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The Transition from In-class to Online Lectures During a Pandemic: Understanding the Student Experience*

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In light of Covid-19, McMaster University abruptly transitioned all classes to an online format in Winter 2020, with online classes continuing through the Winter 2021 term. To improve our existing technological framework for the delivery of online courses, we surveyed undergraduate students in McMaster University's engineering program to assess their online learning preferences and their experience of the transition from in-class to strictly online learning. We identified student preferences for educational video type, number, duration and identified barriers to an online learning environment. In addition to outlining the students' perspective, we present our findings in the context of the students' learning by contrasting student learning in the online environment with the learning of earlier cohorts in the in-person environment (i.e., before the pandemic). We assess learning via student performance in exams and assignments for each course. After considering the student's perspective and learning outcomes, we provide recommendations for an optimal content delivery methodology in an online learning environment.

Keywords: active learning; constructivist theory of learning; Covid-19; education; online learning

1. Introduction

A global pandemic is underway that has required an overwhelming number of universities and other educational institutions across the world to cease all in-person classes. Social distancing guidelines implemented by various governments under the recommendations of leading health authorities to prevent the spread of Covid-19 have, in many cases, led to complete lockdown of affected areas [1]. As a result, universities are currently facing a situation wherein it is believed that this pandemic will eventually be overcome, but if classes are not conducted, and curricula are not completed, students' academic and career progress will be severely disrupted. In a bid to address this, McMaster University abruptly transitioned all classes to an online format in Winter 2020 and has continued to deliver classes in this manner throughout the Winter 2021 term.

The successful delivery of course content in an online environment hinges on adopting the right technology. Integrating appropriate technology into the learning experience can enhance student learning [2]. Technology can also promote students' ability to apply their learning to real-world situations, increasing student interest in and engagement with course content [3]. However, education – particularly in engineering disciplines – also benefits from in-person learning and face-to-face interactions between students and course instructors [4].

Constructivist learning theory (constructivism) recommends a teaching approach in which students actively participate in the learning process [5, 6]. In myriad disciplines, the use of a constructivist approach in teaching has increased substantially over recent years [7]. Typically, a constructivist approach to classroom-based learning centres on students using active learning (e.g., experiments or problem-solving [8]) and social interaction to generate a greater contextual understanding of course content, with students often reflecting on what they are doing and how their understanding of a given subject is changing [9].

The forced transition from in-person to online learning has posed a significant challenge to both instructors and learners in post-secondary education. For example, many in-person courses were forced to move entirely online in a matter of days, placing great strain on instructors and students

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alike [10–12]. Accordingly, the role of instructors has rapidly evolved to accommodate new requirements and challenges associated with online learning [13, 14]. Constructivist learning theory can be readily applied to online learning since the use of technologies that can be used for self-directed learning is already built-in, and the physical distance between instructors and students necessitates greater collaboration among students [15]. Using a constructivist approach, these features of online learning can ultimately benefit students by promoting self-directed learning, space for individual reflection, peer discussion, and peer collaboration [15].

While the benefits of technology for student learning are well-known [2], the optimal pedagogical style for delivering any one course depends on the course content and the target audience [16]. Recognizing the critical role of technology, instructors must constantly adapt to make learning authentic and relevant for students [17]. This is particularly important in the aftermath of the rapid transition to online learning due to the Covid-19 pandemic at McMaster University and many other post-secondary institutions worldwide.

The integration of technology with constructivist methods, such as problem-based learning, ensures that learners are more responsible for and active in their learning process [18–21]. However, switching to a strictly online learning environment during a global pandemic presents significant challenges for both instructors and learners. Engaging students in the learning process, providing direction, support, and feedback to learners, facilitating relationship building among peers, and combatting the social isolation and accompanying mental health and wellness issues brought on by the pandemic that students may be facing are all important and complex challenges to address [22, 23]. To improve our existing technological framework for online courses and ensure the provision of appropriate teaching and learning support materials to students, instructors must consult students, as the key stakeholders, to understand their attitudes and experiences of learning in an online environment.

In this study, we sought to understand the student experience of the transition from in-class to strictly online lectures during a global pandemic. In addition to outlining the students' perspectives, we present our findings in the context of the students' learning in an online setting. We contrast student learning in the strictly online environment with the learning of earlier cohorts in the same courses within an in-person learning environment (i.e., before the pandemic). We assess learning via student's performance in the various assessments we undertake in the courses. Thus, we consider both the student's perspective and learning outcomes and discuss these results in detail. We also provide suggestions for optimal course design and course delivery strategies based on survey responses from over 200 undergraduate students in McMaster University's engineering program (Bachelor of Technology).

2. Materials and Methods

2.1 Course Descriptions

We surveyed students enrolled in McMaster University's Bachelor of Technology program within the Faculty of Engineering during the 2020 academic year to assess their experience of the transition from in-class to strictly online learning in two different courses. The first course (ENGTECH 2MA3 – Mathematics III; hereafter 2MA3) is a fundamental second-year undergraduate math course. Every student enrolled in Automotive and Vehicle Engineering Technology, Automation Engineering Technology, or Biotechnology is required to successfully complete this course before moving forward in their studies. This course focuses on the techniques of solving first- and second-order ordinary differential equations.

We also compared the academic performance of the 2020 cohort with the 2019 cohort that met in-person on campus for biweekly lectures. Typically, the class meets twice a week for 2 h. The 2020 cohort, with 216 students (two course sections, with 99 students in one section and 117 in another), were taught the material in an online mode of instruction where the 2 h biweekly lectures were held over Zoom. Whereas, the 2019 cohort, with 59 students (two course sections), met in-person on campus for biweekly lectures. For both cohorts, the entire course was taught over a period of thirteen weeks.

Each week, in the first lecture, theoretical concepts are taught, and course concepts are illustrated by solving related numerical and application problems. In the second lecture, a review of the first lecture is given, followed by a problem-solving session in which the students are given a set of problems and are encouraged to solve them in a specified amount of time. Students are allowed to communicate with their peers and discuss the solution with the instructor during these sessions. In 2020, this course was offered in an online format due to the restrictions imposed by higher authorities to curtail the spread of Covid-19. Concepts were taught online in the first lecture, and the video recording of the lecture was uploaded on the course management page. To emulate the problem-solving session, students were randomly split into groups and assigned to breakout rooms. The same problems were assigned to solve as given in the in-person environment in each session. Students engage in detailed discussions with their peers and the instructor in solving these problems, sharing their ideas and approaches.

The second course (ENGTECH 3FE3 – Finite Element Analysis; hereafter 3FE3) is a third-year undergraduate engineering course taken by students in the Automotive and Vehicle Engineering Technology program. The course covers the following topics: (i) fundamentals of finite element analysis including the basic steps, generic solution approaches, and verification of solutions, (ii) structural analysis of trusses, beams, and frames, and (iii) thermal analysis. Students are taught to solve one- and two-dimensional problems using theoretical principles. A finite element analysis software, ANSYS, is also introduced in the course to solve problems in one, two, and three dimensions. Students are also trained in using ANSYS because it is widely used in the industry. As part of ANSYS training, six different applied problems are solved in the labs. These lab problems focus on teaching students how to set up the problem, apply boundary conditions, solve the problem, and interpret the data.

In this course, the class meets once a week for 3 h. The 2019 cohort, with 66 students split over two sections, met in-person on campus for weekly lectures. In contrast, the 2020 cohort, with 76 students split over two sections, was taught the same material in an online mode of instruction. Specifically, for the online cohort, the 3 h weekly online lectures were held over Zoom. For both cohorts, the entire course was taught over a period of thirteen weeks.

