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Evaluating STEM Course Re-Design Strategies in Light of COVID-19

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Ulises Trujillo Garcia is an undergraduate student at Boise State University, pursuing a bachelor's degree in Civil Engineering. He is actively involved on campus. Currently, he is a McNair Scholar conducting research on historically marginalized students' challenges during the pandemic under Dr. Krishna Pakala's guidance. He is also the Vice-President of the Society of Hispanic Professional Engineers, Financial Officer of Chi Epsilon-The Civil Engineering Honor Society, and Events Fundraising Officer for Organizacion de Estudiantes Latino-Americanos. Among his numerous accomplishments and awards, Ulises was recently elected as a 2021 fellow for the prestigious Station1 Frontiers Fellowship (SFF). He plans to earn an MS in Structural Engineering to gain further insight into the field of engineering and to be able to teach introductory engineering courses where he can serve students who are at vulnerable points in their degree progression. Subsequently, Ulises wants to pursue a Ph.D. in Engineering Education to help diverse students navigate this challenging field, access resources, and increase their graduation and retention rates.

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Evaluating STEM Course Re-Design Strategies in Light of COVID-19

Abstract

The COVID-19 pandemic brought on unprecedented challenges to the teaching and learning communities that required faculty to make purposeful changes in their teaching approaches. Many faculty members had to shift rapidly from in-person to online mode of instruction. This study documents perceptions of STEM faculty who made the change to online teaching. It reports on what strategies faculty used to transition to remote/online teaching and how this change impacted student learning. The study results indicated that almost two-thirds of the faculty changed how they evaluated their students. Results also showed that the sudden change to remote learning negatively impacted student learning. Due to reduced engagement in this modality, students seemed to prefer in-person learning over remote learning. The faculty reported being more flexible in assessing student learning by offering open-book quizzes and tests. Some faculty have replaced exams with projects to accommodate students facing pandemic-related uncertainties. A majority of the faculty noted that time constraints made a considerable difference in how they were able to assess their students' learning and that the fast pace of events during the pandemic did not allow for much reflection. Overall, faculty felt that a judicious mix of synchronous and asynchronous teaching methods was most conducive to student success during this time of global disruption.

Introduction

Society has faced many threats, but none is more significant and complex than the current pandemic due to the novel coronavirus. Among the many economic and social impacts of this pandemic, the impact on education is the most critical as it is the fundamental base to prepare the current generation for the unknown future. COVID-19 has become one of the most significant challenges that the education system has faced before due to the need to transition teaching to a remote environment [1]. At the university level, institutions across the nation closed their doors to students, and some even stopped their research. For example, Boise State University [2] moved all its courses online and put research on hold to mitigate the spread of the virus. The nation's closures forced faculty to pivot their classes to two popular online learning modalities, *synchronous* and *asynchronous* learning, each with its advantages and disadvantages.

In synchronous online learning, faculty and students interact at the same time. In asynchronous online learning, the instructor prepares the material in advance and students can access the material and learn at their convenience. Table 1 shows some main advantages and disadvantages of these two modalities.

Table 1. *Synchronous vs Asynchronous: Advantages and Disadvantages*

	Synchronous	**Asynchronous**
Advantages	• Better communication reduces the possibility of misunderstanding • More real-time engagement between students and faculty to build a sense of community and avoid feelings of isolation on students	• Greater flexibility making it more accessible for students that lack the time or the technology needed • More time to understand the material which increases intellectual engagement for students
Disadvantages	• Some students may not have fast Wi-Fi networks creating difficulties for them to engage • Set schedule challenging to follow by students that have demands at work and home	• Miscommunication and misunderstanding of the material due to no real interaction • Students may feel isolated and less happy without the interaction with their peers and professor

This table shows some general differences between these two approaches. However, there are several additional variables to consider before determining which of the two systems is better for a specific course. Some of these complex variables are the type of class, the situation, and the student's class standing. In STEM, particularly in the sciences and engineering disciplines, courses are harder to transition to an online platform since most of them have a laboratory component. This hands-on experience is crucial for students' learning and preparation for the workforce. As Feisel and Rosa reported [3], engineers need to be familiar and learn from laboratory practices and not only from lectures in class because labs provide experimental data, answers to questions about nature, and the ability to evaluate the performance of a design. Plus, online learning is not the same as a traditional classroom, as stated by [4]. The interaction between the professor and student is essential for the students learning and is generally difficult to achieve in online courses. Equally important, the situation in which online learning is implemented counts too because there is a difference between emergency remote teaching and online learning.

