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The Impact of COVID-19 on the CS Student Learning Experience

How the Pandemic has Shaped the Educational Landscape

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ABSTRACT

Students have experienced incredible shifts in their learning environments, brought about by the response of universities to the ever-changing public health mandates driven by waves and stages of the coronavirus pandemic (COVID-19). Initially, these shifts in learning (mode of course delivery, course availability, etc.) were considered emergency responses. However, as the pandemic pressed on, students have had to repeatedly adapt to the continuously evolving educational landscape.

This working group builds upon foundations and structure created by a 2021 ITiCSE Working Group exploring the effects of COVID-19 on teaching and learning from a faculty perspective. That working group identified the incorporation of some pandemic-induced changes into future teaching practices. This working group examines the existing literature and insights gained from responses to a multi-national survey to explore the new student experience emerging from the continuously evolving teaching practices catalyzed by the global pandemic.

Traditionally, computing is a subject full of experiential learning opportunities, rich with in-person labs and exercises. We investigate how the changes within the COVID-affected academic landscape have altered that student experience. The current group of computing students will have had experiences under both typical (i.e. pre-pandemic) and COVID-affected teaching practices. It is, therefore, timely that we understand how each has impacted how they perceive their learning environment and educational experience. In turn, identifying those practices that have most benefited the student learning experience will help computing faculty improve their educational methods going forward.

CCS CONCEPTS

• **Social and professional topics → Computing education**.

KEYWORDS

COVID-19; coronavirus; computing education; online education; student perspective

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1 INTRODUCTION

The COVID-19 pandemic forced an "unprecedented global shift within higher education in the ways that we communicate with and educate students" [58]. Since the beginning of this worldwide health crisis, on the receiving end, students have been confronted with these major changes in educational practices and expectations. As provisions were put into place to facilitate both online and in-person teaching, students were thrust into a largely new and constantly changing learning environment, very different than the environment experienced by their peers that came before them. These changes and challenges began during the tail end of the 2019-20 academic year and have persisted in varying degrees since. Thus, over the last two plus years, subjects which traditionally benefit from "in-person" activities such as guided labs, experiential learning activities and tutorials have transitioned into a mix of online, blended and hybrid learning environments through the use of various technologies and innovative pedagogies.

*Working group co-leader

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It is important to remember that the move into higher education is always a pivotal experience for students [56, 60, 74, 75] and COVID-19 triggered sudden and massive disruptions on this and all levels of education. These pandemic-affected students have had to unexpectedly and rapidly adapt to unprecedented, and often newly-created, online and blended learning situations [76]. It is therefore imperative that we capture the student experiences in this moment, as this set of students is unique in that they will have had experiences under both typical (i.e. pre-pandemic) and COVID-affected teaching practices.

These emergency pandemic practices may have provided some challenges for student learning, but there were also silver linings as they sparked some new and creative modes of engagement in higher education. Evaluation of and exposure to new tools and learning techniques took place at a faster rate than ever before [59]. While these experiences remain fresh, it is important that we capture the lessons learned from students. Combined with the insights gained from the faculty perspective [58], this investigation identifies a number of issues experienced by students, and reports on their perception of the educational landscape during such a hugely important and formative experience. These observations can help identify new educational approaches that are beneficial to the student experience and should be incorporated into future practice.

The aims of this working group are:

(1) To explore and understand the existing literature and how it has been shaped over the course of the pandemic;
(2) To better understand the impact of COVID-19 on computer science students in a multinational context;
(3) To discover new and/or newly adopted pedagogies, tools, educational practices, delivery methods and techniques employed throughout the pandemic that positively affected the student experiences and should be kept in place going forward;
(4) To share the results with the wider computer science education community.

1.1 Objectives

Since the makeup of the working group members and their institutions could potentially shape the final study focus, the following research questions functioned as a guide for the membership:

- What new and/or adopted pedagogies employed through the pandemic have been beneficial for students?
- How have students maintained engagement with each other through teaching and community building?

In the broadest sense, the motivation was to explore what we could learn about the impacts that COVID-19 has had on the overall student experience in computing education and how this would shape student expectations moving forward.

2 BACKGROUND

The efforts of this Working Group build upon the existing work carried out for a previous pandemic-related Working Group [57, 58]. While the previous study focused on the experiences of faculty during the pandemic, this study concerns itself with the student experience.

Given the nature of this new focus on students, a further literature review had to take place. It was important to update the source literature with any work that had been published since that previous study, and to ensure student perspectives were a key theme.

There are therefore two main streams of work reported in this report in parallel: results of a multinational survey and corresponding results from the background literature. The review of existing literature is broken up into themes. Because of this, the structure of this Working Group paper will somewhat deviate from tradition. While section 3 expands upon the methodology employed to tackle the aforementioned two streams of work, the sections that follow were informed by the survey. In each of these themed sections 4 through 9, the relevant prior work is presented first, followed by any applicable results from the survey we conducted, and concluded with a discussion.

3 METHOD

Based on the work of an ITiCSE 2021 working group exploring faculty experiences throughout the COVID-19 pandemic [57, 58], the areas of exploration for this working group were identified.

3.1 Review of Prior Work

As a starting point, the foundational work and literature review of [58] was explored, with a focus on identifying articles that touched on the student experience through COVID-19. Given the wide-scale effects of COVID-19 on the educational experiences of all, the body of literature in this area has been steadily growing since that work. The team searched for papers in the ACM Digital Library (Full-Text Collection) and the IEEE Xplore Digital Library by submitting queries looking for literature relating to computing education, higher education, and the student experience which included 'COVID-19', 'COVID' or 'pandemic'. The search was then refined by year to pick out papers that had been published since the start of the previous foundational work in mid-2021, selecting the major CS education conference sources (SIGCSE, ITiCSE, ICER, UKICER, Koli Calling, FIE and EDUCON).

We used inductive reasoning to organize this collected group of papers into one or more key themes, as defined in Section 3.2. This approach allowed the previous work and research questions to narrow the scope of the study. Each of these distinct areas was further explored. Pilot reading and manual filtering were then undertaken. Each key theme was assigned a lead and backup researcher who read the papers to agree on their appropriateness for inclusion in the study. A number of papers were excluded for being outwith CS education. Full text reading was then undertaken, and the dataset updated. Unfortunately, not all themes identified suitable literature and an expanded search was necessary. As the team started identifying gaps in the computing education literature, sources outside of mainstream CS education were consulted where findings could be relevant to students regardless of discipline, particularly relating to mental health and well-being and development of community.

3.2 Key Themes

The process of conducting the literature review allowed for themes to emerge. Initially articles were listed, and the emerging themes highlighted in the data set. The articles were then reviewed and key

concepts identified followed by grouping around key themes. Six themes emerged from the literature and are the focus of this study. These themes look at the questions addressed in the objectives from a broad perspective, acknowledging that a wide range of student experiences influence learning capacity.

Impacts of Technology: What learning tools were you exposed to? How has the technology used to deliver your learning affected your experience?

Experiences of Virtual Learning: How has your learning been delivered? What is your experience with online, blended and hybrid learning?

Health and Wellness: How have you perceived your mental health throughout the pandemic?

Study Skills and Supports: How have you used and evolved your study skills to cope with this new (and at times, unexpected) way of learning? What was your reliance on support, including instructors?

Community Building: Did you develop meaningful communities of practice with your peers?

Modality Preferences: What 'emergency' practices, or innovations to teaching and learning approaches would you like to see retained in a post-pandemic setting? What do you feel your future educational experience should look like?

3.3 Survey

To understand the impact of COVID-19 on computing education learning, we conducted an international survey aimed at computing students in higher education institutions. The survey is included in Appendix A.

The timing of ITiCSE working groups was such that they are formed and begin work at or very near the end of the traditional conclusion to many university semesters. Data collection from students was challenged by this timeline. As such, the basis for exploration within the student survey was largely shaped by the literature review and by the survey conducted by the previous ITiCSE working group focused on faculty. Key themes from both sources were taken forward into the survey in this working group, allowing for large-scale data collection aimed at enabling quantitative analysis, with a selection of open response questions to allow deeper probing into issues, challenges, and successes.

Drawing from background work [57, 58], the leaders of this working group built a survey, based on a previous survey of faculty members in an ITiCSE 2021 working group. The survey was validated by the working group members, and piloted with 7 participants.