Each week during the lecture, theoretical principles were taught, and course concepts were illustrated with examples. This is followed by a problem-solving session in which the students are given a set of problems and are encouraged to solve them in a specified amount of time. In doing so, they are allowed to communicate with their peers and the instructor. In the online environment, students were randomly split into groups and assigned to breakout rooms to emulate this process. The questions posed in these active learning sessions are on the current topics as well as content taught in the recent past. Thus, the students are required to recall the concepts and apply them to solve the problems, helping to reinforce the material [24, 25]. Students engage in detailed discussions with their peers and the instructor in solving these problems, sharing their ideas and approaches.

As a next step, the students are trained to solve more complex problems using the ANSYS software. Again, students are allowed to engage in collaborative work to learn the basic principles of the software. Support materials in the form of ANSYS screenshots are provided to the students. The textbook prescribed in the course also has step-by-step guidelines for solving several similar problems using ANSYS.

In both courses, an active learning environment was maintained inside the classroom, following the principles of the constructivist theory of learning to offer a productive learning ambience for the students. Students received the course materials through video lectures and tutorials that introduced new concepts and illustrated the application of various engineering principles. Further, lecture recordings (2MA3 and 3FE3) and supplementary videos (3FE3 only) were provided to the students through the university's learning management system.

In 2MA3, students had access to 10 classroom video lectures of 90–100 min duration, but no supplementary videos were provided. There were 99 students enrolled in this section of the course at the time of the final grade calculation. In 3FE3, students had access to 6 classroom video lectures. Students attended one 180 min class per week, and lecture duration varied because lectures were paused while students worked on problem sets during each class. Students had access to a total of 9 supplementary videos. These videos covered a variety of topics, such as using remote connections to access online tools and setting up and solving sample problems. There were 76 students enrolled in the course at the time of the final grade calculation.

2.2 Survey Structure and Administration

To assess undergraduate students' learning preferences and experiences in McMaster University's Bachelor of Technology program, we administered a survey via LimeSurvey (Limesurvey GmbH). Responses were anonymous, and we asked students to complete the survey online during the final 20 mins of their final class. To encourage students to participate in the survey, we offered students a bonus of 1% of the total course grade, to be awarded if at least 80% of the class completed the survey. This 1% bonus was not awarded if fewer than 80% of students enrolled in a given course completed the survey. Basic information about the survey goals, potential risks, and incentives were provided via email.

The survey consisted of 23 questions that were broadly categorized as pertaining to (1) lecture and supplemental video usage; (2) supplemental video preferences; (3) student perceptions of online learning; and (4) impacts of online learning. The full survey is available in Appendix-1 These questions were predominantly formatted as radio lists (N = 19 questions), but we also included ranked (N = 2) and free form (N = 2) questions. Students also had the option to choose 'no answer' if they did not wish to respond to a given question. The administration of this survey was approved by the McMaster University Research Ethics Board (MREB # 5145).

2.3 Learning Outcomes

To assess the learning outcomes of 2MA3 and 3FE3 students, we evaluated their performance on various assessments and compared their scores to those of students enrolled in these courses the previous year, prior to the transition to online learning. In 2MA3, we usually create one version of each assessment in an in-person testing environment, and the same assessment is given to all students. In 2020, all assessments were conducted online and monitored via webcam. To minimize collaboration during online testing, we did the following:

Created a question bank consisting of five pools for Test 1. Each pool had four to five different questions from a specific topic but at the same level of difficulty. During the test, each student received five random questions, one from each pool. They were given 1.5 h to write their solutions on paper. An additional 10 min were assigned to take pictures of the answers, compile a pdf document, and upload it to a dropbox. The dropbox was set with time restrictions so that no one could upload the file after the time expired. Test 2 followed the same procedure, except we created four question pools with one question in each pool.

In 3FE3, student learning was assessed via quizzes, labs, two tests, and a comprehensive final exam. All the assessments except the labs focus on assessing student learning of the theoretical principles. In this course, too, we usually create one version of each assessment in an in-person testing environment, and the same assessment is given to all students. In 2020, all assessments were conducted online and monitored via webcam. To minimize collaboration during online testing, we did the following:

> A database of questions was created in the learning management system provided by the university, and a random set of questions was drawn from this database and presented to the students in a random order. This multi-level randomization ensured that each student was more or less appearing for a unique exam. The total number of questions and question types were comparable to the ones used in 2019. This, in combination with the fact that students were monitored during the assessments through Zoom and that they had a strict time duration to finish the assessments, assured a robust mechanism to avoid collaboration during exams.

2.4 Data Analysis

For each of the radio and ranked questions (N = 21), we calculated the percentage of students that selected each response for all courses combined and for each course individually. To evaluate whether students responded differently based on the course in which they were enrolled, we split the data by course (2MA3 or 3FE3) and performed a series of chi-square tests to assess potential differences in the observed frequency of responses to each question. For these analyses, we removed the 'no answer' option. In cases where the assumptions of the chi-square test were violated (i.e., the expected values were not greater than 1 or fewer than 20% of the expected values were greater than 5; N = 5 cases), we ran the chi-square test with these rows retained and again with those rows removed (in each case, only 1 row was responsible for violations of the test assumptions). Statistical analyses were performed in GraphPad V9.0.1 (GraphPad Software, LLC), and alpha (α) was set to 0.05.

3. Results

In surveying the students on the merits and demerits of the pedagogy followed in the online setting, we identified common practices in the student approach to online learning, including student preferences for online lectures and educational video type, number, and duration. We also identified key barriers to learning experienced by students in the online learning environment.

In total, we obtained 200 completed surveys: 62.5% (135/216) of 2MA3 students and 85.5% (65/76) of 3FE3 students submitted completed surveys. An additional 16 surveys were started but not completed, so we excluded these from further analysis. Where results do not add up to 100%, the remainder of the responses were 'no answer.' A full summary of survey responses is available in Appendix-1. Below, we highlight our main findings based on the following survey categories: (1) lecture and supplemental video usage; (2) supplemental video preferences; (3) student perceptions of online learning; and (4) impacts of online learning.

3.1 Survey Responses

3.1.1 Lecture and Supplemental Video Usage

Overall, students prefer to attend lectures and have access to supplemental videos. Indeed, 64% of students said they were extremely or somewhat likely to attend all lectures and watch all supplementary videos. While some students indicated they would miss more lectures if the lecture recordings were available online (19.5%), most students indicated that they would not miss a lecture even if recordings were available (37.5%) and that their attendance is not dependent on the availability of recorded lectures (38.5%) (Supplemental Materials, survey results). Most students watched between 5–20 h of lecture videos (51%), while 20.5% of students watched fewer than 5 and more than 30 h of lectures. With respect to lecture recordings, 48% of students said that if lecture recordings were available, they would take fewer notes in class but still attend most lectures.

When we asked students to rank factors that would influence their attendance, they were more prepared to miss a lecture if the lectures were prerecorded or if short supplemental videos were available to help them learn the concepts. On the other hand, students were not comfortable with missing a lecture and trying to learn from peers even if their friends were attending or tutorials were available (Fig.1A). When we asked students to rank sources that they use to get help on a difficult topic, students were most likely to watch video lectures and use online resources and least likely to contact their teaching assistants and lecturers or professors (Fig. 1B).

