2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #37187

Rapid Change to Refined Teaching: Lessons Learned and Lasting Impacts the COVID-19 Pandemic Had on How We Teach Engineering

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Rapid Change to Refined Teaching: lessons learned and lasting impacts the COVID-19 pandemic had on how we teach engineering.

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Abstract

This research paper will assess the impact the COVID-19 pandemic had on learning strategies implemented by engineering faculty during the purely online phase of the pandemic and following the return to in-person classes.

The Covid-19 pandemic forced faculty to entirely reformat their courses such that they could be accessible in an online format. In this paper, the authors interrogate how this dramatic restructuring of courses has had a lasting impact on how professors think about teaching. A first objective of this study is to identify changes in the learning and assessment strategies employed by engineering faculty pre-pandemic, during-pandemic, and following the return to in-person teaching. Furthermore, this study aims to identify motivations and barriers faculty faced when choosing and implementing various learning and assessment strategies in their courses following the return to in-person classes. To meet these objectives, the authors collected data using an electronic survey that evaluated learning and assessment strategies employed by faculty, along with motivations for selecting these strategies. Forty-five faculty responded and identified 26 unique learning strategies. Fourteen learning strategies showed a greater than 40% growth in implementation between pre-pandemic and the return to in-person teaching. The top six all leveraged technology tools, and the top three leveraged the use of virtual-video platforms for delivering course content. The key motivators for faculty to maintain and improve learning strategies following the return to in-person teaching include striking a balance between effort to implement and positive impact on students, engaging students, and improving the accessibility of course content.

We intend to present this work in the traditional lecture style.
Keywords: Pandemic, COVID-19, Engineering Education, Learning Strategy

Intro

The COVID-19 pandemic has had far-reaching impacts on our society. It changed the way we travel, communicate, and gather. It undoubtedly changed the way that we educate and learn as well. With a rapid shift from traditional face-to-face courses to remote courses in March 2020 came countless novel problems that university systems and faculty had to rapidly address. Universities had to maintain the health and safety of students - many of which reside on college campuses far from their family homes. Faculty had to figure out how to deliver lecture, lab, and studio courses in an online setting. At first, it was unclear if these changes would be temporary (~2 weeks) or extend through the remainder of the semester. Few could initially contemplate how long the disruption would last. It was not only a logistical challenge, but an emotional one. Beyond managing the difficulties of suddenly working from home and teaching and learning online, everyone – students, faculty, and staff alike – worried about their own health and that of their families. Regardless, universities and faculty across the country continued to offer classes and to keep schools open. Many universities operated purely or primarily online for over a year.

Having forced experience in remote learning, most faculty and students still prefer traditional face-to-face teaching [1], but the experience of the remote classroom has undoubtedly changed the way we engage in traditional face-to-face courses today and moving forward. Various studies have been conducted regarding the issues and outcomes of the COVID-19 pandemic [2-9]. The impact on university students [2, 4], university centers for teaching and learning (CTLs) [6, 7], and public K-12 school systems [5, 8] have been initially documented, but further studies regarding the lasting impacts of the pandemic are sure to come. A question that remains is: in what ways have we seen positive change to our higher-educational courses as a result of the pandemic? This study aims to address that question as it applies to university-level engineering courses.

Background

There is a significant delay between when a new evidence-based teaching practice is defined, developed, and studied and when it is widely adopted by university faculty. Education-based institutions, like ASEE, commonly express dissatisfaction with the implementation and adoption of evidence-based educational practices [10-13]; this implementation lag is the inspiration for multiple studies that have been conducted in search of a method to bridge this gap [14-16]. Additionally, there have been studies regarding the motivations of faculty adopting new learning strategies in their courses [17-20]. Some parameters have been identified as key motivators for faculty implementing a learning strategy for the first time. These include the perceived value of the strategy, the expectation for success, and the perceived cost [17]. Specifically, when it comes to the expectation for success, Abrami et. al. showed that faculty who had some level of teaching self-efficacy were more likely to implement a new learning strategy in some way [17]. Furthermore, Lee showed that faculty are significantly more motivated to embrace a new learning strategy when they have strong instructional support from their universities [18]. Nicolle et. al. validated these findings and indicated that along with institutional support, peer-support is a significant motivator for faculty [20].

One study noted that faculty values and beliefs about teaching play a key role [21]. This STEM-based study found that faculty primarily value student engagement, student motivation, demonstrating expert guidance to students through problem solving process, and developing student-independence in the problem solving process [21]. Furthermore, this study highlights how instructors often held conflicting beliefs regarding their professional (subject-specific) values and teaching values. For example, faculty in this study emphasized the value of reflectivity in problem solving. They express that reflection is needed to learn and refine the skill of problem solving, but faculty did not communicate this to students nor did they incorporate reflection into their courses [21]. Additionally, this study notes three barriers that instructors believe limit their instruction: (1) faculty workload and that of their teaching assistants, (2) students' expectations and preferences – things that might cause confusion or additional stress to students, and (3) faculty's limited professional knowledge (as it related to teaching skills) [21].