As established in [5], adequate online learning takes about six to nine months to plan and build for a successful online class. Lastly, each student has different needs and has access to different resources such as a stable internet connection, appropriate technology, and a quiet place to study and join classes. According to [6] in online programs, the differences in students' gender, age, and prior experiences, to mention a few, influence not only the students' choice for a remote class

but also their success in the course. This is because each student has grown in different environments according to their ethnicity, social status, and prior education, which impacts their knowledge of technology in remote learning environments. As seen, the spectrum is more complicated than it seems, especially now that synchronous and asynchronous learning has gained considerable momentum due to the current unprecedented pandemic. Both learning approaches are effective in their own ways. This paper attempts to evaluate the re-design and rapid transition of STEM courses during times of disruption and the use of synchronous and asynchronous approaches.

Methodology

This study used a mixed-method approach by collecting qualitative and quantitative data using several questions (see appendix). The data collected from the study was anonymous and included faculty participants from different genders, ages, different backgrounds, and various position types. Participants were asked questions designed to reflect on the rapid transition to online learning in STEM courses, which helped answer the following research questions:

- R1: In what ways did faculty readjust course content delivery to sudden changes in the teaching environment?
- R2: What is the impact of sudden changes to content delivery on student learning?
- R3: What assessment methods did faculty use to measure student learning during times of disruption when students experienced a sudden change in the learning environment?

Faculty were asked to answer several questions (see appendix), such as multiple-choice questions, linear scale, multiple selections, and few open-ended questions. One of the open-ended questions allowed faculty to share their students' end-of-semester course evaluation comments to capture their online learning perceptions. These course evaluations are distributed by the university for all courses each semester. The evaluation period is open for the last two weeks of a semester, closing the night before finals week. Additionally, some professors offered to send these anonymous course evaluations directly to the researchers, which helped enrich this study. The Center for Teaching and Learning at Boise State University sent the questionnaire to STEM faculty that taught a course in Spring 2020 to gather data. Once the data was collected, percentages, bar scales, and themes were selected to translate the results.

Results and Discussion

A total of 86 (out of a total of 313 STEM faculty members) responded to the questionnaire. Of the 16 questions, half of them were targeted towards finding the responses to the three research questions presented in the previous section (R1, R2, R3), and the other half to record the different positions, disciplines, and years of experience from faculty (see appendix). Figure 1

depicts a flow chart showing the breakdown of the three research questions. The faculty were asked to respond to a series of questions that align with the research focus. Additionally, the boxes show an outline color (green, red, or yellow) to differentiate the type of question asked. Boxes with a green outline mean that the answer to the question was based on a scale from 1 to 5, 1 being strongly disagree, and 5 strongly agree. Red outline boxes are open-ended questions where the qualitative data was classified on common themes. Lastly, the yellow outline boxes are simple yes or no questions.

