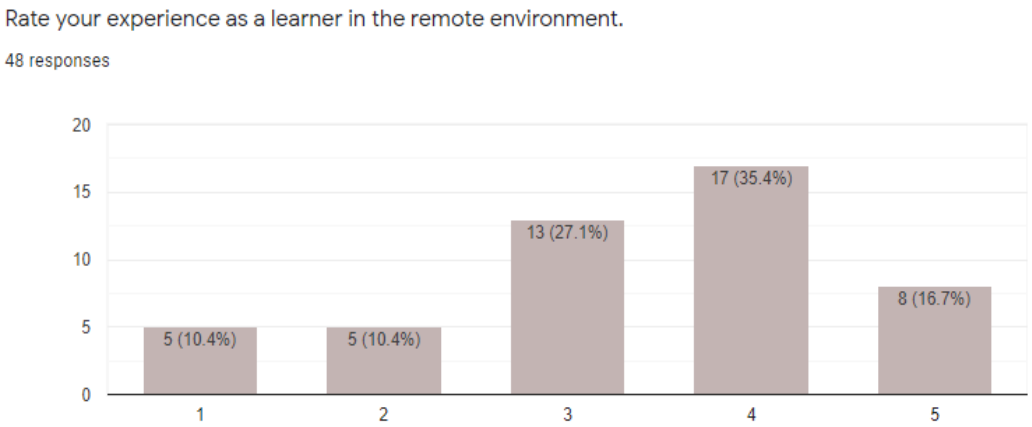

Fig. 3. Ratings of students' experience as learner in remote environment.

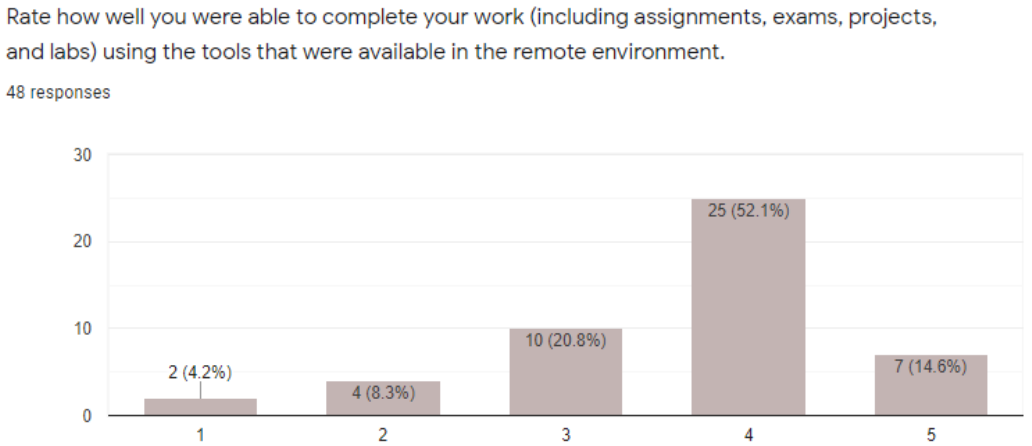

Fig. 4. Ratings of students' ability to complete their course assignments and exams.

Analysis of Student Comments

In addition to numerical ratings presented in Figures 1-4, the survey produced over 400 written comments. Although the numerical ratings provided an indication of the level of satisfaction or dissatisfaction, students' comments painted a much richer picture of the students' experience in the remote learning environment. The authors deliberated on how to compile and condense all the comments to avoid overwhelming faculty while still retaining the meaning and value of students' feedback.