3.1.2 Supplemental Video Preferences

Students preferred shorter videos focused on a specific topic over longer videos or a package of videos (Fig. 2A-B). Students largely expressed a preference for 5 min videos over a 60 min lecture in which the topic is explained in 5–10 min. When given the option between a package of 5–7 min videos, students preferred to watch a single 15–20 min video that explains one concept (Fig. 2A-B). Students were much less likely to watch a video if it was too long (Fig. 2C). Overall, students strongly prefer and do make use of supplemental videos; 53.5% of students watched between 5 and 40 video clips in a single term (Fig. 2D).

3.1.3 Student Perceptions of Online Learning

The majority of students (68%) said that online learning is less preferable to in-person learning (Fig. 3A). Most students (53%) felt that online learning reduced or would reduce their learning (Fig. 3B). Accordingly, 46% of students said they prefer in-person (i.e., on campus) learning, and 40.5% of students said they would prefer a hybrid approach with both in-person and work from home options (Fig. 3C). However, students do want access to online materials; 66.5% of students reported that supplemental videos improved their learning in the course (Fig. 3D).

3.1.4 Impacts of Online Learning

Students overwhelmingly indicated that online learning negatively affected their wellbeing. More precisely, 67.5% of the students reported that their social wellbeing has declined as a result of online learning (Fig. 4A). Moreover, 68.5% of students said that they are negatively affected by the lack of face-to-face peer interaction, and 70.5% of students said that they are negatively affected by the lack of face-to-face instructor interaction (Fig. 4B-C). Students also faced technical difficulties (e.g., with internet connectivity, data, bandwidth, or other technologies) that impacted their ability to attend courses online and/or access course content. Almost

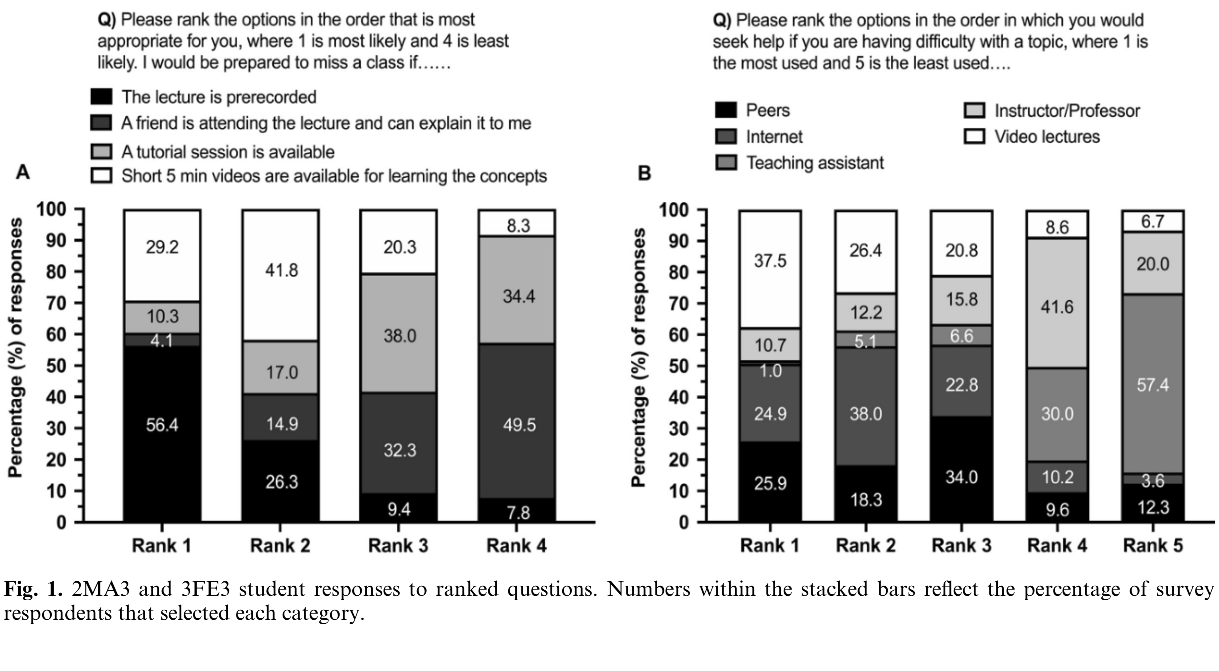

Fig. 1. 2MA3 and 3FE3 student responses to ranked questions. Numbers within the stacked bars reflect the percentage of survey respondents that selected each category.

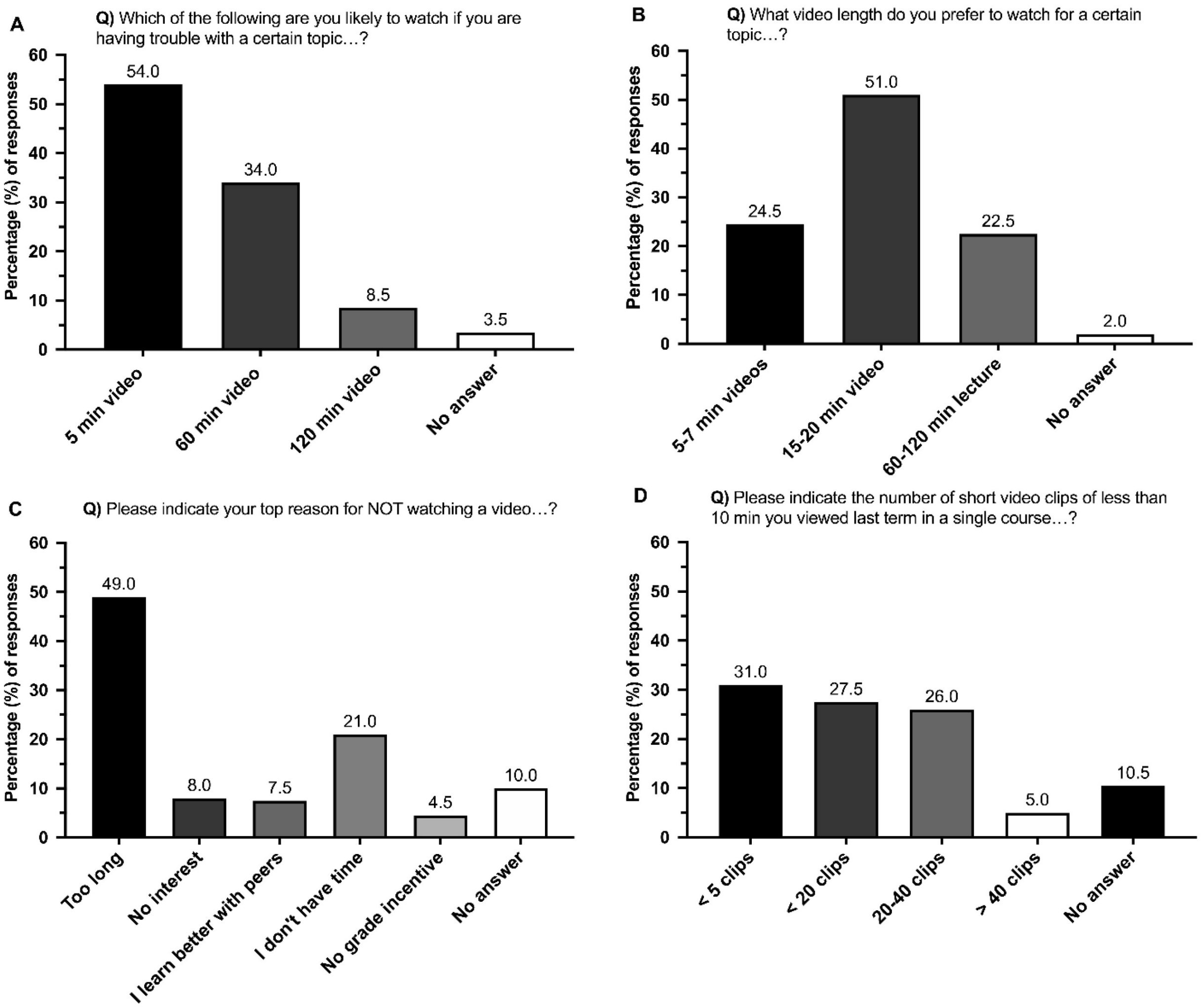

Fig. 2. 2MA3 and 3FE3 student responses to questions about supplemental videos. Numbers above each bar indicate the percentage of survey respondents that selected each option.