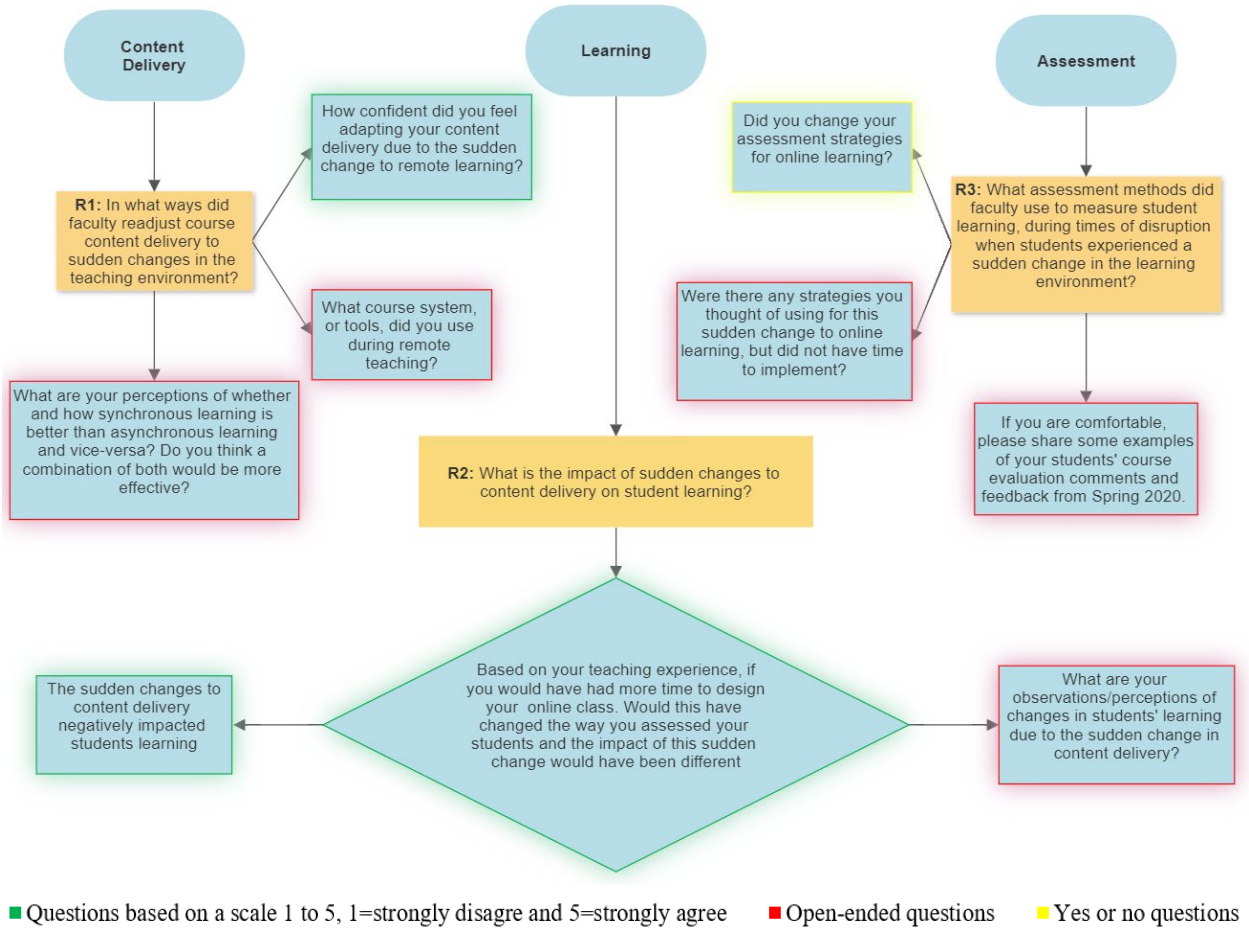

Figure 1. *Flow Chart of Questions Used to Answer the Three Research Questions*

In content delivery, when asking professors about how confident they feel adapting their content to a remote environment, the results were surprising. It is important to note that this data reflects the instructors' self-reported confidence level. Almost 50% responded that they agree and strongly agree to be confident when adapting, and 32.9% answered that they were unsure or neutral on this process. These are unexpected numbers as reported on [7] "a majority of faculty members had never taught an online course before this spring, and many had not had any

training or preparation beyond what institutions were able to give them over spring break." The relatively high percentages were perhaps possible because of all the technology is already used at the university, faculty who had taught courses online helping other faculty transition their courses remotely, and easy access to online platforms for most students. As to how faculty tackled the delivery of their courses, almost 90% of them reported that they used Zoom and Blackboard as main tools. This is essentially interpreted as utilizing one of the two modalities discussed at the beginning of this paper: synchronous (Zoom) and asynchronous (Blackboard) teaching. 96.5% of these courses were lecture/classroom-based instruction originally. In regards to how faculty interacted with students remotely, they used one or more of the following approaches (Table 2):

Table 2. *Approaches used to Interact with Students Remotely*

Approaches	Percent of faculty that used this method to interact with students
Synchronous (real-time)	76.2%
Asynchronous	63.1%
Discussion boards	28.6%
Posting of materials, tasks, and assignments	78.6%
Email	76.2%
Virtual office hours	6%
Other (Slack, Flip grid, Padlet, SMS)	6%