The American Society of Civil Engineers (ASCE) Excellence in Civil Engineering Education (ExCEEd) Model was identified as best suited for the task of analyzing and contextualizing students' comments. The ASCE ExCEEd Teaching Workshop (ETW) is a six-day hands-on faculty workshop focused on the principles of effective teaching and learning. The ETW content

and delivery, derived from a Model Instructional Strategy shown in Fig. 5, are designed to improve teaching – and student learning – through application of the scholarship of teaching and learning, mentored experiences, demonstrations of effective teaching in the context of a classroom, practice classes by workshop participants, assessment, and individualized feedback. The ASCE ExCEEd Model, shown in Fig. 6, has been developed, refined, and advanced through Project ExCEEd for over twenty years and has been documented extensively in the literature [1-6].

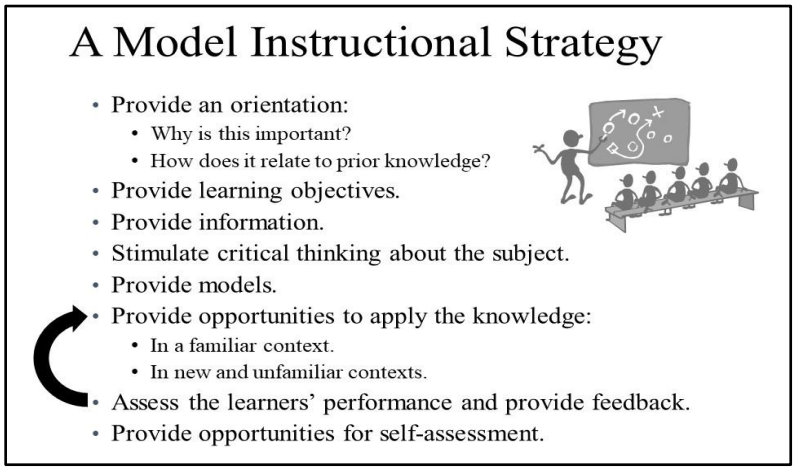

Fig. 5. The Model Instructional Strategy presented in the ASCE ExCEEd Teaching Workshop [1]

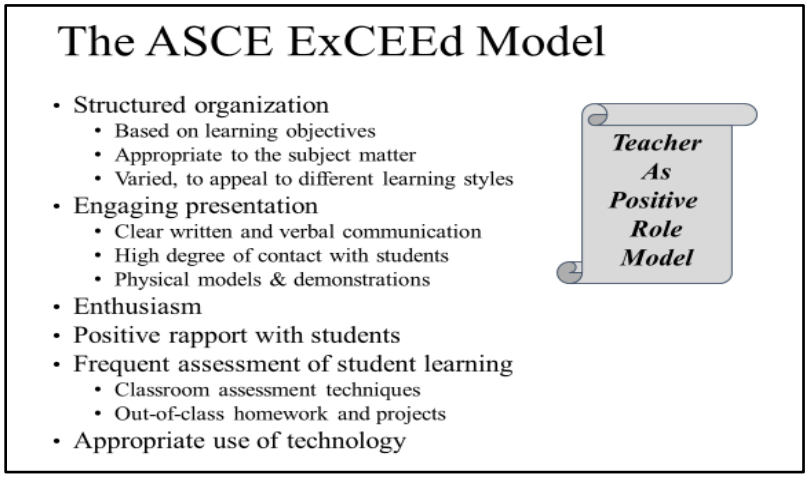

Fig. 6. The ASCE ExCEEd Model presented in the ASCE ExCEEd Teaching Workshop [1]

The ASCE ExCEEd Model focuses on a student-centered learning experience with the teacher providing the structured framework and elements to engage students and promote learning. Using the ASCE ExCEEd Model as a basis, student comments were aggregated into the following categories:

- Structured Organization
- Engaging Presentations

- Opportunities to Apply Knowledge
- Interpersonal Rapport
- Assessment of Learning
- Appropriate Use of Technology
- Personal Factors

The last category, "personal factors," is not represented in the ASCE ExCEEd Model, but was included in our analysis to address factors not well-suited to other categories. Survey results and the authors' own experiences in Spring 2020 revealed numerous external factors affected students' ability to learn including their living situations, health, finances, and family factors.