The study was approved by the Research Ethics Board at one of the lead universities, Dalhousie University, and re-certified as required at the universities of all study co-authors.

The survey was hosted as a Microsoft Forms survey at Dalhousie University, and access was provided via a public link. The survey took approximately 10 minutes to complete if all questions were answered. No compensation was provided to survey respondents.

Responses were anonymous, though potentially indirectly identifying, since respondents were asked to indicate the name of their institution and its location, along with their year of study as part of the demographic information collected. For the remainder of the paper, respondents are referred to by their participant number (between P1 and P304) and their level and year in the program (e.g. undergrad 3 or grad 2 to signify an undergraduate in year 3 of their program or a graduate in year 2, respectively). Quantitative data analysis was performed in R, qualitative data coding was conducted in NVivo.

Country	Count	% of Total
United Kingdom	116	38.2%
Canada	67	22.0%
Japan	66	21.7%
United States	31	10.2%
Pakistan	13	4.3%
Brazil	10	3.3%
Switzerland	1	0.3%
Total	**304**	**100.0%**

Table 1: Survey respondents' institution location.

Program Level	Y1	Y2	Y3	Y4	Y5+	No Resp	Total
Undergraduate	29	39	124	57	5	0	254
Master's	24	8	1	0	6	2	41
PhD	4	1	2	2	0	0	9
Total	**57**	**48**	**127**	**59**	**11**	**2**	**304**

Table 2: Respondents' program level by current year of study: Y1 (year 1/ freshman), Y2 (year 2/sophomore), Y3 (year 3/junior), Y4 (year 4/senior), Y5+ (year 5+), no response.

3.3.1 Recruitment & Data Collection. The survey was distributed using a number of approaches: posting to the SIGCSE mailing list and the ITiCSE mailing list, posting to internal email lists of CS department faculty at author institutions, and posting the link to the survey on Twitter. In all cases, recipients were encouraged to share the link with their students, as well as other interested parties.

The survey was in circulation for a total of 46 days between May 23 and July 8, 2022. At cutoff, 323 responses had been collected. Of these, 7 were test responses and 2 were blank entries, so they were removed. An additional 10 were discarded due to respondents listing a major not directly related to computing (e.g. Anthropology, Political Science, Music, etc.). The remaining 304 responses make up our data set.

3.3.2 Demographics of Respondents. The 304 survey participants included students from North and South America, Europe, and Asia, as seen in Table 1. The majority of responses, 83.5%, were from undergraduates, while 13.5% and the remaining 3.0% came from Master's and PhD students, respectively. The full breakdown of respondents' program level by current year of study can be seen in Table 2.

Respondents were from 23 different institutions, 50.7% of them were from the authors' home institutions.

Survey respondents were prompted to identify whether or not they identified as being part of a racial or ethnic minority in their program. As the survey was accessible worldwide and the term

Racial / Ethnic Minority Status	Count	% of Total
Yes	59	19.4%
No	199	65.5%
Unsure	29	9.5%
Prefer not to respond or no response	17	5.6%
Total	**304**	**100.0%**

Table 3: Survey respondents' self-reported racial or ethnic minority status.

Gender Identity	Count	% of Total
Man	196	64.5%
Woman	86	28.3%
Non-binary	8	2.6%
Prefer not to respond or no response	13	4.3%
Prefer to self-describe	1	0.3%
Total	**304**	**100.0%**

Table 4: Survey respondents' self-reported gender identity.

"minority" takes on a different meaning in different contexts, the authors chose to rely on participants to self-identify whether they belonged to an underrepresented group or not. Participants were also asked to report their gender identity. Answers to those questions are summarized in Tables 3 and 4. Figure 1 shows a breakdown of self-reported gender identities of survey respondents by country.

Question 2 asked students to identify their major, in free response form (see Appendix A, Q2). In order to avoid errors due to typos, abbreviations, and institution-specific terminology, participants' majors were verified against the listed majors on the websites of their institutions. The survey respondents reported 42 unique majors directly related to computing. Majors were then grouped into 4 broad categories:

(1) Computer Science
(2) Applied Computer Science
(3) Data and Information Science
(4) Computing for Engineering

In addition to the classic Computer Science major program the Computer Science label was applied to majors in Artificial Intelligence, Cybersecurity, and Software Engineering.

The Applied Computer Science category spanned major programs where computing accompanied studies in other fields like Art, Digital Media, Business, Economics, Finance, Education, Game Development, Cognitive Science, Design, Forensics, Language, or other STEM fields, like Mathematics and Physics.

Majors in Information Systems, Data Science, and Machine Learning were labeled as Data and Information Sciences.

Finally, the Computing for Engineering category was assigned to majors in Computer Engineering, Electronics, and Robotics.

The distribution of undergraduate and graduate students across major categories is shown in Figure 2. Undergraduates make up 89% and 86% of the Computer Science and Applied Computer Science majors, respectively.

Of the 304 respondents, 118 (38.8%) first became students at their institution before the year 2020, 112 (36.8%) entered their school

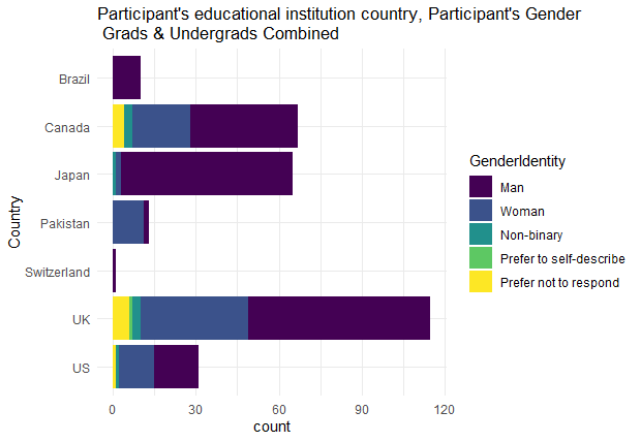

Figure 1: Breakdown of survey respondents' gender identity by country.

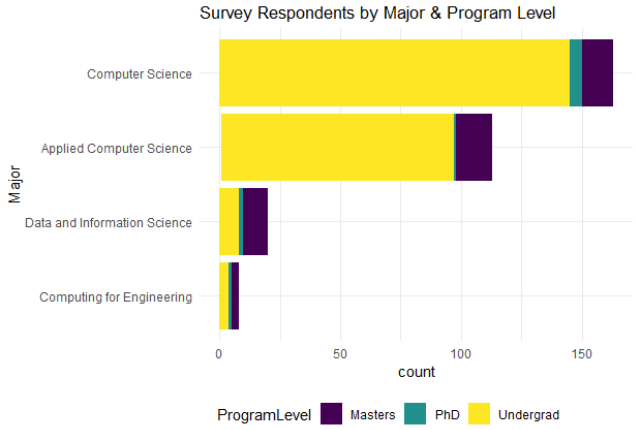

Figure 2: Breakdown of major category by program level.

in 2020, and another 63 (20.7%) joined in 2021. Eleven (3.6%) of the survey participants started at their institutions in 2022. These are shown in Table 5.

Start Year	Count	% of Total
Pre-2020	118	38.8%
2020	112	36.8%
2021	63	20.7%
2022	11	3.6%
Total	**304**	**100.0%**

Table 5: Survey respondents' year of starting at their institution.

During the pandemic, students took classes varying in size, as shown in Table 6. Of the 8 students who didn't study during the pandemic, 2 were students who started at their institution before 2020, 3 began in 2021 and the remaining 3 didn't enter their school until 2022.

Avg Class Size During Pandemic	Count	% of Total
Small (< 50)	95	31.3%
Medium (50-99)	119	39.1%
Large (100-199)	64	21.0%
Very Large (200+)	18	5.9%
I didn't study during the pandemic	8	2.6%
Total	**304**	**100.0%**

Table 6: Average class size taken by survey respondents during the pandemic.

3.3.3 Qualitative analysis. Whilst the majority of questions were quantitative in nature, we included some free text questions. The responses to these were uploaded into NVivo to conduct a thematic analysis. As the key purpose of analysing the free text was to determine what light they shed on the central focus of the study, we chose to code the transcripts according to the themes identified in Section 3.2 but were also open to emerging codes. The coding process was started by one author and then validated by two others. This was captured in a coding book. The key emerging theme was *Vision for the future*. However, within this, most of the discussions of the future referred to one or more of our existing themes, so comments in this coding were double-coded with the particular themes they related to and discussions of the future included in each theme section. Additionally, we developed a more-finely grained interpretation of some themes through emerging coding, particularly as related to tools and support for learning, but felt it was more useful to include these comments within the higher-level theme.