As shown in this table, professors did not stick to only one approach to be in contact with students, which indicates a lot of consideration from faculty by having different ways to be in touch with students. With that being said, 45 of the participants (54%) believe that a combination of these two modalities is the best approach during times of disruption to help all students succeed. A direct quote from one of the instructors "I think a combination is better because of the flexibility. Asynchronous allows the students to proceed through the material in their own timeline (allows them to make decisions for themselves). The synchronous aspects allow them real-time interaction with their instructor and classmates, thus forming a sense of a learning community." Furthermore, Stefan Hrastinski, a prominent researcher in Digital Education, Design for Learning, Online Tutoring, and Collaborative Learning, wrote in [8], "Synchronous e-learning increases arousal and motivation, while asynchronous e-learning increases the ability to process information." In a sense, as stated by experiences and experts, a fusion of these

approaches complements each other. This is meaningful information that should be taken into consideration for future online classes to help students navigate this environment in the best way possible and advance their learning.

This leads to the next category in this study, learning. When asking professors if the sudden changes to content delivery negatively impacted students' learning, 56.7% of the participants expressed that indeed the rapid change impacted students' learning. In addition, the questionnaire included the following scenario statement: If faculty would have had more time to design their online classes, would this have changed the way they assessed their students, and the impact of this sudden change would have been different. More than two-thirds of the participants think that the impact would be different if there was more time to prepare for this transition (results from these two questions are displayed in Figure 2).

As stated at the beginning by [5], to create an adequate online environment, it takes months to design to be successful. Now, when talking about this emergency remote environment, professors had a weekend, five or at most ten days, to transition their courses online, and many students think that they did the best they could and appreciate their work. One student commented in the student course evaluations, "Honestly you guys rocked it, I totally was expecting this to be an absolute disaster and there to be tears and stressed out emails, but you guys totally flipped the course fairly proficiently without any stress." This is the opinion of only one student and does not mean that all think the same way, but due to the circumstances and situation, indeed, faculty went far and beyond transitioning their classes online.