MAXQDA Qualitative Analysis Method

Two independent methods of analysis were conducted to code the data. The first approach involved a manual, detailed analysis of the data catalogued using Excel. The second approach used professional qualitative analysis software, MAXQDA. The results of the two methods were then reviewed and integrated to inform the feedback provided to faculty. These two approaches were conducted by different reviewers acting independently in order to compare our consistency in coding comments. In this section we describe the approach taken using the MAXQDA software.

Survey results were analyzed using the MAXQDA [7] qualitative analysis software, a professional software package for qualitative and mixed methods research. The software enables analysis of data, including documents of all kinds, audio/video files, etc., and importantly for this study, survey responses. Data can be coded using custom or in vivo codes and results can be searched and cross referenced. Additionally, MAXQDA provides a variety of tools for visualizing and analyzing the resulting coded data. Coding was conducted in three broad phases:

Phase 1: An initial parse of the data was conducted and student responses were coded using terms most prevalent/appropriate to the response narrative. Many of these codes were based on in vivo text from the student response. At this point, the focus was on applying one or more relevant codes to the student response, rather than give any consideration of other codes that had already been assigned to previous student responses.

Once all 420 comments were reviewed and an initial code applied, the resulting coding system was reviewed to rationalize the coding structure by identifying common concepts and themes and concepts that could be combined to form a more robust and logical coding framework.

The third and final step in this phase was to allocate each resulting code to one of two categories:

- Helpful – those elements of the remote environment that helped the student learn.
- Not helpful - those elements of the remote environment that students found less helpful or inhibited their ability to learn.

In a few instances where a code embraced both helpful and non-helpful student responses, the code was duplicated to preserve the link to the coded segments and then each code was renamed to reflect the opposing sentiments. The renamed codes were then assigned to the appropriate

category. The students' responses that each code referenced were then reviewed to ensure that the response was assigned to the appropriate category. In those instances, where the student response included both helpful and non-helpful sentiments, the response was coded to both categories.

In instances where a student's response was unclear, we considered the totality of the student's responses on the survey. Proximity to the nature of the survey question was also considered. For example, if a student had responded to the question regarding recorded lectures with a reply of "Good", it may not have been immediately apparent whether they were indicating that the quality of teaching within the pre-recorded lectures was good, or that recording live lectures was a good practice. After reviewing the student's responses to other questions relating to lecture recordings, lecture materials, and faculty availability, etc., we made an educated assessment of the respondent's most likely meaning. If ambiguity still existed, the response was coded against both the helpful and non-helpful categories.

Phase 2: The coded data from phase 1 were then aligned to the ASCE ExCEEd Model categories. In most instances the code categories from phase 1 aligned well with the ExCEEd structure. In those instances where this was not the case, the MAXQDA code was disaggregated, renamed, and assigned to the appropriate ExCEEd categories.

Phase 3: Statistical analysis was conducted to determine the most prevalent ASCE ExCEEd Model categories and thematic responses.

The ASCE ExCEEd Model framework was selected due to its mature and robust focus on the learning experience from both the student and teacher perspectives. In many instances, student responses pertained to multiple codes or ASCE ExCEEd Model categories. In these cases, responses were coded against all appropriate themes/categories. In instances where survey responses were ambiguous, the most appropriate theme/category was determined by considering other responses from that student.

Categories are presented in order of frequency of coded responses. For example, we identified a total of 180 responses that were coded under the "Appropriate Use of Technology" category, representing 43% of all coded responses. Of these 180 coded responses, 116 were identified as "Helpful," and 64 were identified as "Not Helpful." To maintain consistency throughout the document, all percentages are calculated with the respect to the total number of coded responses: 420. For example, the 116 responses coded in the "Helpful" category represent 28% of all 420 responses coded in the survey.

Appropriate Use of Technology: 43% of responses

- The largest portion of responses - 43% of the comments received - addressed appropriate use of technology. 28% of all comments received indicated positive experiences with technology while 15% indicated negative experiences.