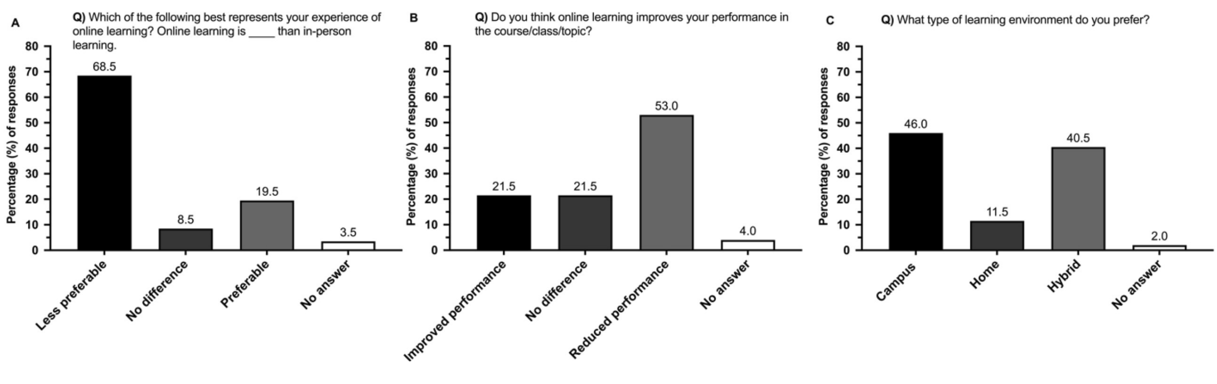

Fig. 3. 2MA3 and 3FE3 student responses to questions about online learning and supplementary materials. Numbers above each bar indicate the percentage of survey respondents that selected each option.

half (44.5%) of students reported occasional technical difficulty, 28% reported some difficulty, and 10% reported extreme difficulty. Only 15% of students reported no technical difficulties (Supplemental Materials, survey results).

3.2 Responses by Course

Most survey responses did not significantly differ between students in the two courses (Table 1). However, students in 2MA3 expressed a preference for a single 15–20 min supplemental video on a

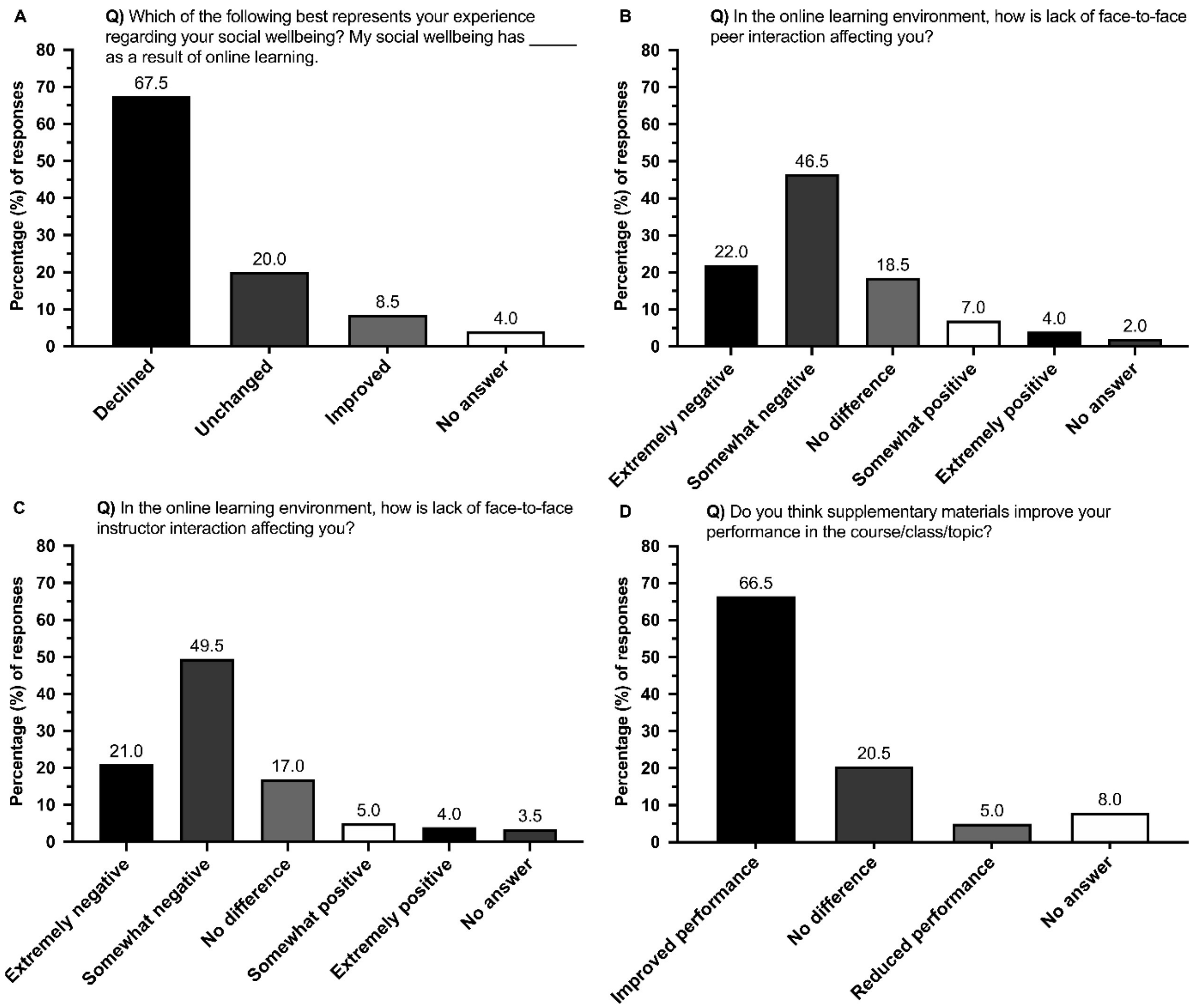

Fig. 4. 2MA3 and 3FE3 student responses to questions about their social wellbeing and performance. Numbers above each bar indicate the percentage of survey respondents that selected each option.