While very few prefer remote learning over traditional face-to-face classrooms, the sudden forced-switch placed a focus on maintaining high-quality education in an entirely new format. Teachers and faculty were forced to re-evaluate how to teach courses they had been teaching, in some cases, for decades. Furthermore, universities had to develop an increased amount of teaching-focused support for faculty during this transition. In fact, a comprehensive study of CTLs across the United

stated conducted by Wright and Rhodenhiser found that CTLs increased offerings in 75% of their instructional development resources. The topics which showed most significant increase were those related to student engagement and active learning; DEI; course and curriculum design; assessment, grading and feedback; and online-remote and hybrid transition [7]. While one may have expected that teaching during the COVID-19 pandemic would demonstrate that educators required more access to and technological literacy in infrastructure for online learning [5], the majority of offerings from CTLs were not inherently technological in nature. Indeed, common challenges faced by faculty were maintaining student engagement, DEI, adjusting curriculum, and coping with the loss of personal connection that teaching often brings [3, 8].

One concern that the pandemic specifically highlighted was the need for equity in education. This is not a new concern, but the added layer of unequitable impacts of the virus itself and unequitable distribution of resources highlighted the need for equitable improvements to our education system [3, 7]. In fact, a 2020 study by Gillis et. al. found that even at an "elite university" students experience internet and housing insecurity which can be prohibitive to online learning. Furthermore, there are significant differences in the ability of various student groups to be able to work and study from home. Some students had no access to a dedicated workspace, and others had increased personal finance concerns as a result of the [4].

With this intensified focus on our "classrooms" during the pandemic, one must wonder: what are the long-term impacts this has had on our teaching? In this study, we seek to identify the specific ways engineering faculty at an elite university have refined their traditional face-to-face courses based on their experiences during the remote teaching phase of the pandemic.

Methods

The participants for this study were limited to faculty within the College of Engineering at the Georgia Institute of Technology. To achieve a sufficiently large sample size of participants and to gain initial insights to changes in teaching, a survey-based study was designed. The survey was distributed in two rounds. First, it was distributed to a select subgroup of engineering faculty that had been recognized in the past 15 years for excellence in teaching and had participated in a faculty learning community or Fellows cohort hosted by the Center for Teaching and Learning. The intent of distributing the survey initially to a smaller sub-group of faculty was to ensure that we had as complete a list of learning strategies as possible and to provide the opportunity to clarify any questions if necessary. The survey results collected from the first group prompted the addition of two additional learning strategies (LS13 and LS26 – see Table 1). Once this modification had been made, the refined survey was distributed to the college of engineering faculty at large.

Survey Development

To develop this survey, a literature review of learning and assessment strategies was conducted [22-30]. Approximately 50 different learning strategies were synthesized into the list shown in Table 1. The goal was to provide an exhaustive list of learning strategies to survey participants that would aid in recall or identification of a learning strategy they used. For this study, learning strategies were defined as any pedagogical or assessment method which deviates from the typical structure of an engineering course that could be used with the intent to better facilitate learning. We defined the "typical" learning strategies used in engineering courses as typical "chalk-talk" or PowerPoint style lectures, and traditional in-class timed paper tests or quizzes. Providing

participants with the aforementioned list was particularly important since it is likely faculty engage in many learning strategies that they would not recognize as learning strategies or categorically remember to list if asked an open-ended question. Furthermore, the specific name of a learning strategy was forgone in favor of a brief description of the activity or assessment. For example: faculty might engage their students in a specific learning strategy which leveraged "web-based interactive methods asynchronously to gauge student understanding and adjust synchronous lecture material/activity accordingly" but they might not recognize it named as *Just-in-time Teaching* [30]. As such, each learning strategy was given a number identifier and a corresponding description (shown in Table 1).

First, participants were asked to complete the matrix shown in Table 1. For each learning strategy identified, participants were asked to indicate which instructional strategies they implemented during various phases of the pandemic. Three phases were defined (P1, P2, and P3 noted in Table 1) and described to the participants as follows:

P1 – Implemented prior to the pandemic (before spring semester 2020).
P2 – Implemented during the first phase of the pandemic (remote and hybrid learning phase).
P3 – Maintained use following the return to in-person classes.