- Those students who had access to effective technology (<5% of responses) including a good laptop and adequate internet access at their study location reported the technology

made studying easier. Technology also enabled students to engage effectively in online video conference sessions. Some students (<5% of responses) also reported they found the use of non-university online tools helpful, e.g., Slack, Group Chat, and Google Docs.

- 9% of responses related to technical difficulties of various types (i.e., negative). These included both hardware (e.g., printing/scanning) and software challenges. Availability of, and access to, all of the required software was a common issue. Poor quality internet connectivity was also a common complaint. Several students pointed out the lack of consistency in technology use – for example, some professors used Webex, some used Zoom, some used Canvas videos etc. YouTube videos were mentioned by several as being of inferior quality and inappropriate as a lecture medium.

- Several students (<5% of responses) pointed out that faculty seemed unfamiliar with the technology (e.g. Zoom/Webex/Canvas).

- The feedback on pre-recorded videos was somewhat mixed. Some students (<5% of responses) implied these were not helpful while fewer still found them useful.

- <5% of responses indicated screen sharing as a positive capability.

- Canvas was seen as a useful vehicle (<5% of responses) for class materials, file sharing, and as a communication platform for informing students of class schedules and assignment deadlines.

- Some students felt video recordings of classes were useful (>7% of responses). These videos allowed students to review the material multiple times. A further 7% of responses indicated that live online classes were effective. The similarity of these results reflects the common practice of video recording the live online classes and making these recordings available for post-class review.

Opportunities to Apply Knowledge: 25% of responses

- 10% of responses addressed the challenges of working from home (or the home environment). Comments indicate that a lack of dedicated study space at home, coupled with home distractions (family members, pets, noise) resulted in a poor study environment. However, respondents also indicated (<5% of responses) that studying from home was a more relaxing and comfortable environment where they could focus without the distractions of on-campus life, such as clubs.

- The ability to work at one's own pace was cited by several students as beneficial (<5% of responses). The ability to access materials and conduct labs or study activities when it suited them was viewed as helpful.

- The inability to collaborate with peers, and in some cases the professor, was reflected in 6% of responses. Students also reported that a lack of in-class discussions was a problem.

- Some students (<5% of responses) reported that working from home was less efficient than working in the classroom due to environmental distractions or having a poor study environment at home. This issue was compounded by what many described as an increase in workload assigned by faculty.

- Some respondents (<5% of responses) indicated that asynchronous lectures (presumably through pre-recorded videos/good quality materials) were useful, but a greater number (7% of responses), preferred live classes.

Structured Organization: 23% of responses

- One of the most frequent comments (5% of responses) in this category related to poor quality of content delivered. This included the way materials were presented or delivered to the students. Labs, and the difficulty conducting them, was a challenging issue for some.

- A further 5% of responses addressed an increase in workload. Some students perceived an increase in assignments to make up for lost time due to the extended spring break, or the lack of consideration of the compressed schedule by some faculty.

- Some students (<5% of responses) provided feedback on office hours. The feedback was largely positive although a subset found availability of online office hours inadequate.

- Faculty preparation and support was seen as very important (7% of responses). Several respondents complimented faculty on the efforts they put into preparation, with well-structured materials and timely feedback and responsiveness.

- Some students (<5% of responses) reported that timely posting of materials, reminders, and clear schedules of activities on Canvas was very helpful. Well-structured materials with clear class notes/presentation decks were important. Clear and consistent lesson plans and clear deadlines on the Canvas LMS made life easier for students.

Positive Rapport: 5% of responses

- The lack of availability of faculty to discuss issues or provide immediate answers and feedback was indicated as an issue (5% of responses). Students also commented on what they perceived as poor communication with their professors.

Enthusiasm: <5% of responses

- Some students (<5% of responses) indicated a lack of - or reduced - motivation. This lack of motivation was generally attributed to the difficulty students had in maintaining their focus and concentration given the lack of regular structure and lack of engagement with other students and faculty in the physical learning environment.