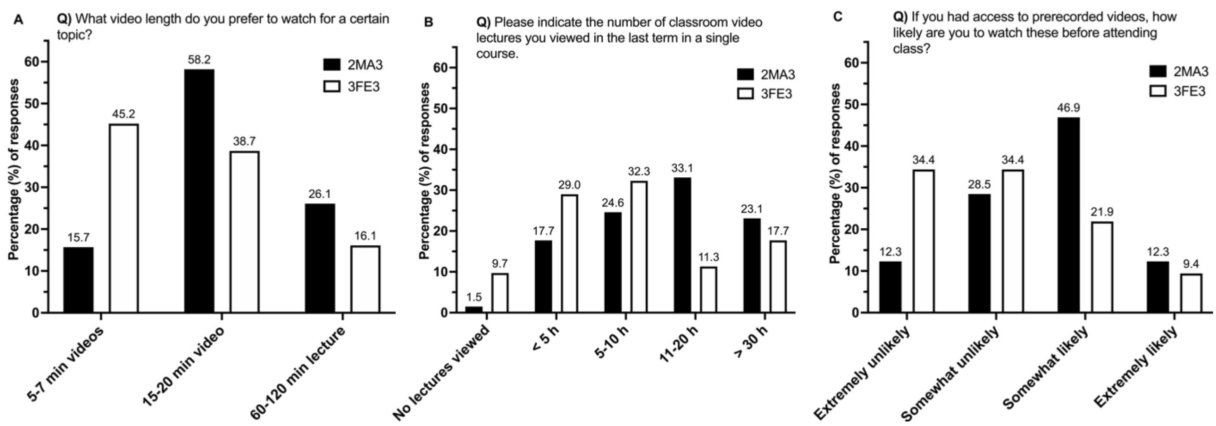

Fig. 5. 2MA3 and 3FE3 student responses differ for questions about supplemental video usage and lecture attendance. Numbers above each bar indicate the percentage of survey respondents that selected each option.

topic, while students in 3FE3 expressed a stronger preference for a package of 5–7 minute videos on a topic (Table 1 question B, Fig. 5A). Students in 2MA3 also watched more lectures than students in 3FE3; the majority of 2MA3 students reported watching between 11–20 hours of lectures, whereas most students in 3FE3 watched between 0–10 hours of lectures (Table 1 question E, Fig. 5B). Further,

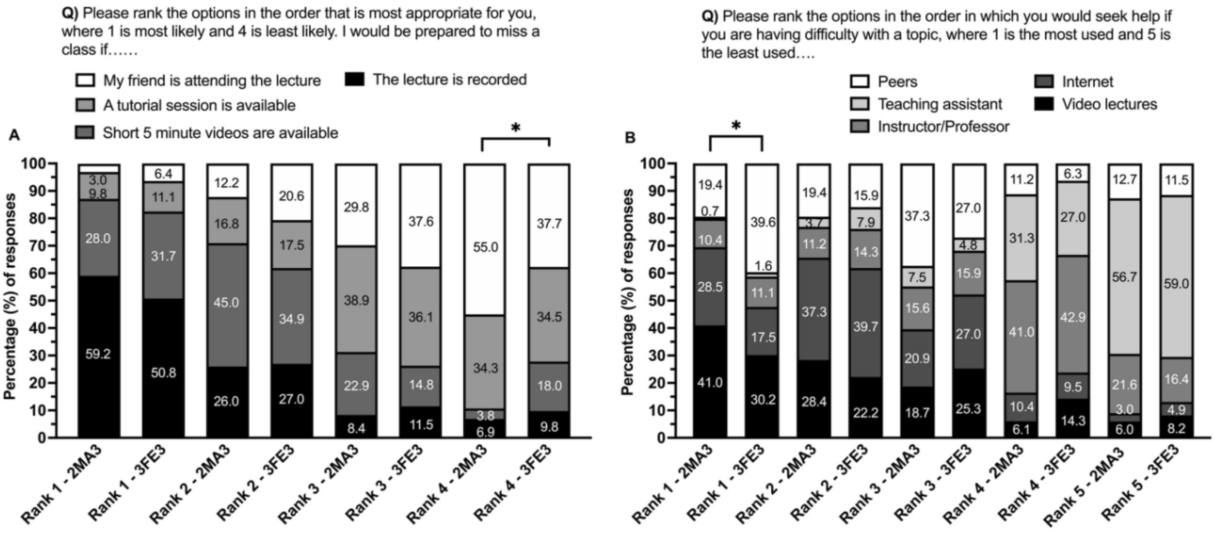

Fig. 6. 2MA3 and 3FE3 student responses differ in response to questions about missing lectures and seeking assistance with difficult topics. Numbers within the stacked bars reflect the percentage of survey respondents that selected each category. An asterisk indicates a significant difference in the responses between students in 2MA3 and 3FE3.

Table 1. Chi-square tests for differences in the frequency of survey responses from students in courses 2MA3 and 3FE3. All tests were two-tailed. Bold font indicates a statistically significant difference between groups at $\alpha = 0.05$. For questions with an asterisk (*), assumptions of the chi-square test (all expected values are greater than 1 and at least 20% of the expected values are greater than 5) were violated. Here, chi-square tests results are reported anyway, but we also ran chi-square tests with the rows responsible for the assumption violations removed; both methods gave similar results. For questions L and M, students ranked 4 or 5 options (L. I would be prepared to miss a class if: My friend is attending lecture; A tutorial is available; 5 min videos are available; Lecture is recorded. M. I would seek help for a difficult topic from: Peers; Teaching assistant; Instructor/Professor; Internet; Video lectures).

Question	df	χ^2	p
A. Which of the following are you likely to watch if you are having trouble with a certain topic?	2	2.12	0.347
B. What video length do you prefer to watch for a certain topic?	2	19.68	<0.0001
C.* Please indicate your top reason for NOT watching a video:	3	1.91	0.590
D. Which of the following is more applicable to you?	2	1.07	0.587
E. Please indicate the number of classroom video lectures you viewed in the last term in a single course	4	18.32	0.001
F. Please indicate the number of short video clips of less than 10 minutes you viewed last term in a single course	3	6.59	0.086
G.* Where do you look for videos to learn a certain topic?	3	6.09	0.107
H.* Which of the following is acceptable to you if the video recording of the lecture is available?	3	4.92	0.178
I. For a given course, how likely are you to watch all videos and attend all lectures?	3	0.32	0.957
J. If you had access to pre-recorded videos, how likely are you to watch these before attending class?	3	18.44	0.0004
K. Which of the following is most likely in your study habit?	3	6.18	0.103
N. Do you think supplementary materials improve your performance in the course, class, and/or topic?	2	0.44	0.802
O. Which of the following best represents your experience?	2	3.01	0.222
P. Which of the following best represents your experience?	2	1.30	0.521
Q. Do you think online learning improves your performance in the course, class, and/or topic?	2	4.04	0.133
R. In the online learning environment, how is the lack of face-to-face peer interaction affecting you?	3	2.68	0.443
S. In the online learning environment, how is the lack of face-to-face instructor interaction affecting you?	4	4.86	0.302
T. What type of learning environment do you prefer?	2	4.88	0.087
U. Have you had or do you have issues with internet connectivity, data, bandwidth, or other technology that impacts your ability to attend online courses and/or access course content?	3	2.87	0.412
L. I would be prepared to miss a class if – rank 1	3	1.93	0.586
L. I would be prepared to miss a class if – rank 2	3	3.09	0.378
L. I would be prepared to miss a class if – rank 3	3	2.68	0.443
L. I would be prepared to miss a class if – rank 4	3	13.07	0.005
M.* Where would you seek help if you are having difficulty with a topic – rank 1	4	10.52	0.033
M. Where would you seek help if you are having difficulty with a topic – rank 2	4	2.80	0.593
M. Where would you seek help if you are having difficulty with a topic – rank 3	4	3.45	0.486
M. Where would you seek help if you are having difficulty with a topic – rank 4	4	4.82	0.306
M.* Where would you seek help if you are having difficulty with a topic – rank 5	4	1.41	0.842

Table 2. 2MA3 student performance on the final exam in 2019 (in-person learning) compared to 2020 (online learning during the global Covid-19 pandemic)

Cohort	Test 1 (%)	Test 2 (%)	Final Course Grade (%)
2019	54	66	56
2020	56	72	61

Table 4. 3FE3 student performance on the final exam in 2019 (in-person learning) compared to 2020 (online learning during the global Covid-19 pandemic)

Cohort	Test 1 (%)	Test 2 (%)	Final Course Grade (%)
2019	78	79	56
2020	79	84	63

unlike the students in 3FE3, students in 2MA3 were more likely to watch prerecorded supplementary videos before attending lectures (Table 1 question J, Fig. 5C).