4 IMPACTS OF TECHNOLOGY

4.1 Prior Work

When the COVID-19 pandemic started, modern technology allowed us to remain in contact. In many countries, the readily-available Internet bandwidth and deep proliferation of personal computers and smart devices allowed some to continue the delivery of both K-12 and higher educational programs.

As many classrooms were shut down across the globe, and students and teachers were sent home indefinitely, institutions leveraged the use of various technologies to allow for teaching to continue in a mostly uninterrupted manner, despite its existing limitations and the relative lack of experience on the sides of both teachers and learners. Such a transition to technology-aided course delivery typically requires more time, preparation, and training prior to adoption. Given the abrupt shift to online learning, instructors, institutions, and the technology we chose to use were often far from ready [15]. While technology itself has helped during the pandemic, it has presented its own set of challenges.

With the necessary modifications taken to ensure continued educational delivery, institutions were dealing with new challenges regarding academic integrity and proctoring of online exams [2], despite the fact that tools to implement uniquely identifiable but conceptually identical exams existed before the pandemic [53]. To aid in ensuring academic integrity, some institutions used strategically-placed cameras during at-home exams [63].

Privacy concerns are among the most significant problems with rapid adoption of new tools and technologies [19]. Many institutions have strict policies in place that require new software tools to be thoroughly reviewed and approved before they enter the classroom, and there are certain restrictions on where, how and how long student data is being stored and retained, especially if those students are minors [19, 64]. In the chaos of the first months of the pandemic, these data privacy concerns were sometimes put aside to facilitate a faster transition to an online modality. For vulnerable populations like K-12 students, even simple data points like names, birthdays, or location could be considered sensitive information that should be considered before being shared with the companies or organizations that run education-enabling services. Privacy issues become even more significant when minors are on camera [19]. Thus, certain level of vetting needs to take place before a software or service is used in the classroom. This vetting process, however, takes time.

Through a prior survey with computing faculty [58], it became increasingly obvious that the lists of - often new and untested - tools and technologies that were considered to meet the educational needs of students during the pandemic were extensive; with multiple tools often being proposed by institutions to tackle various needs. The implementation of these tools would at times be set by institutions, but the decision of which tool to deploy would often depend on the preference of faculty members. This resulted in a lack of consistency for students in the early days of the pandemic. For example, in-class communication and lecture delivery might be achieved with Zoom, Microsoft Teams, Blackboard Collaborate or Google Classroom. Student engagement might have been done through tools like Kahoot, Nearpod, Gather.Town, Gatherly, or WebEx. Computer programming labs might have relied on zyBooks, Mimir, Codio, or Jupyter Notebooks.

Research suggests that some of the tools used during remote learning would be useful even after the conversion back to in-person learning [54]. Although implemented under pressure, the transition to online learning has paved the way for additional development and improvement of this modality, and of the technology used to deliver education in this way [51]. At the time of writing, it can be seen that these reflections and lessons learnt are leading to these temporary implementations to facilitate online teaching being made more permanent [10], as a blended modality starts to become more commonplace.

4.2 Results

In the results collected in the survey conducted for this working group, a few things can be observed in regards to the use of technology. Chief among them is the fact that opinions vary from tool to tool, and results are not entirely one-sided. To start, we posed a more general question of how students would rate their experiences in accessing technology and the Internet during the pandemic (see Appendix A, question 13).

Students' (undergraduates and graduates combined) ratings in answer to that question are shown in Figure 3. Ratings are on a 10-point scale. The mean value for online access is 8 for students who began their studies pre-pandemic, and 7.7 for those who started in 2020 or later. The responses were not normally distributed and a

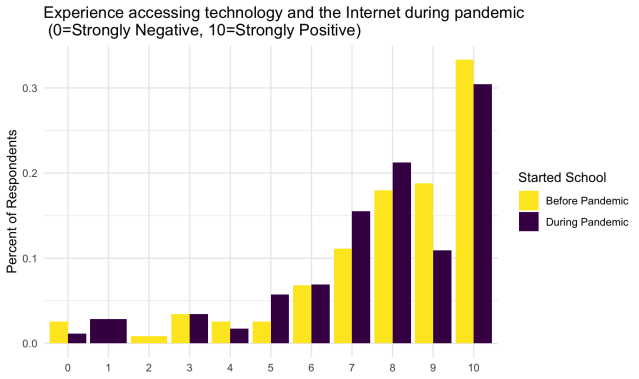

Figure 3: Experience accessing technology and the Internet during the pandemic, grouped by whether respondents began their university studies before (yellow) or during (black) the pandemic.

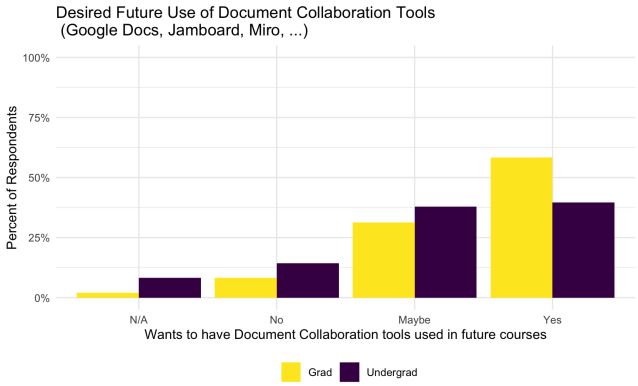

Figure 4: Desired future use of document collaboration tools.

Mann-Whitney test showed no statistically significant difference between them (W = 9317, p-value = 0.2103). For both groups, it is clear that most students did not have a negative experience with accessing technology and the Internet, but the number of students who had poor experiences in this area is non-zero. The students who had a negative experience did not provide qualitative comments to explain their responses. Some respondents experienced difficulties because their instructors' access to proper technology was poor *"some lecturers had very poor Internet connections, or poor quality microphones, and combination of the two"* (P75, undergrad 3).

When asked to rate their experience adapting to new technologies used for learning during the pandemic (see Appendix A, question 12), students' rating on a scale 1-10 was 7.343 on average with a median of 8. This seemingly comfortable transition is probably due to the fact that CS students are already largely at ease with technology.

Additional results involve the specific technologies and tools that students used during the pandemic, and their views on whether they would like to see these tools used upon returning to some form of normalcy.

Document collaboration was an important aspect of the switch to online learning. In tasks like group projects, students needed a way to share work. Applications such as Google Docs, Jamboard, and Miro facilitated this collaboration, and in many cases, they did so even before the pandemic. Upon asking students whether they would like to see these tools used moving into the future (see Appendix A, question 23), the vast majority, 79.5%, of all responding students said they would, or they maybe would (Figure 4). A possible reason for the split between "Yes" and "Maybe" could be that these tools are useful on an "as-needed" basis as not every course involves group work, and not all group work involves digital content collaboration. Furthermore, the desire to continue using collaboration tools could be impacted by a student's individual experiences with collaborative work - not everyone enjoys their time working in a group, for a variety of reasons.

To make online teaching possible and facilitate easier lecture access to students in different time zones, lecture recording was a very common practice during the pandemic. Shown in Figure 5, this was among the most highly one-sided results observed in the technology or modality sections of this study with 75.6% answering in the affirmative and another 14.8% answering "Maybe". This is probably due to the fact that recorded lectures allow students to revisit content at their own pace or to catch up if they miss class - sentiments echoed in participants' comments. As a matter of fact, when asked a free-response question about innovations or new teaching and learning approaches that students experienced during the pandemic and wanted to see continued use of (see Appendix A, question 24), respondents were overwhelmingly in favor of recorded lectures, so much so that several respondents even preferred them to in-person lectures. Among the numerous comments on lecture recordings, one student said *"Live recordings of lectures were a major boon during the pandemic. I cannot stress enough how much I and my friends would love to see this continue"* (P134, undergrad 4). *"I want to see ALL lectures recorded and posted online. Both live lectures or pre-recorded/non-live lectures"* (P64, undergrad 3). One student acknowledged that having those available is great but could lead to undesirable behavior *"Recording (and potentially livestreaming) lectures _additionally_ to having them in person can be helpful in case I miss a lecture. On the other hand it kind of encourages me to miss lectures, because I could always watch them later, which I obviously won't actually do beyond some point"* (P154, undergrad 3).