Table 1. Learning strategy implementation matrix table recreated from Rapid Change to Refined Teaching survey

LS#	LS Description	P1	P2	P3
1	Leveraging web-based interactive methods to measure student understanding and adjust synchronous lecture content accordingly in real time.			
2	Use of case-studies where students problem solve historical or hypothetical situations in course assignments (projects/homework/etc.)			
3	Fostering collaboration and group work among students in class. (This could be assigning group projects, pairing students to work together on homework, creating "break-out rooms" for students to work on problems in synchronous class meetings or office hours.)			
4	Introducing lessons (either synchronously or asynchronously) by presenting students with questions, problems, or a set of observations and using this to drive the desired learning.			
5	Use of concept tests in which the instructor poses the conceptual question in a synchronous class and then shares the distribution of responses with the class (possibly using web-based tool). Students discuss their answers, and then vote again and using this to drive the desired learning.			
6	Use of concept tests but there is no interaction between students. Students may receive feedback through instructor or Canvas guiding or indicating correct/incorrect answers.			
7	Facilitating problem-based learning: placing students in self-directed teams to solve open-ended problems that require significant learning of new course material			

8	Fostering communication between students by leveraging online chats, forums, Piazza, etc. for assignments or during lecture/instruction.			
9	Leveraging Canvas to upload course materials for easy access by students.			
10	Use of a virtual whiteboard for lectures (either synchronous or asynchronous).			
11	Use of pre-recorded videos (lectures, mini-lectures, instructions, review sessions, etc.).			
12	Use of audio/video conferencing for meetings and office hours			
13*	Use of in-person assessments (traditional quizzes, tests, etc.)			
14	Use of open-note timed online quizzes and exams.			
15	Use of closed-note timed online quizzes and exams.			
16	Use of test-taking monitoring software (like Lockdown Browser).			
17	Use of "take-home" exams (given one or more days to complete on student's own time).			
18	Implementation of project-based assessments.			
19	Use of computer simulation experiments or models.			
20	Use of video demonstrations of experiments.			
21	Instructing your course as a flipped classroom (with asynchronous pre-recorded videos or reading assignments followed by synchronous meetings focused on students working problems/exercise)			
22	Synchronous course meetings over Bluejeans/Teams/Zoom/etc.			
23	Asynchronous course meetings over Canvas.			
24	Use of reflection activity following lectures, assignments, or assessments.			
25	Use of online grading tools (Canvas rubrics, Gradescope, Mathworks Grader, WeBWork, etc.).			
26*	Use of peer-grading or peer-reviews			
27	Other: *Insert Text*			

*Responses from the first distribution of the survey prompted the additions of learning strategies 13 and 26.

Following the completion of the matrix shown in Table 1, participants were presented a refined list limited to only the learning strategies they reported using. They were asked to categorize which learning strategies had a positive or negative impact on them. Additionally, they were asked to similarly categorize the learning strategies based on the perceived impact the learning strategy had on the students. Participants filled out a second matrix-table for each learning strategy as demonstrated in Table 2 below.

Table 2. Impact categorization matrix table recreated from Rapid Change to Refined Teaching survey

LS Description	Of the instructional and assessment strategies you selected above, please select those which had a significantly…			
	positive impact on you as the **instructor**.	**Negative** impact on you as the **instructor**.	**Positive** impact on your **students**.	**Negative** impact on your **students**.

Text description carried over from selected choices				

Finally, participants were given a free-response question and asked to identify the most important factors guiding their decision about which teaching changes they would make and keep.

Participant Demographics

A total of 45 participants responded to our initial survey. Twenty-one participants were from the first group of faculty and 24 were from the second. The demographic data of the participants are shown Table 3 below. The mean number of years of experience teaching of the participants is 16.71±10.75 years.

Table 3. Participant demographics results

Individual Level Variables	**N**	**Percent [%]**
Ethnicity		
Hispanic	3	6.7
Not Hispanic	41	91.1
Prefer not to say	1	2.2
Race		
White/Caucasian	31	68.9
Black/African American	0	0
American Indian/Native American/Alaska Native	0	0
Asian	8	17.8
Native Hawaiian/Pacific Islander	0	0
Other	0	0
Prefer not to say	3	6.7
Gender		
Male	31	68.9
Female	11	24.4
Non-binary/Third gender	0	0
Prefer not to say	3	6.7
School/Dept.		
Aerospace	4	8.9
Biomedical	5	11.1
Chemical and Biomolecular	4	8.9
Civil and Environmental	2	4.4
Electrical and Computer	10	22.2
Industrial Systems	6	13.3
Materials Science	5	11.1
Mechanical	9	20.0
Level of Course Taught*		

1000	4	8.9
2000	26	57.8
3000	27	60.0
4000	25	55.6
Graduate	33	73.3
Course Classification*		
Lecture	44	97.8
Lab	13	28.9
Studio	9	20.0
Faculty Classification		
Tenure Track	35	77.8
Academic Professional	3	6.7
Research Faculty	0	0
Lecturer	3	6.7
Other	1	2.2

*participants were asked to "select all that apply" for categories that are not mutually exclusive. Therefore, percentage totals can be greater than 100%.