We also noted some differences in students' responses to our ranked questions between the two courses. Compared with students in 3FE3, 2MA3 students were more prepared to miss a lecture if a friend was attending (Table 1 question L rank 4; Fig. 6A). Students in 2MA3 were also more likely to seek out peer support when having difficulty with a topic than students in 2FE3; students in 3FE3 were more likely to rely on video lectures and internet resources (Table 1 question L rank 1; Fig. 6B).

3.3 Student Performance

3.3.1 Student Performance in 2MA3

As the 2MA3 course progressed, students in the online format (2020 cohort) performed better than the students in the in-person format (2019 cohort) (Table 2). The average grades in 2020 increased by 2%, 6%, and 5% in Test 1, Test 2, and final grades, respectively (Table 2). To further investigate this, we compared the grade distribution between in-person and online learning (Table 3). Students obtained better grades in 2020 (online) compared with 2019 (in-person). For example, in Test 1, 28% of the students received an A or B grade in 2020 versus 22% in 2019. Students received 62% versus 58% in Test 2, and 31% versus 29% in their final grade. On the other hand, the failure rate dropped by 4%, 3%, and 15% in Test 1, Test 2, and the final grade, respectively, which explains the small increase in class averages (Table 2).

3.3.2 Student Performance in 3FE3

Like 2MA3, as the 3FE3 course progressed, the students in the online format (2020 cohort) performed better than the students in the in-person format (2019 cohort) (Table 4). Again, this is somewhat contradictory to the preference of the students, in which we found that they prefer in-person over online lectures.

A closer look at the data revealed that the 2019 cohort had a much higher failing percentage than the 2020 cohort (24% of students failed in 2019 compared to only 4% of students in 2020; Table 5). The group that failed was mainly comprised of students who gave up on the course midway and did not participate in numerous assessments, significantly lowering the overall class average. If we analyze the average performance of the students in the two cohorts after removing the students who failed the course, we find that the average course grade in 2019 and 2020 is 62% and 64%, respectively. In other words, the mode of instruction had little, if any, impact on student performance.

4. Discussion

The Covid-19 global pandemic has interrupted post-secondary education delivery and has posed a significant challenge to both instructors and learners, and we sought to understand the student experience of this transition from an in-person to a strictly online learning environment. Herein, we identified student learning preferences that fell into four main categories. First, students preferred to attend lectures at the time they are offered (i.e., synchronously) rather than missing classes and catching up later. Students also preferred to have access to supplemental videos that they could use to

Table 3. Distribution of course grades of students in the two cohorts (2019, in-person; 2020, online) in 2MA3. The numbers in the table represent the percentage of students that received a given letter grade

	Test 1 (%)		Test 2 (%)		Final Grades (%)	
Grades	**Online**	**In-person**	**Online**	**In-person**	**Online**	**In-person**
A	12	16	48	32	12	9
B	16	6	14	26	19	20
C	14	21	13	12	30	22
D	20	15	8	10	25	20
F	38	42	17	20	14	29

Table 5. Distribution of course grades of students in the two cohorts (2019, in-person; 2020, online) in 3FE3. The numbers in the table represent the percentage of students that received a given letter grade. The numbers in the table represent the percentage of students that received a given letter grade

	Test 1 (%)		**Test 2 (%)**		**Final Grades (%)**	
Grades	**Online**	**In-person**	**Online**	**In-person**	**Online**	**In-person**
A	47	44	63	68	1	3
B	36	30	22	6	24	18
C	9	12	11	6	42	18
D	5	8	1	9	29	36
F	3	6	3	11	4	24

enhance their understanding of key topics in their courses (i.e., self-directed learning). Second, when it comes to supplemental videos, students preferred shorter videos focused on a specific topic over longer videos or a package of videos explaining the concept. Third, students indicated that strictly online learning is less preferable than in-person learning. Students overwhelmingly expressed a preference for either fully in-person learning or a hybrid learning approach in which they could attend a combination of in-person and online classes. Fourth, students indicated that the online learning environment negatively impacts their social wellbeing. Finally, we note that most students experienced at least occasional difficulty with internet connectivity or other technological issues that interfered with their ability to access course content.

The rapid switch to online learning brought about by the global Covid-19 pandemic has inspired research that assesses the student experience. Understandably, many students report struggling with a lack of motivation and focus after making the switch to online learning under pandemic conditions [13, 26, 27]. Our results are consistent with other studies indicating that students prefer synchronous classes and in-person learning to asynchronous classes and online learning [10, 28, 29]. Yet, despite the challenges of online learning for students, there are many opportunities to implement teaching practices and technologies that enhance the student learning experience. For example, video lectures can have many benefits for students, from reinforcing new knowledge and identifying knowledge gaps to improving student outcomes [30–32]. Our results are consistent with other research demonstrating that supplementary videos are desirable to students in mathematics [32], engineering [33, 34], and other disciplines [35, 36]. Importantly, supplementary videos can also improve student performance [33, 35, 36].

Most students (82.5%) experienced at least occasional difficulty with internet connectivity or other issues that impacted their ability to access course content (Supplemental Materials, survey results, question U1). In fact, 10% of students surveyed indicated they had extreme difficulty accessing course content. This is consistent with recent studies finding that access to online learning resources is an issue for students [13, 26], especially those in rural areas [37]. Even though McMaster University is in an urban centre (Hamilton, Ontario), many students migrate from rural areas in southern Ontario and elsewhere to attend university. After the switch to online learning and implementation of travel restrictions, many students stayed in their home communities, which may decrease their access to online learning resources. Many students likely face additional (e.g., financial) barriers to accessing high-speed internet or other technological resources. It is therefore important to provide resources such as recorded lectures, options to view lectures asynchronously, and low-bandwidth, low-cost learning materials such as e-textbooks and downloadable videos and lecture materials to accommodate students with reduced access to technology.

Interestingly, we also noted some differences in students' responses depending on the course they were in. Students in the second-year mathematics course (2MA3) preferred longer (15–20 min) videos and watched more lectures, while students in the third-year finite element analysis course (3FE3) preferred shorter (5–7 min) videos and watched fewer lectures. Notably, 2MA3 students were not provided with supplementary videos for this course, but they nevertheless indicated strong preferences for having access to supplemental videos in general. Mathematics students were also more likely to watch pre-recorded videos before attending lectures. Finally, mathematics students were more likely to seek peer support than finite element analysis students, who were more likely to rely on video lectures and online resources. These differences may be due to differences in course design as well as the students' level of experience (second-year *versus* third-year).