Assess Performance & Provide Feedback: <5% of responses

- Of the few comments that fell into this category, all coded to the 'not helpful' category. All comments related to difficulties associated with taking quizzes and exams remotely.

Strengths, Areas for Improvement, and Suggestions

In addition to using MAXQDA to code and collate comments, we cataloged comments using a spreadsheet and calibrated our coding approaches for consistency. We found strong consistency in codes used to categorize student comments. However, we did not quantify the frequency of responses using the spreadsheet analysis, but instead focused on capturing the descriptive student feedback which we could then provide to faculty.

We adopted the assessment process used in the ASCE ExCEEd Teaching Workshop to organize feedback within each category. Specifically, comments were classified into subcategories identified as "strengths," "areas for improvement," and "suggestions for improvement". This framework allowed us to organize the 420 disparate comments into categories that could then be used to provide specific and actionable feedback to faculty with the goal of improving the quality of teaching and student learning. Similar comments were combined and paraphrased to capture the gist of the comment(s). Comments and groupings are presented below.

Structured Organization

Strengths

- Synchronous lectures, also recorded and posted - easier to keep up with material.
- Office hours
- Organized Canvas (weekly plan as well as assignments and materials posted)
- Class notes posted
- Asynchronous (pre-recorded lecture) with live office hours
- Projects broken down into intermediate steps
- Email reminders and announcements
- Timely responses to student questions

Areas for Improvement

- Increased workload (more assignments, more out of class work)
- Lack of clarity on Canvas announcements or assignments
- Abandoned lecture; replaced with assignments
- Lack of, or insufficient or inaccessible, office hours
- Felt shortchanged, e.g., some videos < 30 mins for 1.5 hour class.

Suggestions

- Provide clear due dates, well planned classes and assignments
- Centralize course content delivery and maintain a consistent system
- Use handouts for lecture and lab that are annotated and explained in class
- Upload videos with some more complex problems
- Stick to class times, don't go over time or change class meeting times

Engaging Presentation

Strengths

- Synchronous class meeting - engaging, students are accountable for participating when professor asks questions, easier for students to ask questions
- Lab content was adapted to online environment
- Videos posted online
- Online office hours helpful
- Availability and accessibility of materials & professor (course notes, video, office hours)

Areas for Improvement

- No in-class discussion if asynchronous
- Just posting slides, assignments, or videos (not enough to help or engage students)
- No hands-on lab experience or engagement
- Long videos - hard to focus without engagement
- Lack of interaction with class
- Bad videos
- Tedious PowerPoint lectures
- Difficult to focus during Zoom lecture
- Need better use of Canvas
- Lack of contact with professor or peers
- Technical difficulties or video issues made it hard to follow the class
- Lack of class notes and discussion
- Easily distracted in home environment

Suggestions

- Meet with class to ensure understanding and adjust/adapt teaching
- Hold live meetings so students can ask questions
- Incorporate discussions with classmates and teammates so students are held accountable
- Promote study groups and group work

Interpersonal Rapport

Strengths

- Scheduling of office hours, extra office hours
- Professors' empathy
- Different ways to contact professors (e.g., Slack, text, quick email response)
- Adjusted expectations to accommodate conditions (e.g., assignments due at 11:59 p.m.)

Areas for Improvement

- Lack of professionalism of class mates (coming to class in pajamas, eating)
- Lack of in-class discussion, feeling disconnected
- Overwhelming workload. Professors should realize that everything takes longer online.
- Lack of email response to student questions
- Lack of flexibility on some deadlines, due times
- Lack of in person communication
- Lack of opportunities to work with classmates, solve problems together.