Results and Discussion

Trends in Learning Strategy Implementation

Table 4 shows the percentage of faculty that implemented each learning strategy and the corresponding phase in which they implemented the strategy. We are particularly interested in the changes in the way faculty approached teaching and the learning strategies they used as a result of the pandemic. Therefore, we have also included a whisker plot (Fig. 1) of the difference in implementation-percentage of each learning strategy between phases covered in this study. The learning strategies which are outside the bounds of the 25th and 75th percentiles are of particular interest and have been indicated and labelled with their number indicator (LS#) in the figure.

Table 4. Learning strategy implementation percentage totals for each learning strategy at each phase.

LS#	**% of Faculty that Employed the learning strategy during…**		
	P1	**P2**	**P3**
1	15.6%	33.3%	28.9%
2	53.3%	51.1%	53.3%
3	80.0%	77.8%	82.2%
4	48.9%	48.9%	53.3%
5	15.6%	15.6%	13.3%
6	26.7%	33.3%	33.3%
7	44.4%	46.7%	51.1%
8	53.3%	60.0%	57.8%
9	91.1%	91.1%	97.8%
10	15.6%	62.2%	42.2%
11	22.2%	73.3%	66.7%
12	11.1%	93.3%	86.7%

13*	83.3%	20.8%	66.7%
14	13.3%	60.0%	35.6%
15	8.9%	31.1%	22.2%
16	4.4%	28.9%	13.3%
17	17.8%	40.0%	26.7%
18	68.9%	71.1%	75.6%
19	55.6%	57.8%	60.0%
20	24.4%	40.0%	31.1%
21	28.9%	35.6%	31.1%
22	6.7%	93.3%	53.3%
23	4.4%	26.7%	24.4%
24	15.6%	17.8%	22.2%
25	37.8%	55.6%	62.2%
26*	33.3%	29.9%	29.2%

*note that LS13 was only included in the second distribution of this survey and therefore the sample size of this group is N=24.

The learning strategies of greatest interest are those that resulted in a significant change in implementation between the two phases of in-person teaching (P1 – pre-pandemic and P3 – following the return to in-person classes). There were five learning strategies that resulted in a significant decrease in implementation. They are (LS3) *Fostering collaboration and group work among students in class*, (LS21) *instructing your course as a flipped classroom*, (LS5) *use of concept tests in which the instructor poses the conceptual question in a synchronous class and then shares the distribution of responses with the class,* (LS 26) *use of peer-grading or peer-reviews*, and (LS13) *use of in-person assessments (traditional quizzes, tests, etc.*).

It is interesting and encouraging to note that the majority of these learning strategies below the 25th percentile show minimal change in implementation (just +/- 2%). Learning strategy 3 and 21 show a 2.2% increase in implementation. Learning strategy 3, *Fostering collaboration and group work among students in class,* while showing one of the lowest increases in implementation, initially started off with an implementation rate of 80% and remains one of the top 3 most implemented learning strategies. This indicates that faculty place an emphasis on the importance of collaboration between students. It is likely that the pandemic solidified this view and opened new pathways for fostering collaboration and groupwork via technological tools. Next, learning strategy 21, *instructing your course as a flipped classroom,* also showed a 2.2% increase in implementation from 28.9% to 31.1%. A possible significant barrier to teaching a course as a flipped classroom is generating the asynchronous video-lecture content. One might think that the pandemic, which forced faculty to host their courses virtually, might have given faculty an opportunity to generate this content. Indeed, learning strategy 11: *Use of pre-recorded videos (lectures, mini-lectures, instructions, review sessions, etc.)* increased from 22.2% to 73.3% between P1 and P2 respectively. While some of the content that is included in this learning strategy might not be applicable to a flipped classroom setting (review sessions), this result indicates an alternate reason that faculty are reluctant to implement flipped-classrooms.

The next learning strategies in the bottom 25th percentile are learning strategy 5 and 26. Both show a net decrease in implementation. Learning strategy 5, *use of concept tests in which the instructor poses the conceptual question in a synchronous class and then shares the distribution of responses with the class,* decreased by 2.3% from 15.6% to 13.3% from P1 to P3. Learning strategy 26, *use of peer-grading or peer-reviews,* decreased by 4.1% from 33.3% to 29.2%. It is not clear why these learning strategies were implemented less following the pandemic. Given that all but three learning strategies show an increase in implementation between P1 and P3, it is possible that faculty chose to forgo these practices in favor of another learning strategy.