From the responses to our survey, it is clear that the majority of students, 89.7% of undergraduates and 93.8% of graduates, are in favor of continuing with the use of lecture recordings, even after classes return to in-person learning.

A similarly one-sided result is on the topic of future use of communication tools. Of all respondents, 88.7% answered "Yes" or "Maybe" to their desire for the continued use of tools such as Slack, Discord, Microsoft Teams, WhatsApp, etc. These results are visualized in Figure 6. This could likely be attributed to the improved communication that some students feel can get from their teachers and teaching assistants online, as well as the sense of community that can come from being a few clicks away from communicating with peers. As one respondent noted *"External resources like Microsoft Teams is very useful for communication. It is easier to connect with TAs or professors, and it can encourage problem solving between students"* (P129, undergrad 4). Another added *"Piazza is helpful for*

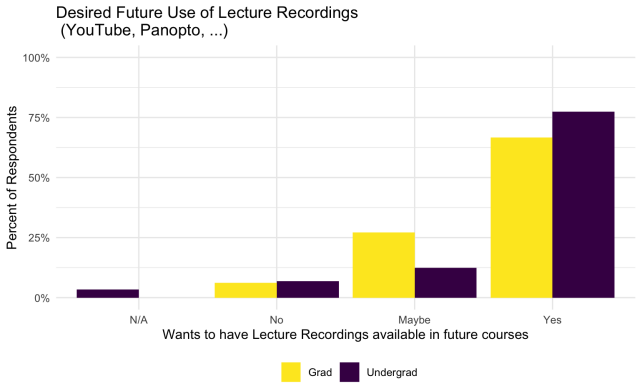

Figure 5: Desired future use of lecture recording

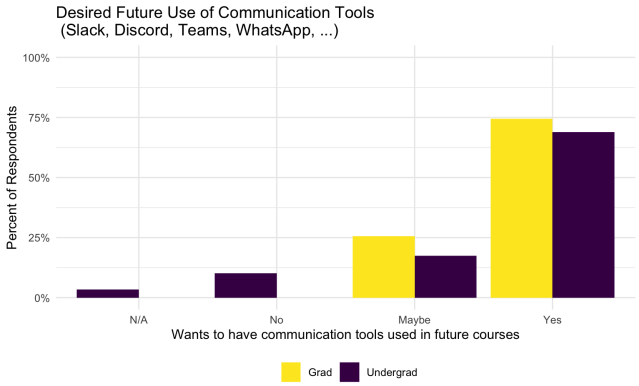

Figure 6: Desired future use of communication tools.

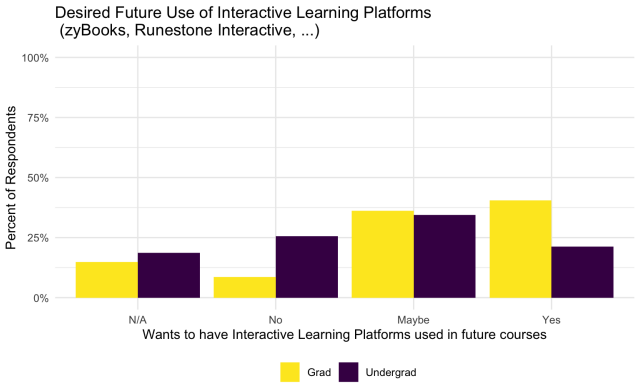

Figure 7: Desired future use of interactive learning platforms.

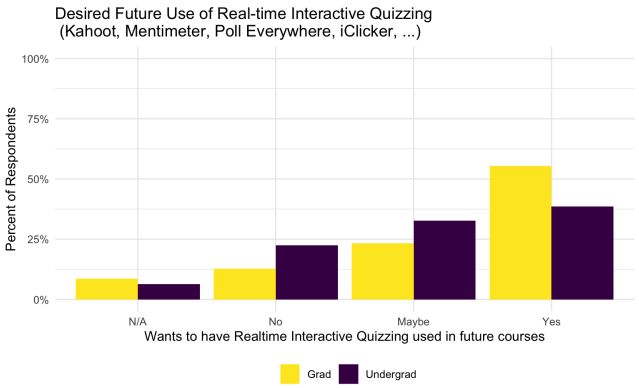

Figure 8: Desired future use of interactive quizzing.

asking questions and having both instructors and students answer" (P150, undergrad 4).

Among the most mixed outcomes are the answers to the question about continued use of interactive learning platforms, as can be observed in Figure 7. When compared to the results from the inquiries about other forms of technology and respondents' desire for their continued use, interactive learning platforms are the only technology for which the majority of students say they would either not want to or maybe want to continue using them. This is also the area with the highest number of "N/A" responses. It should be noted that the responses to this question are not one-sided. The responses of "N/A", "No", and "Yes" are all relatively close to one another with 18.1%, 22.7% and 24.5%, respectively. Only the responses of "Maybe" are higher than the others at 34.7%. The qualitative comments did not provide any further insight into the reasons for these responses.

The last set of results from our survey question about the use of technology is that of real-time interactive quizzing tools, such as Kahoot, Mentimeter, Poll Everywhere and iClicker. As shown in Figure 8, we see a majority of students saying that they would like to see these tools used in the future. However, there is a much larger number of "No" (20.8%) and "Maybe" (31.1%) responses. The qualitative comments did not provide any further insight into the reasons for these responses. Survey respondents who commented on interactive quizzing expressed sentiments that they'd like to see those continue to be used *"I really enjoy when an instructor includes a quick Mentimeter or Kahoot in their lecture. It helps cement important ideas in my mind and gives me an insight into what the instructor considers the key points are"* (P213, undergrad 4), *"online quizzes and tests that gets marked instantly"* (P99, undergrad 2).

Students wanted to see all materials made available online, more hybrid instruction, many said they didn't mind online lectures but wanted those to be recorded and made available so they can rewatch them later. Some students expressed liking the flipped classroom approach. About a third of respondents reported either not seeing any innovations beyond Zoom or other similar software that was necessary to make instruction possible, or not wanting any of these innovations to be retained in the future. One student commented *"No, everything should be in person. 'Innovation' = doesn't work half the time"* (P172, undergrad 4). However, most students expressed their desire to see the continued use of technology enabling classroom discussion, interactive textbooks, recorded video materials, video communication software for office hours etc. even after their return to the in-person classroom.

4.3 Discussion

The approach taken and aided by technology usually depended on the course curriculum, the instructor and the institution. Results show that student experiences were often quite different, even within the same department. Some courses may be better suited to online learning than others, and some tools may be better suited to one particular course. There is still a lot of work to be done to better understand how technology can be leveraged to better support student learning. However, our results suggest that, at least for computer science students who are generally comfortable with the use of software, some technological steps taken to ensure emergency remote teaching may be worth keeping in place going forward. In particular, using communication tools and recording lectures and making them available for students to revisit seem to be what the majority of students would like to see used even after the return to normal.

5 EXPERIENCES OF VIRTUAL LEARNING

5.1 Prior Work

The existing literature shows mixed impressions of teaching and learning of Computer Science during the pandemic. For example, a small survey (n=10) conducted with instructors in CS and Engineering disciplines [24] suggested that teachers felt that their instruction was more effective during the pandemic. Some teachers perceived that their CS/engineering students were able to concentrate more and that the CS educational platforms available provided an advantage. Similarly, a study of 22 Computer Science instructors in Norway by Hjelsvold et al. [27] reported overall positive experiences of CS instructors. These studies, which represent instructor viewpoints on pandemic teaching that are more positive than negative, stand in contrast with some empirical data which showed less positive impacts on students.

YeckehZaare et al. [73] examined ebook usage before and during the pandemic to understand how much time students spent studying and how much spaced practice they engaged in. The study found that both of these were lower during the pandemic than in previous semesters. The researchers note that comparing study time across semesters before and during the pandemic is a better gauge of performance than considering grades, which may be inflated by a lack of exams, pass/fail grading, or unproctored online exams with the possibility of rampant cheating. Similarly, Aucejo et al. [4] studied students' weekly study hours during the pandemic and found that students spent on average 0.9 fewer hours studying per week due to COVID-19. Also due to the pandemic, study time decreased by 5 hours at the 25th percentile and increased by 4 hours at the 75th percentile.