Frequent assessment of student learning

Strength

- Quick turnaround on homework

Areas for Improvement

- Harder to take exams and quizzes online than in-person; time constraints and technology issues.
- Lack of in person feedback and discussion

Appropriate use of technology

Strengths

- Online office hours
- Asynchronous lectures with a few days to submit work
- Live lectures are also recorded so students could ask questions and watch videos again.
- Effective use of Canvas to organize materials and announcements
- Extra time for exams to overcome technology issues
- Ability to share screens, collaborate

Areas for Improvement

- Constantly changing Zoom meeting IDs or switching platforms
- Proctoring exams via camera
- Asynchronous/video lectures not effective
- Low quality images (e.g., poor quality webcam), legibility of notes via webcam or document camera
- Access to software (e.g., Matlab) needed for the course
- Three different platforms is overwhelming
- Don't skip labs - find a virtual workaround, some hands-on component
- Technology issues in class - missed materials
- Difficult to focus for 1.5 hour online class
- Lack of access to decent computer, printer, software

Suggestion

- Everyone should use consistent platforms (Canvas, Zoom, Webex)

Personal Factors

Strengths

- Flexibility to work on own time, convenient access to coursework
- Lack of workspace, distractions and responsibilities at home
- Nothing else to do, so I studied more
- Support (family, pets)

Areas for Improvement

- Hard to get motivated at home environment
- Lack of personal contact with others
- Distractions (phone, tablet)
- Home stresses (employment, housing, family stress)
- Unstructured time, competing class workload
- Tired of staring at a screen

It is apparent from the insightful comments listed above that students can clearly identify elements that are effective and identify areas in need of improvement. One important lesson drawn from this experience is the importance of asking students for feedback during the semester. Their life situations can be surprising or shocking, sometimes conducive to learning and sometimes inhibiting students' ability to learn. By asking for feedback, faculty can also learn about effective practices used by other faculty that can be adopted or adapted for use.

Conclusions

The ASCE ExCEEd Model provided a useful, structured framework for analyzing quantitative and qualitative feedback provided by students at the end of the Spring 2020 semester. The results of our survey clearly showed that neither the faculty nor the students were fully prepared for the abrupt shift to teaching and learning in remote environment. Although a majority of respondents described their overall experience as positive, there were a large number of comments pointing to areas in need of improvement, most significantly among them:

- Inadequate technology, especially on the students' side.
- Challenges associated with working from home.
- Lack of collaboration and in-person contact with peers.
- Remote classes and labs that were not engaging.
- Lack of access to faculty and teaching assistants for help outside classroom.

From the suggestions made by the students, it was clear that students prefer live classes with recorded lectures for later use together with ample opportunity for office hours and contact and communication with faculty and their peers. These results were shared with faculty prior to the start of Fall 2020 to improve the quality of student learning in the remote environment.

The primary goal of this study was to provide faculty with actionable feedback to improve student learning in a remote environment. These insights also were also used to inform School-wide initiatives such as providing hardware to students and using Canvas more effectively to enhance the clarity of communications with students. Repeating this type of study in the future may be beneficial to see if the changes made by the faculty and the School have had a positive effect on student experiences. It is likely that many of the practices identified through this study will continue to evolve as faculty and students become more skilled in remote teaching and learning.

Acknowledgments

The authors wish to thank our students for their insightful feedback. We are grateful for the reviewers' careful review of this manuscript.

References

[1] S. Ressler, A. Estes, C. Saviz, B. Barry, C. Considine, D. Coward, N. Dennis Jr., S. Hamilton, D. Hurwitz, T. Kunberger, T. Lenox, T. Nilsson, L. Nolen, J. O'Brien Jr., R. O'Neill, D. Saftner, K. Salyards, and R. Welch, "The ASCE ExCEEd Teaching Workshop: Assessing 20 Years of Instructional Development," *International Journal of Engineering Education*, Vol. 35, No. 6(A), pp. 1758–1786, 2019.