The most significant decrease in implementation of a learning strategy was of LS13: *use of in-person assessments (traditional quizzes, tests, etc.*). Learning strategy 13 saw a 16.6% decrease in implementation from 83.3% to 66.7%. It has long been known that traditional tests and quizzes do

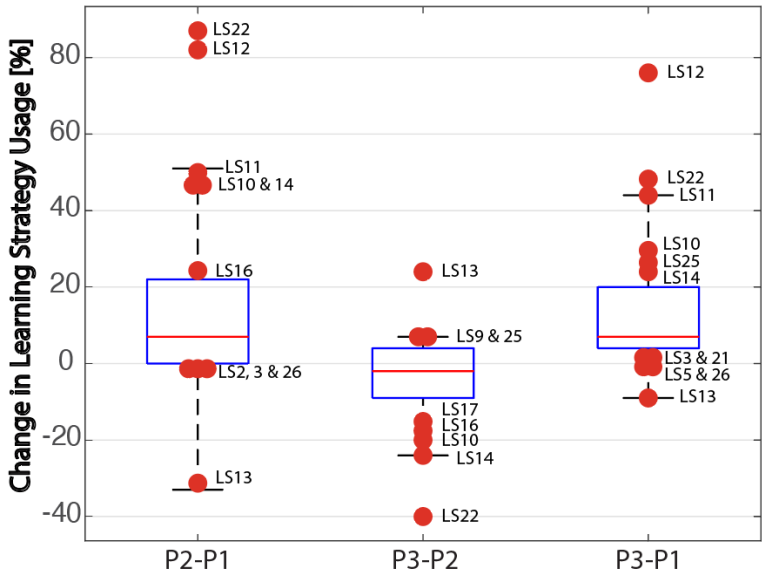

Figure 1. Changes in learning strategy implementation (by percent) between the different phases of the pandemic. The median is indicated by the red line while the 25th and 75th quartiles are indicated by the lower and upper blue lines respectively. Ie. if the median is not centered in the box, the data is skewed. Observations beyond the whisker length are outliers: more than 1.5 times the interquartile range away from the bottom or top of the box.

not necessarily best-represent a student's abilities [31-37], yet engineering faculty have continued to use these assessments as the primary measure of student learning. The pandemic, which eliminated the possibility of administering in-person assessments, created a significant barrier to implementing these more-traditional assessments.

There were virtual options for giving timed quizzes and tests, but concerns regarding academic integrity were cited by many faculty [38-42]. Technologies implemented to mitigate opportunities to cheat also had many drawbacks, such as causing students undue stress as well as possible legal concerns regarding a student's right to privacy [43-46]. It is very likely that the lack of a satisfactory solution in timed closed-notes individual tests and quizzes led faculty to implement other forms of assessment during P2, where in-person testing was not possible. In fact, learning strategies 7, 18, and 24 which, all relate to project or reflection-based assessments all increased in implementation by 6.7% between P1 and P3. Furthermore, learning strategies 14, 15, and 17,

which are all alternative platforms for traditional assessments (virtual or take-home), increased in implementation by 22.3%, 13.3%, and 8.9% respectively; faculty have continued to use these methods of assessment even though classes occur in-person once more. This indicates that some of the hurdles associated with online testing do not outweigh the benefit of using in-person class time. Ultimately, the data indicate that faculty value in-class time and interactions between the members of the course differently than before.

There were six learning strategies that showed a significant increase in implementation between P1 and P2. The learning strategies that fell above the 75th percentile for changes between P1 and P3 are (LS14) *use of open-note timed online quizzes and exams*, (LS25), *use of online grading tools*, (LS10) *use of a virtual whiteboard for lectures*, (LS11) *use of pre-recorded videos*, (LS22) *synchronous course meetings over Bluejeans/Teams/Zoom/etc,* and (LS12*) use of audio/video conferencing for meetings and office hours*.

An interesting result of this study is that learning strategy 14, *use of open-note timed online quizzes and exams,* is one if the learning strategies in the top 25th percentile. This learning strategy increased from 13.3% in P1 to 35.6% in P3. Of the four learning strategies that maintain the traditional assessment strategies (quizzes/tests) via an alternate platform (virtual/take-home), this is the only strategy that ranked in the top 25th percentile in growth between P3 and P1. It is possible that, since faculty are less inclined to give in-person assessments, some prefer to host these assessments in an open-note, timed, online setting. This may be the solution that best balances the cost-benefit of online testing. Alternatively, it is possible that faculty indicated the continued use of this practice based on case-by-case usage where faculty now have the flexibility to make accommodations for students who cannot attend an exam in person. Follow-up interviews are currently underway that will hopefully elucidate the reasons behind the documented growth in implementation of this learning strategy.

Faculty showed the next-largest increase in implementation of learning strategy 25: *use of online grading tools*. With P1 implementation at 37.8%, this learning strategy increased by 24.4% between P1 and P3. It might be that if there is not a significant problem with submitting and returning on-paper work, the desire to become technologically fluent in online options is low. Even so, once technologically fluent, the benefits of the online tool remain. For example, it might be less cumbersome to upload, grade, and give feedback on assignments virtually. Furthermore FERPA-certified virtual grading platforms might limit the risk of losing or misplacing paper copies of graded student work. This is an example of an existing technology solution that, without sufficient motivation and stimulation to overcome instructor's inertia, was largely unleveraged.