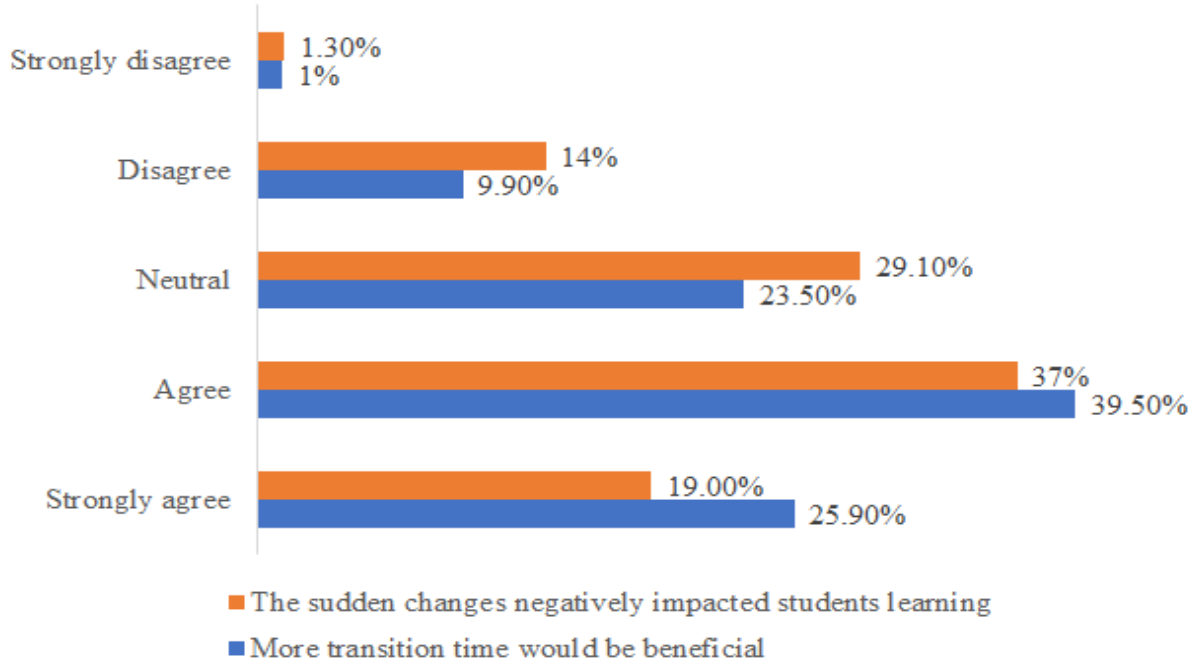

Figure 2. *Rapid Transition vs Planned Transition*

To enhance the learning section better, qualitative data about the observations and perceptions of changes in students' learning from faculty was captured. This data was sorted into common themes to identify what were common issues students face in their learning. With 94.2% of the faculty surveyed providing their observations of students' learning changes due to the sudden change in content delivery, the following are the most common themes reported: 32.6% stated less engagement, 12.8% less communication between classmates and faculty, 9.3% more responsibilities, and the rest stated to be unsure, students were happy with the online classes, and connection and technology issues. The following direct quotes from faculty exemplified how students were less engaged and struggled with more outside problems:

"Students were suddenly required to self-manage their time and were expected to succeed using resources that were not reliable. This included internet access, home printers/computers and blackboard knowledge."
"They managed well, but the external stresses (family member concerns, etc.) were a big problem."
"Less enjoyment, less engagement, less participation, more disconnection from other students, more anxiety over exams, network and connectivity problems."
"Lack of interactions between students/students and students/instructor; lack of hands-on in-class activities."
"Most of my students were very distracted; some had sick family members, some lost their jobs, some, their homes. The youngest students were disproportionately affected."

By including this thematic analysis this study provides a clearer perspective of all the variables that affected students' learning. Plus, it helps faculty understand students' challenges and needs for future online courses. This was something that the professors expected and why 60% of them changed their assessments strategies to compensate for the uncertainty and barriers this pandemic brought. Some of these changes were more flexibility on deadlines for assignments, offering more time and open books and notes for quizzes and tests, and replacing exams for individual or team projects, and presentations. Those who did not change their assessment methods evaluated their students through tests/quizzes/exams, projects, writing assignments, presentations, weekly homework and discussion boards.

Students' Perception

This section will summarize the perceptions of students given the change in content delivery, as evidenced in the end-of-semester course evaluations and faculty comments. To better understand the rapid transition and re-design of STEM courses during times of disruption, it is essential to capture the experiences from both sides of the education experience: faculty and students. Supplemental analysis was done on the faculty comments and their student course evaluations. According to the comments and course evaluations provided by faculty, students reported mixed

feelings towards online learning. This is not a surprise since the quick transition is more complicated than it seems. The unexpected switch to online learning not only changed the classroom experience, but many students also relied on the university's general environment, from study spaces, free Wi-Fi, computer labs, and working out and getting their food on campus. In a matter of days, the students' entire experiences were flipped on their heads. In addition, as expressed by faculty, many students have more responsibilities outside of the classroom, and with the pandemic, these responsibilities increased. Some students had to watch their kids during the day with K-12 online or take some extra hours to pay bills. In addition, other barriers appeared due to the sudden change; students had to study from home where it could be noisy and difficult to engage in their classes. What is worse, some students did not have the resources needed to complete assignments or connect to classes "some students' best Wi-Fi access was in a nearby parking lot [7]." These reports by Inside Higher Ed align with what was expressed on the student's course evaluations and the challenges they faced in the online environment.

From the qualitative data obtained, the following themes were identified as the most common: staying motivated/engaged was the most popular, followed by losing connection with classmates and being overwhelmed with the rapid transition and the whole situation. Given that some faculty shared complete student course evaluations, some only positive or negative comments, and others just stated in a sentence the sentiment their students shared in content delivery made it difficult to get an accurate percentage. However, given what most students expressed and what faculty stated in response to the questionnaire, a trend exists. Less engagement and losing in-person interactions were the most common challenges students and faculty faced due to the change in content delivery. Here are some of the direct comments expressing the barriers students faced:

"Overwhelmed with the stress of potential/actual illness, trying to pay bills without work and unreliable internet services."
"We lost group interactions and hearing different perspectives of situations."
"COVID-19 obviously made class more difficult in a variety of ways, mainly by taking away in-class engagement."

However, not all were challenges and barriers for students learning; that is why it is valuable to include what went well during this experience. Students appreciate recorded lectures, flexibility on assignments, and small group discussions. Here are some of the directed comments expressing the positive things students experienced:

"The prerecorded lectures were very helpful since I can rewind and watch sections multiple times to help clarify what is being said rather than a live lecture"
"Having team sessions in class and online were valuable to my learning experience because I could collaborate with my peers about complex problems"

"This semester, due to the coronavirus, we have been taking exams at home...I think that I learned more with this last exam because I was able to take breaks from it (take naps and then return to the exam with new insight)."