Gonzalez et al. [25] reported on results of a survey about COVID-19 remote learning experiences of students in an information technology degree in Norway. They highlighted three themes related specifically to the use of tools in digital learning: fear of exposure, slow transition away from active learning and participation to more traditional lecture, and challenges related to media quality and chat usage. In the fear of exposure theme, the authors highlight that students reportedly did not want to participate or turn on their cameras, because many of their peers wouldn't be on camera either. In terms of active vs. traditional learning, students felt that their instructors seemed frustrated by everyone's cameras being off and that this led to teachers attempting to engage students less frequently. Students reported preferring live lectures to just prerecorded lectures, but wished the live lectures were broken up with interactive activities. In the media and chat theme, some of the students in the Norwegian survey disclosed that they found the chat distracting, and reported that their instructors seemed distracted by it as well. However, others liked the ability to ask and answer questions with classmates.

Lohiniva et al. [40] conducted a qualitative interview study of novice programming students' experiences studying during the pandemic, focusing on factors impacting motivation. They found that students experienced lower levels of motivation to study resulting from pandemic worries and lack of time, and also difficulties in coordinating collaboration. These results demonstrate the importance of community and self-belonging to help students stay motivated to study. In a similar study, Thiry and Hug [65] surveyed over 900 computing students at Hispanic-serving institutions in the US to understand their experience with learning in the early part of the pandemic. They found that students at these institutions reported serious financial and mental health challenges, but they also reported that some of their instructors supported them by arranging for laptops and WiFi hotspots and holding Zoom practice sessions just prior to the move to emergency remote teaching. Such supports were reported by students as helpful in the transition to remote learning.

The move to emergency remote teaching led to a number of innovative practices, and students' experiences of these practices have been evaluated by researchers in some cases. For example, VenDeGrift et al. [67] implemented a system for students to record and upload videos explaining their exam answers. While this was intended to deter cheating, students reported a variety of positive benefits, including the chance to review, reflect and correct their answers. There were also innovations in delivery formats. Various instructors tried non-conventional platforms to engage students in online learning, and formally studied student experiences. For example, Latulipe and De Jaeger [34] analyzed student learning experiences in a CS1 course held in Gather.Town. They found that students felt more like they were in a real classroom and appreciated the agency to express themselves, move around the virtual classroom, and engage in smaller conversations while still remaining connected to the larger class. Similarly, Najjar et al. [48] used Gather.Town across 5 different computing courses and conducted a formal survey. Their students found that courses taught in the platform allowed for easier collaboration and interaction with others, fostered a stronger sense of connection to peers, and made the learning experience fun. These results show that pandemic-induced innovations in certain cases led to positive student experiences of virtual learning.

Some prior work has shown positive or mixed reactions to virtual learning in CS, especially during the initial Spring 2020 switch to remote learning. Lishinski et al. [39] found that 40% of CS1 students surveyed in the initial move to emergency remote learning found the change very difficult. Moore et al. [47] studied video-watching behaviour in a flipped CS1 course. Students with prior programming experience watched fewer videos and students performed similarly on tests despite their vastly different video-watching behaviours.

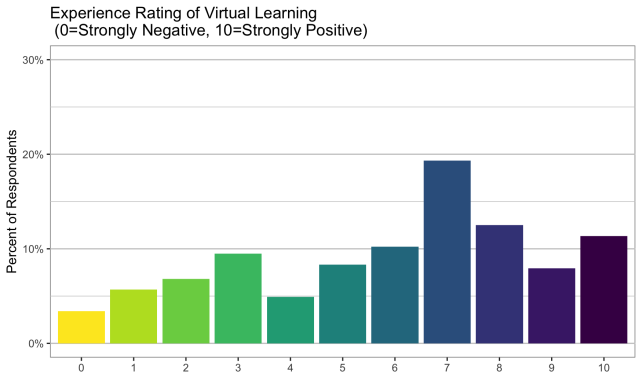

Figure 9: Histogram of respondents' ratings of their virtual learning experiences during the pandemic (0 = Strongly Negative, 10 = Strongly Positive).

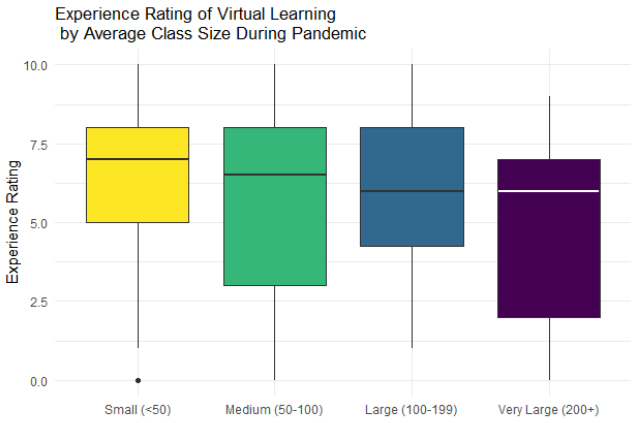

Figure 10: Boxplot of respondents' ratings of their virtual learning experiences (0 = Strongly Negative, 10 = Strongly Positive), grouped by reported typical class size during the pandemic.

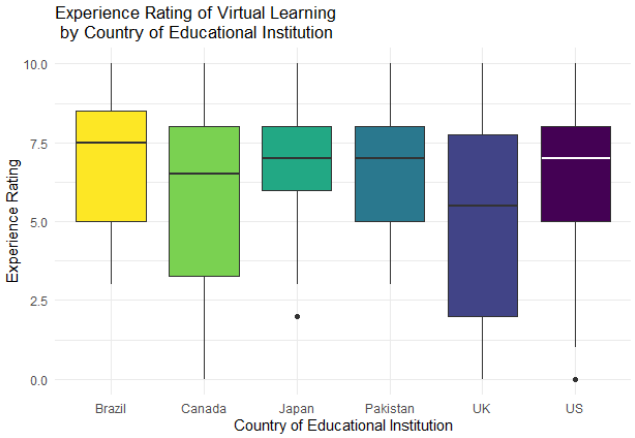

Figure 11: Boxplot of respondents' ratings of their virtual learning experiences (0 = Strongly Negative, 10 = Strongly Positive), grouped by country of educational institution.

This study covered the Fall 2019 and Spring 2020 semesters, and so data collection included several weeks at the end of the Spring 2020 semester when the course being studied went online. The authors did not detect any change in video-watching when the in-class portions of the course moved to online synchronous sessions, suggesting that students' study behaviours tend to be set patterns and did not change significantly, at least in the initial switch to online learning. Similarly, Lewis et al. [37] studied 6 computing classes at University of California San Diego (UCSD) comparing student data in Spring 2020 to prior semesters and found that students reported similar levels of stress and challenge. However, they did find decreases in students' level of peer connection, and there were higher rates of dropping and/or failing courses.

5.2 Results

We examined student respondents' ratings of their virtual learning experience (see Appendix A, question 11) to see how these differed across demographic dimensions and how they differed according to the characteristics of their classes taken during the pandemic. Figure 9 shows the histogram of student experience ratings of virtual learning during the pandemic. The mean rating was 5.587, the median was 6.

We see that ratings of virtual learning experiences were higher for smaller class sizes than for larger class sizes, as shown in Figure 10.

Figure 11 demonstrates that experience ratings of virtual learning during the pandemic differed depending on the country of the educational institution.

We found no differences in ratings of virtual learning experiences by gender, as can be seen in Figure 12. We also found no differences based on respondents' self-reported status as a racial or ethnic minority within their program.