[2] A. C. Estes, R. W. Welch, S. J. Ressler., N. Dennis, D. Larson, C. Considine, T. Nilsson, J. O'Brien, and T. Lenox, ExCEEd Teaching Workshop: Tenth Anniversary, *Proceedings of the 2008 ASEE Annual Conference and Exposition*, Pittsburgh, PA, June 22-25, 2008.

[3] A. C. Estes, R. W. Welch, S. J. Ressler, N. Dennis, D. Larson, C. Considine, T. Nilsson, R. J. O'Neill, J. O'Brien, and T. A. Lenox, Ten Years of ExCEEd: Making a Difference in the Profession, *International Journal of Engineering Education.* **25**(1), pp. 141-154, 2010.

[4] A. C. Estes and R. W. Welch, Teaching Pedagogy 101, *Proceedings of the 2005 ASEE Annual Conference*, Portland, OR, June 12-15, 2005.

[5] A. C. Estes, R. W. Welch, and S. J. Ressler, Teaching lessons learned: The ExCEEd teaching model, *Journal of Professional Issues in Engineering Education and Practice*, **131**(4), pp. 218–222, 2005.

[6] R. W. Welch, J. Baldwin, D. Bentler, D. Clarke, S. Gross, and J. Hitt, The ExCEEd Teaching Workshop: Participant's perspective and assessment, *Proceedings of the 2001 ASEE Annual Conference*, Albuquerque, NM, June 24-27 , pp. 10057-10070, 2001.

[7] MAXQDA qualitative data analysis software, https://www.maxqda.com

APPENDIX 1. Survey Administered at the end of Spring 2020 Semester

Section 1: Assessment of Remote Learning Experience

Our faculty will appreciate your input on your experience with the transition from in-person to remote teaching. Our intent is to improve the quality of teaching overall, but specifically, if we are faced with these conditions for an extended time. We would like your feedback regarding all of the Engineering and/or Computer Science courses you are taking during the transition from in-person to remote teaching. Some of your courses may have been conducted synchronously (in real-time, with your professor) and some asynchronously (in your own time). This is not an assessment of a particular instructor or course. We are looking for your general impressions of what has been effective during your remote learning experience as well as things that could be improved.

- What is your class standing in spring 2020? (Check all that apply.)
  Possible responses: Freshman, Sophomore, Junior, Senior, Graduate

Section 2: Remote Delivery of Content

- Rate your experience of instructors' delivery of course or lab content in the remote environment.
  Response: 1 to 5 Likert scale, where 1 = "poor experience" and 5 = "great experience".
- What elements of remote delivery were effective?
  Response: short text
- What elements of remote delivery were not effective?
  Response: short text
- Do you have any specific suggestions for improving delivery of course or lab content in remote environments?
  Response: short text

Section 3: Remote Learning

- Rate your experience as a learner in the remote environment.
  Response: 1 to 5 Likert scale, where 1 = "poor experience" and 5 = "great experience".
- What elements of the remote environment made it easy to learn?
  Response: short text
- What elements of the remote environment made it difficult to learn?
  Response: short text
- Do you have any specific suggestions that could improve students' ability to learn in remote environments?
  Response: short text

Section 4: Remote Working

- Rate how well you were able to complete your work (including assignments, exams, projects, and labs) using the tools that were available in the remote environment.
  Response: 1 to 5 Likert scale, where 1 = "poor experience" and 5 = "great experience".
- What elements of the remote environment made it easy to complete your work?
  Response: short text
- What elements of the remote environment made it difficult to complete your work?
  Response: short text
- Do you have any specific suggestions for things that could make it easier for students to complete their work in remote environments?
  Response: short text

Section 5: Other Factors

- Please identify other factors that significantly affected your learning. Examples can include personal factors (e.g., time, space availability), technical (e.g., computer access), instructional (e.g., office hours), or any other factors that will help us identify ways to help students.
- Top three factors that affected your learning negatively.
  Response: short text
- Top three factors that affected your learning positively
  Response: short text