In Finite Element Analysis (3FE3), students are required to solve equations that take 45–50 minutes to complete. Students may have trouble solving only a subset of the equations required and may therefore prefer to watch a package of several videos in which the required calculations are split up, rather than watching a single longer video that guides them through the entire solution. This is consistent not only with 3FE3 students' preference for shorter videos but also with the finding that they watched fewer videos overall compared to 2MA3 students. It is also possible that second-year students (i.e., those in 2MA3) prefer to watch longer videos and more lectures to ensure they are taking in all the relevant course content because they are less experienced and may still be navigating ways to increase their learning efficiency. It is also possible that 2MA3 students indicated a greater likelihood to watch longer videos and more lectures because they did not have access to short supplementary videos specifically designed for this course. Alternatively, 2MA3 students may simply have more time to watch lectures and lengthy videos, which is also consistent with the finding that they were more likely to watch pre-recorded videos ahead of lectures. The intensity of undergraduates' course schedules tends to increase in their third year, and 3FE3 students may simply not have time to consume all of the available course content to the extent that second-year students are able to. That said, the fact that finite element analysis students were less likely to watch supplemental videos before lectures may be related to the course design. Finite element analysis presents complex and lengthy problems to students, who may prefer to attend the lecture first to get an introduction to the concepts, and then review the concepts afterwards using supplementary videos.

With respect to performance, students in both 2MA3 and 3FE3 performed better in the online than the in-person environment, which is contradictory to the student preference for in-person learning and their perception that their performance suffered as a result of online learning. In both courses, the 2019 cohort had a higher failing percentage compared to the 2020 cohort. In 3FE3, after controlling for this difference, we found that the average performance of students in both cohorts was similar (62% vs 64% for in-person and online learning, respectively). One might argue that the gain is statistically insignificant in the online environment, and one can concede to that claim. Nevertheless, our point is that contradictory to the student's perceptions, they performed at par if not better than the in-person cohorts. That said, it is important to note that assessments for the 2020 cohort were necessarily adapted for the online environment to minimize collaboration, so it is difficult to directly compare performance results between the 2019 and 2020 cohorts. By combining performance data with the student feedback on our survey, we can perhaps conclude that since the students are not accustomed to an online mode of instruction and were abruptly forced into it due to the pandemic, they found that less preferential. However, it is difficult to conclude at this stage whether the online format has any impact on student's learning. It is possible that, although we took steps to minimize collaboration during exams, students could have found ways to take advantage of the online testing system to increase opportunities for collaboration, leading to increased grade scores in the online cohort. Another possibility is that variation in performance is simply due to natural variation between the cohorts. It would be interesting to obtain and analyze a second iteration of student feedback after exposing them to this performance finding; this could yield alternative opinions on our finding of similar or slightly increased performance in the online compared to the in-person learning condition.

Constructivist learning theory has the potential to transform distance and online learning [15], and instructors must adapt accordingly to ensure they can successfully integrate students into the online learning environment while fostering a productive collaborative learning environment. Given the mental health challenges many students have reported with the switch to online learning during the global Covid-19 pandemic, and the many benefits of applying constructivism to online learning, instructors should strive to facilitate meaningful interactions and discussions among students and instructors. Based on survey responses from 200 undergraduate students in McMaster University's Bachelor of Technology program within the Faculty of Engineering, we propose a set of "good practices" derived from the students' input in Table 6.

In summary, engineering students prefer in-person learning but also desire access to online supplementary materials such as short video tutorials and worked problems. Most students (86.5%) prefer either fully on-campus learning or a hybrid approach with both in-person and work-from home learning options. This highlights the ongoing demand for in-person learning, the critical role of university instructors, and the value of having face-to-face interactions with instructors and peers. Overall, students perceive a decrease in their performance and have experienced a decline in their mental wellbeing as a result of the switch to fully online learning during the Covid-19 pandemic. However, student performance did not reflect students' perception of impaired learning in an online environment. While students do not prefer fully online learning, they are still able to meet – and

Table 6. Good practices for online learning based on the input of undergraduate engineering students as key stakeholders in their education

Delivery of educational materials	Technological solutions	Promotion of interactions
1. Lecture and supplemental video usage		
Students prefer to attend lectures synchronously but also benefit from access to recorded lectures.	Record lectures and make these available to students after the scheduled lecture.	Posting lecture recordings after the live lecture may promote student attendance during live lectures.
Short supplementary videos are desirable, but course structure should be considered in their design.	Short supplementary videos should be made available online.	Creating “breakout rooms” for students to discuss video and lecture content during class may promote student-student interactions and decrease feelings of isolation.
2. Supplemental video preferences		
Complex courses may benefit from short videos on key topics.	For complex topics, supplemental videos may not need to be available before lectures.	Schedule short “check-ins” during lecture slots to ensure students can access and understand course materials.
For more general topics, video length can be increased as needed.	For general topics, students may benefit from supplemental videos in advance of lectures.	Schedule short “check-ins” during lecture slots to ensure students can access and understand course materials.
3. Student perceptions of online learning		
Students readily access online course content but report hesitancy to seek peer and instructor support for difficult course content.	Building a 15 min “debrief” into the end of each week’s lectures may increase student engagement and decrease feelings of hesitancy.	Where possible, add opportunities for student-student and student-instructor interaction during lectures. Encouraging students to make use of office hours may reduce hesitancy to contact instructors and teaching assistants.
Hybrid learning (in-person and online learning) is preferable to many students.	Post-Covid-19, post-secondary institutions should consider redesigning courses to allow for hybrid learning.	Use online course management platforms to ensure clear communication about in-person and online learning expectations.
4. Impacts of online learning		
Students report online learning negatively impacts their learning.	Create an online forum for weekly discussion, with students posting questions, comments, or answers.	Discussion threads may increase student engagement, improve learning, and increase focus.
Students report a decline in their social wellbeing due to online learning.	Implementing student-only online social hours may decrease feelings of isolation.	Encouraging students to engage in peer discussion may ease the negative impacts of online learning.

even exceed – typical performance scores in the online environment. That said, given the negative impacts students report on their social wellbeing, we recommend careful consideration before making any decision to switch to a fully online format of learning.

Based on the feedback of students as key stakeholders in their education, we conclude that students will benefit most from a return to in-person learning on campus, when it is safe to do so, or a blended format of learning. Students will also benefit from modifications to current teaching practices – such as an increase in the flexibility of learning options, as well as increased access to online supplementary learning materials.

From the perspective of faculty and staff, the ongoing challenges to online and remote learning include (i) technical and technological issues faced by both students and instructors, (ii) the inability to adequately deliver all course content (e.g., laboratory sessions) in an online format, and (iii) mental health impacts of remote learning and isolation [38, 39]. While these issues are not necessarily insurmountable, they are consistent with our findings that students – and faculty – are most likely to benefit from a return to in-person learning or a blended learning approach.

5. Conclusions

We have provided important insights into how students perceive the transition to a strictly online learning environment, and what students want out of their online educational experience. Students have clear preferences for the delivery of online content; however, their preferences are influenced to some extent by both the courses they are enrolled in and the stage they are at in their academic career or journey. In contrast to the somewhat negative student perceptions of online learning, their performance was marginally better in the online format compared to in-person learning, even though students did not prefer online to in-person learning. Overall, the rapid shift from in-person to online learning has significantly impacted student’s mental health and wellbeing. This is of substantial concern and requires close attention by instructors. Taking our findings into consideration, we have provided guidelines for good educational practices, with a focus on technological solutions and promoting interactions among students and instructors. We hope these guidelines will be adopted by instructors to improve the learning experience and mental wellbeing of students. By assessing the student experience of the rapid transition from in-person to online learning during the global Covid-19 pandemic, we have gained important insights into how we, as instructors, can ensure that the provision of higher education to students can be modified in the future to improve the sustainability, desirability, and efficacy of both teaching and learning.