Interesting differences in student experience ratings appear when the data is sliced according to the percent of each respondent's classes that were taught online synchronously versus asynchronously. Figure 13 shows these ratings. The data indicates a negative correlation between experience ratings and the proportion of courses taught asynchronously, and a positive correlation between experience ratings and the proportion of courses taught synchronously. This result was confirmed statistically using a linear regression model, which showed the proportion of online courses taught synchronously was predictive of experience ratings (t-value = 2.712, p = 0.00732). Some student comments reflect issues with asynchronous learning, such as *"Felt Extremely disconnected to everything taught, was forced to [teach] myself most of the content through Google, very hard to understand things without a live demonstration or lectures or lab classes"* (P79, undergrad 2). In contrast, students who had synchronous classes in some cases had two opportunities to engage: during the live lesson, and then by rewatching the recording, as noted by P106, grad 1 who commented *"Lectures*

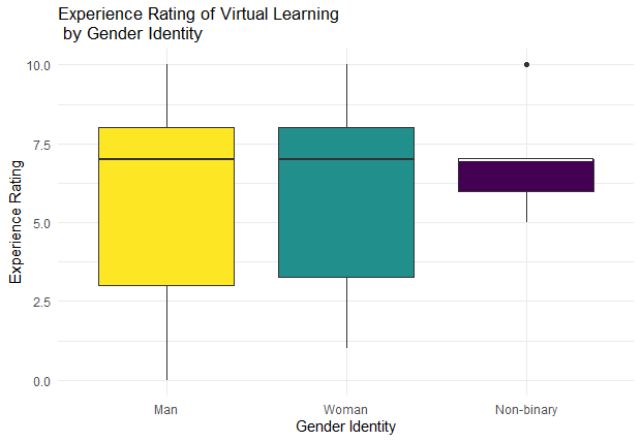

Figure 12: Boxplot of respondents ratings of their virtual learning experiences (0 = Strongly Negative, 10 = Strongly Positive), grouped by respondent's self-reported gender identity.

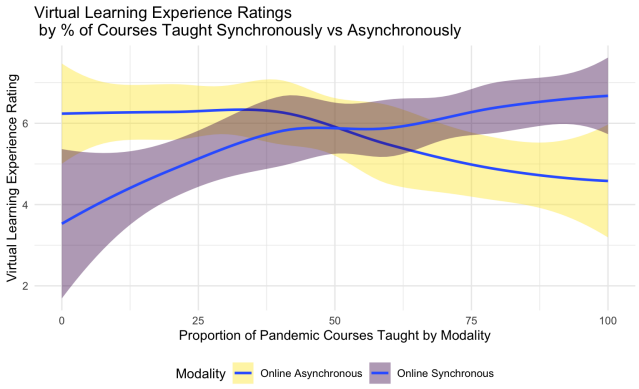

Figure 13: Virtual learning experience ratings (0 = Strongly Negative, 10 = Strongly Positive), plotted against % of respondent's pandemic online courses taught asynchronously (yellow) and synchronously (purple) during the pandemic.

worked just as well online (in fact it was an advantage them being recorded and being able to rewatch them when studying)".

The open-ended responses from students about their virtual learning experiences (see Appendix A, question 19) highlighted the polarity between loving or hating online learning. Some students found it exceedingly difficult, such as an undergrad respondent who said, *"My learning experience during the pandemic was significantly worse than any other time. My grades have been much lower during any online class than any in-person classes, and I can feel that the content is not being retained nearly as well."* (P29, undergrad 1) This is in contrast to students who really enjoyed it, such as this undergrad who noted *"I learned that this distance method of learning works exceptionally better for me than on campus teaching. I'm more productive, lessons are far more enjoyable, I have the ability to push myself further with my coursework than I can with on campus classes. I am not distracted by meaningless conversations happening in class spaces."* (P72, undergrad 3)

5.3 Discussion

Very little data exists on students' actual learning during the pandemic. Being fully aware that the difficulty and uncertainty of the situation put even more stress on students, and sharing into that stress by a suddenly heightened workload, institutions and instructors made a number of concessions. By putting less focus on assessment, allowing the transition to pass/fail grades, and putting policy changes into place to allow for that (e.g., removing student evaluations from tenure and promotion consideration, foregoing office hours, etc.) much of the actual learning was washed away in the effort to keep things moving.

The relationship between virtual learning experience ratings and country of educational institution, while interesting, should not be considered representative. For some of these countries the students reporting were all from one or two institutions. To understand country level differences in any meaningful way, a more diverse sample of students from each country would be needed.

We found the trends in virtual learning experience ratings versus online modality to be particularly compelling. Given the widespread pandemic-related lockdowns, providing synchronous classes was potentially one of the only ways that students could interact with others. Synchronous classes, if done well, with reasonable use of breakout rooms, could allow students to interact with one another. However, what we saw in student comments is that this wasn't typically done well, but that students interacted with one another in real time using chat features, and that created at least a temporary sense of community.

6 HEALTH AND WELLNESS

6.1 Prior Work

While we found an overall lack of research on the impacts of COVID-19 on the mental health and well-being of CS students in particular, there is a wealth of research for students in general, and it is reasonable to assume that these findings will be replicated to a large extent in CS students. However, there is some research that indicates that CS students may be more vulnerable to mental illness than the general population: Passos et al. [49] demonstrated that a group of CS students showed higher levels of anxiety and depressive symptoms than either the general population or medical students. In a group of 174 students, the researchers found that 81% reported that their well-being had been negatively affected by the pandemic, with social isolation being the most reported factor, followed by delay in academic progression, risk of infection and death of family and friends. They found that both the number of factors affecting well-being and the mean number of negative feelings were higher for female students [49].

Mooney and Becker [46] investigated the impact of the pandemic on computing students' sense of belonging as discussed in section 8. Their study was motivated by a university-wide survey of the students at their university in 2020 where half of students ranked "COVID-related stress and anxiety" as "extremely challenging" or "very challenging".

These findings are broadly in line with research exploring the impact on students generally. Multiple studies in many different countries found mental well-being in students was negatively affected by the pandemic, and where the sex of the respondents was considered, female students largely reported more negative impact than male.

As noted by Schlesselman, Cain, and DiVal [55], not all students responded to the pandemic similarly as each person has a unique set of resilience factors which only become particularly apparent during traumatic events. A variety of factors affect how traumatic the pandemic period was for any particular student.

Many studies found immediate negative impacts on students from COVID-19. Section 8 discusses many of the issues surrounding community building during the pandemic. Isolation and loneliness are highlighted in much of the literature around mental health and well-being as being exacerbators of poor mental health, depression and anxiety, so the discussion in section 8 is very pertinent to the issues discussed here.

Several papers reported increases in stress and anxiety (e.g., [16, 26, 29, 31, 62, 78] and difficulty in focusing on learning ([31, 62]). Chierichetti and Backer [12] reported the results of surveys that were administered to US university students in Spring and Fall 2020 to understand the effects of the COVID-19 pandemic. 79% of students reported either a moderate or a great deal of stress related to having to stay at home. Chirikov et al. [13] found that the prevalence of major depressive disorder amongst graduate and professional students at 10 American universities in 2020 was double the prevalence from 2019, and generalised anxiety disorder was 1.5 times higher.

Issues around mental health and anxiety were generally found to be worse for female students [26, 52]. Other groups identified as being particularly at risk include students of color, LGBT students and students who are caregivers [13] as well as rural, low-income and academically underperforming students [36]. In addition, Cao et al. [11] found that living in an urban area, living with family and having a stable family income were protective factors against anxiety while having relatives and friends with COVID exacerbated anxiety.

Evans et al. [18] provided longitudinal analysis of 254 UK undergraduates, mostly female, finding that over a third of them could be classified as clinically depressed, as opposed to 15% in 2019, prior to lockdown. Son et al. [62] also found that 86% of 195 US students reported disruptions to sleep. In contrast to some popular narratives around behaviour during lockdown, Evans et al. [18] found that alcohol consumption decreased in the students they surveyed; however, Zimmermann, Bledsoe and Papa [78] found that a quarter of the 205 US students they surveyed reported using drugs and alcohol to manage pandemic-related stress, and Prowse et al. [52] also reported similar findings for Canadian students.

Wasil et al. [70] looked into what the common stressors were for 305 students - specifically graduate and professional students - during the pandemic, and strategies they used to ameliorate these. The key factors identified were problems with productivity (27%), physical health (26%) and emotional health (14%). Students that commonly used strategies that they believed to be effective (primary behavioral patterns such as exercising and social strategies such as seeing friends) to deal with these issues reported 29% lower depressive symptoms than those who believed their common coping strategies were not effective (for example, watching television).