As seen here there are some themes that are common in students. However, as stated throughout this study a few times, this is a complex topic due to the high number of factors to consider since each student is a different case and issues and challenges change from student to student.

Conclusion

As seen, this study evaluated the rapid transition to online learning from STEM courses during the global pandemic of the novel coronavirus. In addition, it highlights the two most popular modalities of online learning, synchronous and asynchronous, by providing the pros and cons of these two approaches. Faculty believe that combining these two approaches can help students adjust more easily during disturbance times by providing some freedom to students with different responsibilities and avoiding misunderstandings with real-time online meetings. Additionally, this study found that the rapid transition of in-person classes to online modalities considerably affected students' learning as there are many outside variables to consider in this environment. This study contributes to the literature on remote learning in general but focuses on the course design in STEM courses. The contributions from faculty's feedback and experience through the questionnaire provide valuable information about what worked well and what needs improvement when designing STEM online classes. Further research plans to include interviews with faculty and surveying students to capture their perceptions and needs for their learning during times of disruption.

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Appendix

1. Position Title:

2. Position Type (choose all that apply):
    - Tenure Track
    - Assistant Professor
    - Associate Professor
    - Professor
    - Adjunct Professor
    - Research-focused
3. Please state your primary discipline (e.g. Chemistry, Engineering, Math, etc.):

4. Years of Experience Teaching:
    - < 5
    - 5 - 10
    - 10 - 15
    - 15 - 20
    - 20 +

5. What type of course(s) have you transitioned to the online learning environment? (Check all that apply)
    - Lecture/classroom based instruction
    - Laboratory course
    - Design course
    - Other

6. In your class:
   What percentage of time would you spend "lecturing" in your typical class?
    - 0% to 20%
    - 20% to 40%
    - 40% to 60%
    - 60% to 80%
    - 80% to 100%

   What percentage of time would you spend "in-class problems" in your typical class?
    - 0% to 20%
    - 20% to 40%
    - 40% to 60%
    - 60% to 80%
    - 80% to 100%

   What percentage of time would you spend in "discussions Q/A" in your typical class?
    - 0% to 20%
    - 20% to 40%
    - 40% to 60%
    - 60% to 80%
    - 80% to 100%

What percentage of time would you spend in "Problem/Project Based Learning" in your typical class?

- 0% to 20%
- 20% to 40%
- 40% to 60%
- 60% to 80%
- 80% to 100%

7. How did you typically interact with your students during remote learning? (Check all that apply)
   - Synchronous (real-time)
   - Asynchronous
   - Discussion boards
   - Posting of material, tasks, assignments
   - Email
   - Other (Please explain)

8. How confident did you feel adapting your content delivery due to the sudden change to remote learning?

   Strongly disagree | Disagree | Neutral | Agree | Strongly agree

9. What course system, or tools, did you use during remote teaching?
   - Blackboard
   - Zoom
   - Google Classroom
   - Other

10. The sudden changes to content delivery negatively impacted students learning

    Strongly disagree | Disagree | Neutral | Agree | Strongly agree

11. Did you change your assessment strategies for online learning?

    Yes | NO

    If No, how did you assess your students?

    - Writing assignments
    - Projects
    - Presentations
    - Test/Quiz/Exam
    - Other

    If Yes, what strategies, did you deploy for assessing your students?

12. Based on your teaching experience, if you would have had more time to design your online class. Would this have changed the way you assessed your students and the impact of this sudden change would have been different

Strongly disagree | Disagree | Neutral | Agree | Strongly agree

13. What are your observations/perceptions of changes in students' learning due to the sudden change in content delivery?

14. What are your perceptions of whether and how synchronous learning is better than asynchronous learning and vice-versa? Do you think a combination of both would be more effective?

15. Were there any strategies you thought of using for this sudden change to online learning, but did not have time to implement?

16. If you are comfortable, please share some examples of your students' course evaluation comments and feedback from Spring 2020. Note: This is an optional response and does not impact the completion of this survey, however it will substantiate your overall response.