The third learning strategy with greatest growth in implementation between P3 and P1 is learning strategy 11: *the use of pre-recorded videos*. This learning strategy increased from 22.2% in P1 by 44.5% to 66.7% in P3. As noted previously, this is an interesting finding since one might assume it implies that faculty leveraged these videos to flip their classrooms, but that is not the case. One possible explanation for this result is that that faculty are using these videos as supplementary material for students to access in-case they missed a lecture or wanted to go over something from the lecture a second time for studying purposes. This result is also being further-explored in follow-up interviews.

The two learning strategies that showed the greatest implementation-increase both leveraged virtual meeting spaces. Learning strategy 22, *synchronous course meetings over Bluejeans/Teams/Zoom/etc,* grew by 46.6% to a P3 implementation rate of 53.3%. Learning strategy 12, *use of audio/video conferencing for meetings and office hours,* grew by 75.6% to a P3 implementation rate of 86.7%. Whether using the platform to host class synchronously, for group project meetings, or for virtual office hours, the significant increase in implementation of virtual meeting technologies indicates that these tools have been incorporated into university-teaching and are here to stay. There are many benefits that result from these tools. Many engineering faculty balance multiple roles in both their professional and personal lives. For example, in addition to teaching, faculty often are researchers who travel regularly for academic conferences. They are also often administrators or mentors who mentor student groups/teams outside of regular working hours. It is no wonder that faculty continue to leverage the flexibility that virtual meetings provide. Furthermore, virtual meetings platforms potentially aid faculty in name-face recognition and provide a better record for reference of what was covered in the meeting.

Learning Strategies ranked by Impact

Table 5 and 6 show the ranked responses from faculty when asked to categorize learning strategies by either positive or negative impact on themselves and their students. The percentage values shown in the tables indicates the percentage of faculty that categorized a learning strategy as either positively or negatively impactful. It should be noted that faculty were allowed to select either, both, or no-impact for each learning strategy.

Table 5. Top-ranked learning strategies for both positive and negative impact on faculty.

Rank	**Most Positive Impact on Faculty**		**Most Negative Impact on Faculty**	
	LS# and description	**Selected**	**LS# and description**	**Selected**
1	9: Leveraging Canvas to upload course materials for easy access by students.	66.7%	13*: Use of in-person assessments (traditional quizzes, tests, etc.)	25%
2	12: Use of audio/video conferencing for meetings and office hours	60.0%	21: Instructing your course as a flipped classroom.	20.0%
3	11: Use of pre-recorded videos.	57.8%	12: Use of audio/video conferencing for meetings and office hours	13.3%
4	3: Fostering collaboration and group work among students in class.	42.2%	15: Use of closed-note timed online quizzes and exams.	13.3%
5	8: Fostering communication between students by leveraging online chats, forums, Piazza, etc. for assignments or during lecture/instruction.	33.3%	14: Use of open-note timed online quizzes and exams.	8.9%

6	18: Implementation of project-based assessments.	31.1%	11: Use of pre-recorded videos.	6.7%
7	10: Use of a virtual whiteboard.	31.1%	8: Fostering communication between students by leveraging online chats, forums, Piazza, etc. for assignments or during lecture/instruction.	6.7%

*note that LS13 was only included in the second distribution of this survey and therefore the sample size of this group is N=24.

The learning strategy that most faculty (66.7%) indicated had a impacted them positively was learning strategy 9: *Leveraging Canvas to upload course materials for easy access by students*. This learning strategy did not show a significant increase in implementation (7.7%) between P1 and P3 in part because it had a large percentage of employment prior to the pandemic (at 91.1%). Even though 91.1% is a firm majority, it is interesting to note that almost 10% of faculty were not using this tool to upload material for students prior to the pandemic. Even more surprising is the fact that even following pandemic-teaching, one faculty member reported that they still do not use this tool.

Three of the learning strategies with the most positive impact on faculty were also in the learning strategies group showing the most growth in implementation between P1 and P3. These are learning strategy 10: *use of a virtual whiteboard for lectures, 11: use of pre-recorded videos,* and 12*: and use of audio/video conferencing for meetings and office hours*. The percent of faculty that ranked these as positively impactful are 60.0%, 57.8%, and 42.2% respectively. Two of these strategies also ranked high for their positive impact on students. As seen in Table X, learning strategy 11 was selected by 51.1% of faculty and learning strategy 12 was selected by 46.7% of faculty. All of these learning strategies likely met latent needs of the faculty and potentially of the students as well. Each of these strategies present technological solutions to problems that were likely not severe enough for faculty to be able to self-identify as needs yet rank high for the positive impact they have once adopted.