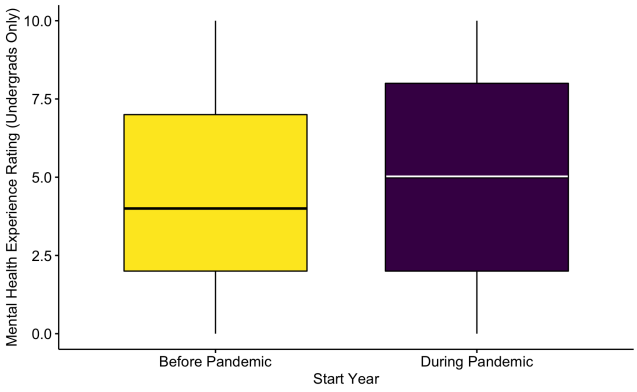

Figure 14: Boxplot of undergraduate survey respondents' rating of mental health/personal well-being during pandemic (0=Very Negative, 10=Very Positive), grouped by when the respondent first became a student at their current institution.

In addition to increasing existing anxiety symptoms, new symptoms emerging from the pandemic, like concerns about contracting illness, or concerns for the safety of family and friends, were commonly reported [26]. Where students from different regions were surveyed, concerns about mental health were found to correlate with pre-pandemic patterns (for example, mental health issues appeared to be higher in the US) [26].

Eaton and Turner's [16] small study suggested potential issues of academic integrity were exacerbating mental health difficulties in students. This research in particular provides emerging evidence that e-proctoring exacerbates stress levels far beyond what might normally be expected in face-to-face exams.

Conrad et al. [14] found that students who were mandatorily relocated due to campus closures reported higher levels of grief, loneliness and anxiety, especially those who had to leave personal possessions behind.

There is evidence of serious ongoing mental health issues coming out of the pandemic. Research on 4355 students in Wuhan [38] - where the pandemic was originally reported and where lockdown was severe and prolonged - found that 16.3% of students were assessed as having post-traumatic stress disorder (PTSD). In contrast to several reports that found female students suffered more severe mental health issues, this research found that male students were more likely to suffer from PTSD, with older male postgraduate students specifically at risk.

6.2 Results

Figure 14 shows a boxplot of undergraduate students' ratings of their mental health/personal well-being during the pandemic grouped by the year students started their program of study (see Appendix A, question 14). The overall mean rating was 4.717 and the median was 5.0. Undergraduate students starting at their current institution before the pandemic reported slightly lower mental health experiences (mean 4.5, median = 4) compared to students starting

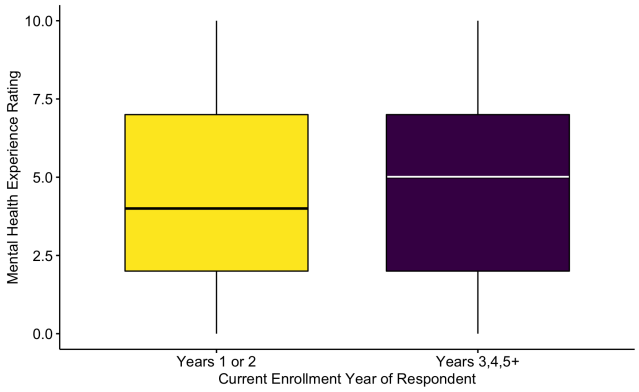

Figure 15: Boxplot of undergraduate survey respondents' rating of mental health/personal well-being during pandemic, grouped by their enrollment year at time of response (0=Very Negative, 10=Very Positive).

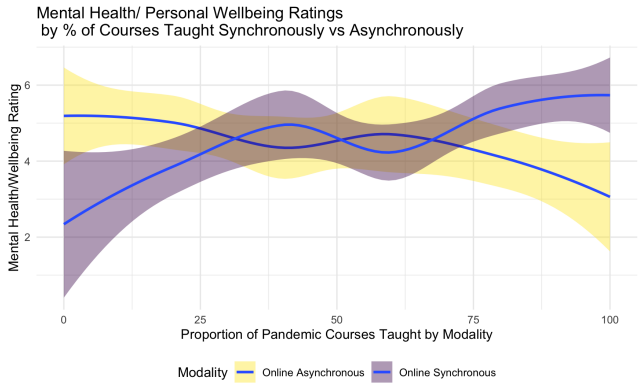

Figure 16: Undergraduate survey respondents' rating of mental health/personal well-being during pandemic (0=Very Negative, 10=Very Positive), plotted against % of respondent's pandemic online courses taught asynchronously (yellow) and synchronously (purple) during the pandemic.

at their institution during the pandemic (mean = 4.8, median = 5). These figures suggest that ratings of mental health and personal well-being were slightly worse for students starting pre-2020, but per a Mann-Whitney test (as ratings are not normally distributed) the difference was not statistically significant (W = 8056, p-value = 0.335). Slicing the mental health ratings data by program level (graduate vs. undergraduate) did not show any significant differences (W = 5372.5, p-value = 0.903).

When comparing whether mental health and personal well-being ratings differed depending on the year of study of the respondent, there was also no significant difference noted. Figure 15 shows a boxplot of mental health and personal well-being ratings from students, grouped by respondents in years 1 and 2 of their studies vs. respondents in years 3, 4, and 5 of their studies. The mean rating for students in years 1 or 2 is 4.365 and the median rating is 4.0, whereas the mean rating for students in upper years is 4.837 and the median rating is 5.0. The boxplot suggests that ratings of mental health and personal well-being were slightly worse for students currently in years 1 and 2 of study, but not statistically significant (per a Mann-Whitney test with W = 5257.5 and p-value = 0.269).

An investigation into the relationship between online class modality during the pandemic indicated that mental health ratings had a positive correlation with the proportion of online classes taught synchronously and a negative correlation with the proportion of online classes taught asynchronously, as shown in Figure 16. This relationship was confirmed statistically using a linear regression model, which showed the proportion of online courses taught synchronously was predictive of mental health ratings (t-value = 2.197, p = 0.0293).

Student health and well-being was a subject that came up frequently in the free-form comments. In line with what we found in the existing literature, most comments around mental health were negative, with a significant focus on loneliness and isolation: "*[there] was a lot of loneliness and learning to do things on my own, I felt very isolated*" (P32, undergrad 3), *"I got really isolated by living alone"* (P34, grad 3), *"It was difficult to adapt to extreme isolation, truly a soul-altering experience"* (P204, undergrad 3). One student mentioned that having moved for studying meant they were very susceptible to isolation. Lack of exercise due to lockdown and difficulty sleeping were also mentioned as challenges: *"I even can't fall asleep normally"* (P161, grad 5+). One student highlighted how constantly being online - for work, socialising, entertainment, etc. - led to feelings of burnout. There were many comments from students around lack of community and networks, with clear linking of this to mental health challenges for some students *"The lack of socialising made it much less like a university feeling, leading to mental health issues"* (P99, undergrad 2), *"the social skills I had built up through in person were severely diminished"* (P176, undergrad 5+). A neurodivergent student (P3, undergrad 2) reported finding it nearly impossible to learn in online lectures.

However, a few students had more positive views on the pandemic's impact on their well-being, and valued that the flexible approach to learning and the opportunities of remote learning. *"Having online classes didn't impact me as much because I have difficulty paying attention to classes, and end up studying everything on my own anyway"* (P17, undergrad 3), *"Not having to waste on commuting and having a flexible schedule was a big positive for me"* (P17, undergrad 3), *"Maintaining a consistent schedule is extremely difficult, particularly with mental health issues and things like burnout, so being able to drop in and watch pre-recorded lectures when I was "in the mood to" contributed substantially to my academic success during the pandemic"* (P65, undergrad3). Some students struggle with social issues on campus, and these students may find benefits in remote learning: *"I don't feel alone when I study at home, whereas on campus I feel alienated and isolated due to a variety of personal factors"* (p72, undergrad 3).

It is important to note that whilst the literature supports the theory that mental health in students declined during the pandemic and provides a basis for believing that this is likely to be the case in the students surveyed, we do not have any direct evidence to prove this is the case. The survey asked students about their mental health during the pandemic, and did not ask them whether they perceived any change in their mental health prior to the pandemic. We also

do not have any data about the mental health and well-being of this group of students outwith this survey.

6.3 Discussion

Both the literature review and the results from our survey follow the general narrative we have seen developing during the pandemic: that mental health and well-being have been negatively affected, with feelings of isolation and anxiety intensified when compared to pre-pandemic levels. One interesting finding in our survey responses was that while student comments largely followed the patterns in the literature, some students commented positively on how COVID-19 affected their mental health. While few students want to see a continuation of the kind of remote learning they did during COVID, many of them also do not want to see a wholesale return to pre-pandemic learning. Instead, many students want to see aspects of pandemic learning continue - primarily recorded lectures and options for hybrid learning - while returning to face to face for other aspects. A move towards more flexible education, with different options for students with different needs, could help to improve student well-being for all.