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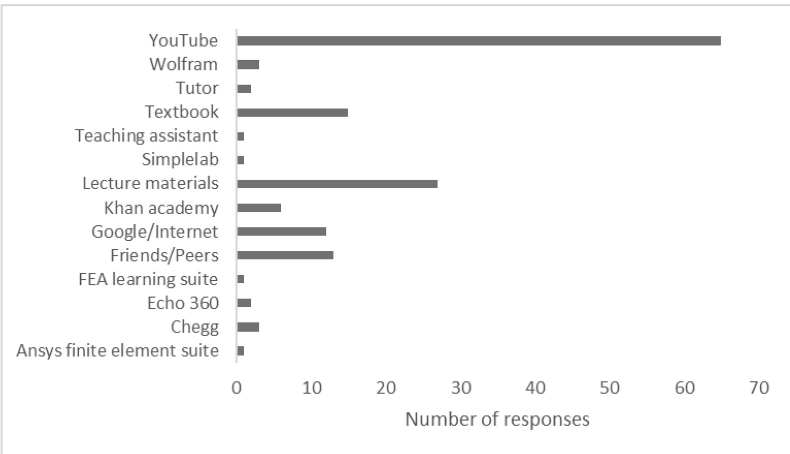
1. Appendix-1: Survey Questions & Response

The response from a total of 200 students was recorded in an anonymous survey that contained the following questions.

1. Which of the following are you likely to watch if you are having trouble with a certain topic?
   - 5 minute video specifically on the topic – **54%, A%, C%**
   - 60 minute lecture video in which the concept is explained for 5–10 minutes – **34%**
   - 120 minute lecture video in which the concept is explained for 5–10 minutes – **8.5%**
   - No answer – **3.5%**
2. What video length do you prefer to watch for a certain topic?
   - A concept with examples explained using a package of 5–7 minute videos – **24.5%**
   - A concept with examples explained in one 15–20 minute video – **51%**
   - Full 60–120 minute lecture video consisting of multiple concepts with examples – **22.5%**
   - No answer – **2%**
3. What other resources, if any, do you access if you are having trouble with a certain topic?



4. Please indicate your top reason for NOT watching a video:
   - It is too long – **49%**
   - It is of no interest – **8%**
   - I learn better with peers – **7.5%**
   - I do not have time – **21%**
   - There is no grade incentive – **4.5%**
   - No answer – **10%**

5. Which of the following is more applicable to you?
   - I would miss more lectures if the lectures are recorded and available online – **19.5%**
   - I would not miss a lecture even if the recorded lectures are available online – **37.5%**
   - My attendance is not dependent upon the availability of lecture recording – **38.5%**
   - No answer – **4.5%**
6. Please indicate the number of classroom video lectures you viewed in the last term in a single course
   - Did not view any video lectures recorded by the instructor – **4%**
   - Less than 5 hours – **20.5%**
   - Between 5–10 hours – **26%**
   - Between 10–20 hours – **25%**
   - More than 30 hours – **20.5%**
   - No answer – **4%**
7. Please indicate the number of short video clips of less than 10 minutes you viewed last term in a single course
   - Less than 5 clips – **31%**
   - Less than 20 clips – **27.5%**
   - Between 20-40 clips – **26%**
   - Greater than 40 clips – **5%**
   - No answer – **10.5%**
8. Where do you look for videos to learn a certain topic?
   - Avenue to Learn in conjunction with Echo 360/MS Teams/Pebblepad (as used in the course) – **47%**
   - Google/Internet Search Engine – **13%**
   - YouTube – **33%**
   - Other – **3.5%**
   - No answer – **3.5%**
9. Which of the following is acceptable to you if the video recording of the lecture is available?
   - Be a little less attentive in classroom but attend most lectures – **29.5%**
   - Take less notes in the classroom but attend most lectures – **48%**
   - Miss more lectures, but still attend some – **10%**
   - Miss the lectures – **1.5%**
   - No answer – **11%**
10. For a given course, how likely are you to watch all videos and attend all lectures?
    - Extremely likely – **18.5%**
    - Somewhat likely – **45.5%**
    - Somewhat unlikely – **23.5%**
    - Extremely unlikely – **9%**
    - No answer – **3.5%**
11. If you had access to pre-recorded videos, how likely are you to watch these before attending class?
    - Extremely likely – **11.5%**
    - Somewhat likely – **37.5%**
    - Somewhat unlikely – **29.5%**
    - Extremely unlikely – **19%**
    - No answer – **3%**
12. Which of the following is most likely in your study habit?
    - I watch the recorded lecture after every class – **12%**
    - I watch some of the recorded lecture before an exam – **38.5%**
    - I watch all of the recorded lecture before an exam – **27.5%**
    - I rarely watch the recorded lectures – **18.5%**
    - No answer – **3.5%**
13. Please rank the options in the order that is most appropriate for you, where 1 is most likely and 4 is least likely.
    - I will be prepared to miss a class if:
    - The lecture is recorded – **56.41%**
    - My friend is attending the lecture instead and can explain it to me – **4.1%**
    - A tutorial session is available – **10.26%**
    - Short 5 minute videos are available for learning the concepts – **29.23%**
    - No answer – **0%**

14. Please rank the options in the order in which you would seek help if you are having difficulty with a topic, where 1 is the most used and 5 is the least used.
    - Peers – **18.27%**
    - Internet – **38.07%**
    - Teaching assistant – **5.08%**
    - Instructor – **12.18%**
    - Video lectures – **26.4%**
    - No answer – **0%**
15. Do you think supplementary materials improve your performance in the course/class/topic?
    - Supplementary videos/recorded lectures improve my performance. – **66.5%**
    - Supplementary videos/recorded lectures are no different than in person learning for my performance. – **20.5%**
    - Supplementary videos/recorded lectures reduce my performance – **5%**
    - No answer – **8%**
16. Which of the following best represents your experience?
    - Online learning is less preferable than in-person learning – **68.5%**
    - Online learning is no different than in-person learning – **8.5%**
    - I prefer online learning to in-person learning – **19.5%**
    - No answer – **3.5%**
17. Which of the following best represents your experience?
    - My social wellbeing has declined as a result of online learning – **67.5%**
    - My social wellbeing has not changed as a result of online learning – **20%**
    - My social wellbeing has improved as a result of online learning – **8.5%**
    - No answer – **4%**
18. Do you think online learning improves your performance in the course/class/topic?
    - Online learning improves my performance – **21.5%**
    - Online learning is no different than in person learning for my performance – **21.5%**
    - Online learning reduces my performance – **53%**
    - No answer – **4%**
19. In the online learning environment, how is lack of face-to-face peer interaction affecting you?
    - I am extremely negatively affected – **22%**
    - I am somewhat negatively affected – **46.5%**
    - I am somewhat positively affected – **7%**
    - I am extremely positively affected – **4%**
    - I am not at all affected – **18.5%**
    - No answer – **2%**
20. How is lack of face-to-face instructor interaction affecting you:
    - I am extremely negatively affected – **21%**
    - I am somewhat negatively affected – **49.5%**
    - I am somewhat positively affected – **5%**
    - I am extremely positively affected – **4%**
    - I am not at all affected – **17%**
    - No answer – **3.5%**
21. What type of learning environment do you prefer?
    - Campus environment – **46%**
    - Work from home – **11.5%**
    - A hybrid approach with both in-person and work from home options – **40.5%**
    - No answer – **2%**
22. Have you had or do you have issues with internet connectivity, data, bandwidth, or other technology that
    - impacts your ability to attend online courses and/or access course content?
    - Yes, extreme difficulty – **10%**
    - Yes, some difficulty – **28%**
    - Occasional difficulty – **44.5%**
    - No difficulty – **15%**
    - No answer – **2.5%**
23. Please provide any final comments indicating how the instructor can improve your online learning experience:
    Response not included to maintain student privacy.

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