Two of the learning strategies which had the most positive impact on faculty are centered around fostering connection between students in the class. Learning strategy 3, *fostering collaboration and group work among students in class*, and learning strategy 8,*fostering communication between students by leveraging online chats, forums, Piazza, etc. for assignments or during lecture/instruction*, both were selected by 42.2% and 33.3% of faculty respectively. These learning strategies were also selected by 60% and 42.2% of faculty when asked to categorize the impact on students. These differences indicate that while the positive impact on the students might be more-direct (building community, learning from each other, etc) that faculty not only acknowledge and appreciate the impact on the students but experience personal positive impact as well. It is possible that encouraging the students to work together or communicate via forums like piazza decreases the workload of faculty by providing other sources of feedback.

Table 6. Top-ranked learning strategies for both positive and negative perceived impact on students.

Rank	Most Positive Impact on Students		Most Negative Impact on Students	
	LS# and description	**Selected**	**LS# and description**	**Selected**
1	9: Leveraging Canvas to upload course materials for easy access by students.	64.4%	21: Instructing your course as a flipped classroom.	20.0%
2	3: Fostering collaboration and group work among students in class.	60.0%	13*: Use of in-person assessments (traditional quizzes, tests, etc.)	16.7%
3	11: Use of pre-recorded videos.	51.1%	11: Use of pre-recorded videos.	15.6%
4	12: Use of audio/video conferencing for meetings and office hours	46.7%	15: Use of closed-note timed online quizzes and exams.	15.6%
5	8: Fostering communication between students by leveraging online chats, forums, Piazza, etc. for assignments or during lecture/instruction.	42.2%	12: Use of audio/video conferencing for meetings and office hours	8.9%
6	18: Implementation of project-based assessments.	33.3%	22: Synchronous course meetings over Bluejeans/Teams/Zoom/etc.	8.9%
7	17: Use of "take-home" exams (given one or more days to complete on student's own time).	33.3%	14: Use of open-note timed online quizzes and exams.	6.7%

*note that LS13 was only included in the second distribution of this survey and therefore the sample size of this group is N=24.
**It should be noted that this is the *perceived* impact on students as reported by faculty

Alternatively, faculty were also asked to select the learning strategies that had the most negative impact on them and their students as well. These results highlight that there can potentially be a wide variety of how faculty experience certain learning strategies. This is likely the case when we look at learning strategy 11, *use of pre-recorded videos*. While this learning strategy saw both one of the highest increases in implementation between P3 and P1 and ranked third in positive impact on faculty, it also ranked 6th in most negative impact on faculty. It is possible that the quality of the video has a strong function on whether or not this learning strategy has a positive or negative impact on the faculty member. Furthermore, generating video content may come very easily to some and not others which can lead to significant frustration. Lastly, since faculty are primarily not using these videos to flip their classrooms, it is also possible that faculty see releasing video content to students as a detriment to attendance and therefore negatively impactful. While some faculty might view this flexibility in accessing lecture content asynchronously as a convenience and a benefit, others could have the opposite experience as it might lead students to engage less in the in-person lectures. Similarly, faculty listed this learning strategy also to have a negative impact

on the students. Learning strategy 8, *fostering communication between students by leveraging online chats, forums, Piazza, etc. for assignments or during lecture/instruction*, also ranked among the top 7 most for negative impact on faculty. Clearly, there is a difference either in class type, instructor ability, or application that can lead to disagreement among faculty as to the nature of the impact of some learning strategies.

Two of the learning strategies that ranked most-negative were also below the 25th percentile in implementation change between P3 and P1. These are learning strategy 13: *Use of in-person assessments (traditional quizzes, tests, etc.)* and learning strategy 21: *Instructing your course as a flipped classroom*. One major commonality between these two learning strategies is that they relate to the nature of *how* we spend our in-class time. For in-person assessments, students are gathered together to work silently and independently. In a flipped class, while there might be a lot of collaboration and group-work during the class meeting, most of the theoretical lecture content is covered independently. This would indicate that the pandemic has changed the way that faculty value and leverage their in-class time.

Three learning strategies were ranked among the most negatively impactful on both students and faculty. These were Learning strategy 12: *Use of audio/video conferencing for meetings and office hours*, Learning strategy 15: *Use of closed-note timed online quizzes and exams*, and Learning strategy 14: *Use of open-note timed online quizzes and exams*. Learning strategy 12 had 13.3% and 8.9% of faculty select that this learning strategy had a negative impact on faculty and students respectively. 13.3% and 15.6% of faculty indicated that learning strategy 15 had a negative impact on both faculty and students respectively. Learning strategy 14 had 8.9% and 6.7% of faculty select that this learning strategy had a negative impact on both faculty and students respectively. It is no surprise that online-testing was negatively impactful, yet given that learning strategy 12 which showed the greatest increase in implementation also ranked 3rd and 5th most negatively impactful on faculty and students respectively. Similarly, learning strategy22, *Synchronous course meetings over Bluejeans/Teams/Zoom/etc.*, ranked 7th for negative impact on students. This is a particularly interesting result since it is one of the learning strategies which showed an overall significantly large increase in implementation between P3 and P1. Yet, 8.9% of faculty perceive that is has a negative impact on students.

Factors influencing Decision

The last question in our study asked faculty to describe the factors that influenced their decision to keep or modify learning strategies in P3. Faculty submitted text responses which were thematically sorted into six discrete factors. The most faculty (at 49%) reported that *effectiveness* of the learning strategy was a influenced their decision. Faculty related effectiveness to the impact the learning strategy had on students. To assess effectiveness, many faculty cited student feedback and opinion or student-performance compared to previous semesters. One faculty stated: "I keep them if I seem to be able to reach more students or reach them at a deeper level." As also shown by Abrami et. al. [17] effectiveness seemed to be balanced against difficulty in implementation of a learning strategy. One faculty stated that they chose to keep and refine a learning strategy based on, "What is helpful for student learning [and] what is logistical[y] practical to implement given the course size and format." In fact, 29% of faculty reported that the *ease of implementation* played a key role in the continued use of a learning strategy. In particular faculty cited that technology

glitches were a significant barrier to implementation and that there needed to be a balance between the effort it cost faculty to implement and the positive impact that it had on students.

Twenty percent of faculty reported that *student engagement* and *universal design for learning (UDL)* played a key role in their decision to keep/refine a learning strategy. Regarding engagement, faculty primarily cited attendance as the measure of engagement. One faculty even stated that "…tools designed to facilitate hybrid synchronous or asynchronous learning largely resulted in students not showing up for class" but a few others mentioned student enthusiasm and keeping students "present in the moment" as measures of engagement. The pandemic might have impacted on the way faculty view engagement: while many long-tenured faculty were accustomed to interacting regularly with their students in face-to-face classes, the pandemic did not allow this, therefore it is natural to feel a shift in engagement. This shift can be the result of either or both the quantity or quality of engagement perceived by faculty. Faculty likely had to develop alternative measures of engagement since their ability to watch students pay attention and take notes in real time was diminished.

Next faculty cited an appreciation for UDL. Faculty cited increased accessibility and equity of lecture material influenced their decision. Many online tools have been designed with this in mind, but because of the start-up time-investment of learning the tools, and not necessarily meshing well with in-person lecture material faculty may have been slow to adopt them. When forced by the circumstances, and given the chance to experience the benefits of tools designed to improve UDL firsthand, faculty report a significant appreciation for it.

Lastly, 4% of faculty cited that *managing student expectations* and *leveraging pandemic-driven opportunity* influenced their decisions. Faculty citing student expectations indicated that the pandemic has also changed what students expect stating "clarity of instruction" as paramount. One faculty noted, "students expect an 'on-rails' experience in all classes now, with a clear agenda for each lab period." Last, the pandemic provided faculty with an opportunity to implement previously ideated learning strategies. Given the very multi-faceted role of faculty, it is likely that they might have more ideas for course-improvements than they have time or resources to implement them. Thus, naturally the pandemic opened the door to developing/refining course content that faculty had wanted to, but hadn't had the resources, skill, or student buy-in to develop/refine until the pandemic.

Conclusions

In this study 45 engineering faculty were surveyed at The Georgia Institute of Technology. Faculty were asked questions regarding the learning strategies they have used during the different phases of the pandemic. Based on the results of this survey the following conclusions can be made:

- The pandemic resulted in the growth-in-implementation of 88% of learning strategies identified in this study. This suggests that in-general faculty are likely to have success with- and value implementing a new learning strategy.
- The learning strategy that resulted in the greatest decrease-in-implementation (down 16.6%) was the use of in-person traditional assessments such as quizzes and tests.
- The six learning strategies that resulted in the greatest growth-in-implementation all leveraged technology-based teaching tools (like virtual whiteboards, virtual meeting rooms, technology-based grading tools, etc.).

- Faculty categorization of learning strategies by either positive or negative impact suggest that non-traditional learning strategies are more likely to be positively impactful on both faculty and students.
- When deciding to implement or refine a learning strategy, faculty are primarily motivated by the strategy's effectiveness, ease of implementation, impact on student engagement, improvement in accessibility or UDL, and management of student expectations.

Limitations and Future Work

Survey results are inherently subjective and only as reliable as the participant's ability to self-report. While care was taken to present a though survey with low likelihood of mis-interpretation, it is always possible that some details were omitted or mis-interpreted. In an attempt to limit mis-interpretation the scope of this survey was deigned primarily to measure the usage of various learning strategies. The nuances of how each learning strategy was used in the context of different courses was not studied and the motivations for implementation were only briefly touched on. The preliminary results gathered from this survey are being used to inform follow-up interviews which are currently underway. The goal of these interviews is to better identify the nuances of how and why certain learning strategies were implemented and the motivations and values of faculty.

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