Additionally, educators will need to be aware of and responsive to the trauma and challenges students have faced during the pandemic years, and be sensitive to the ways in which it will affect learning in the future.

7 STUDY SKILLS AND SUPPORTS

7.1 Prior Work

There is a lack of literature on students' study skills during the pandemic. The available studies focused on early 2020 when universities adopted emergency online instruction. Students inevitably struggled through this sudden change to online learning. Boardman et al. [7] surveyed 109 undergraduate students in a liberal arts college - finding that students felt less motivated to work and spent more time procrastinating after the switch to emergency online learning.

Fortunately, the emergency move to remote instruction in early 2020 positively impacted students by encouraging self-regulated learning. Korkmaz et al. [32] surveyed and interviewed students in traditional and online flipped classes during the Spring 2020 semester at Middle East Technical University in Turkey. They found that students' self-regulation skills improved significantly at the end of the semester. One possible explanation for this is that online learning might have forced all students to self-regulate their learning more than usual. Similarly, Watson et al. [71] measured students' self-directed learning readiness in undergraduate engineering courses at The Citadel, a US residential military college. The results showed that for all the students except juniors, their self-directed learning increased during the six weeks of emergency online instruction.

Instructor support is vital for students' learning, and that was especially true during the pandemic. Lohiniva et al. [40] showed that students in an introductory programming course found it imperative to receive feedback, help and encouragement from the instructor.

During the pandemic, many instructors adopted virtual office hours to help and support their students. These virtual office hours were highly utilized [22, 30]. Gao et al. [22] found that virtual office hours were significantly more utilized compared to in-person office hours but had longer interactions and wait times in a CS2 course. Similarly, Jiang and Simion [30] found that instructor virtual office hours were overwhelmingly busy, which may deter students from using them.

Virtual office hours encourage attendance from students with specific characteristics. In an online CS2 course, Gao et al. [22] found that students with low confidence and low enjoyment of solving CS problems were more active in virtual office hours. They hypothesized that virtual office hours offer students a sense of security and make them less embarrassed when asking simple questions. Moreover, attending virtual office hours correlates significantly with an increased interest in CS study. The researchers recommended offering in-person and virtual office hours in the future since the virtual option attracts students with low confidence and low enjoyment, whereas the in-person option may minimize wait time [22].

Some instructors took it one step further to offer more virtual help to students during the pandemic. For instance, Bridson et al. [9] experimented with providing round-the-clock support to students using Discord in a remote software engineering course. They received a high volume of positive feedback — students mentioned liking Discord and the availability of round-the-clock help. They found that the 24/7 approach led to a considerable increase in student-teacher interaction compared to in-person office hours and an online discussion forum. Students from underrepresented groups utilized Discord as much as the other students.

Overall, despite the sudden shift to online instruction, teachers made use of novel technologies to provide sufficient virtual help to students. Students reported receiving adequate support and guidance from instructors during online learning [9, 35].

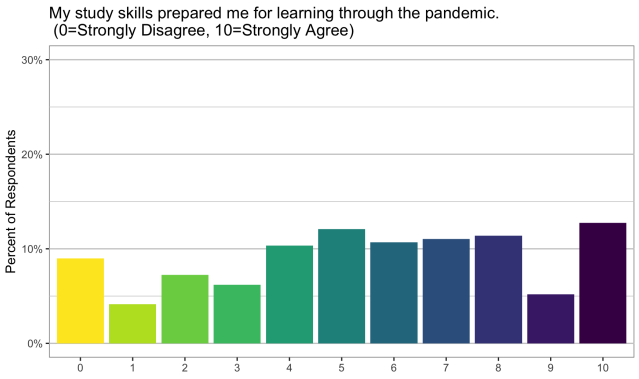

Figure 17: Histogram of respondents' agreement with "My study skills prepared me for learning through the pandemic." (0=Strongly Disagree, 10=Strongly Agree).

7.2 Results

Figure 17 shows the histogram of student agreement with the Likert scale statement *"My study skills prepared me for learning through the pandemic"* (see Appendix A, question 15). The mean agreement score was 5.332, and the median was 5.

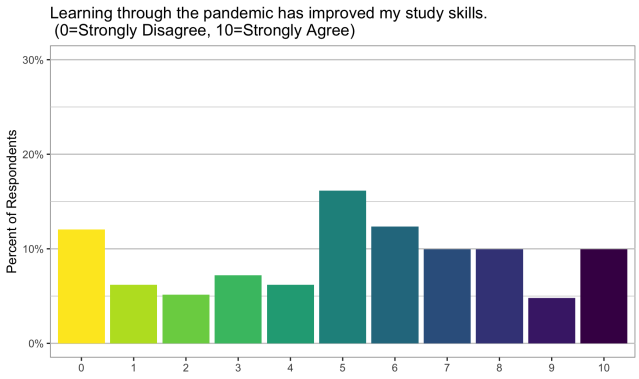

Figure 18: Histogram of respondents' agreement with "Learning through the pandemic has improved my study skills." (0=Strongly Disagree, 10=Strongly Agree).

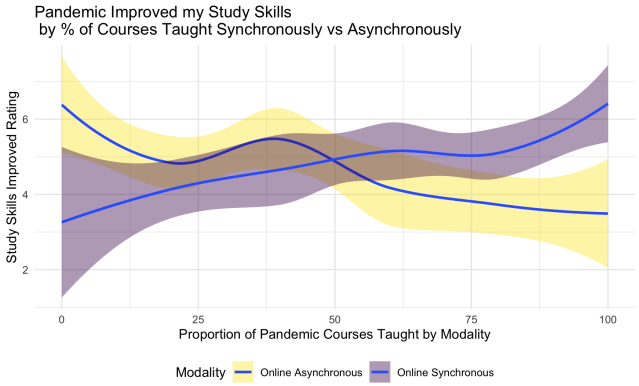

Figure 19: Undergraduate survey respondents' agreement with "Learning through the pandemic has improved my study skills." (0=Strongly Disagree, 10=Strongly Agree), plotted against % of respondent's pandemic online courses taught asynchronously (yellow) and synchronously (purple).

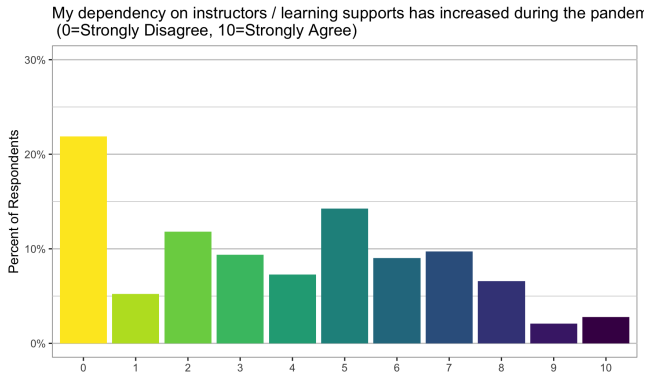

Figure 20: Histogram of respondents' agreement with "My dependency on instructors / learning supports has increased during the pandemic." (0=Strongly Disagree, 10=Strongly Agree).

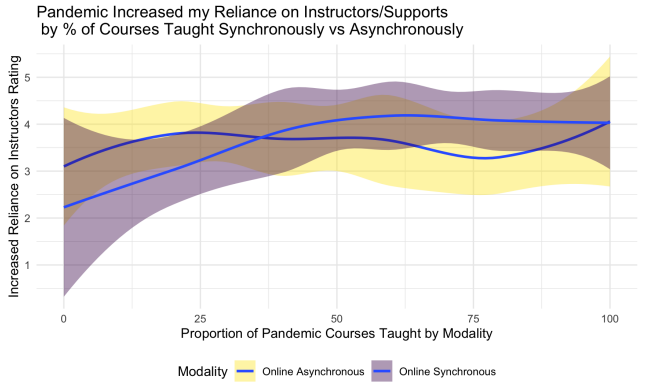

Figure 21: Undergraduate survey respondents' agreement with "My dependency on instructors / learning supports has increased during the pandemic." (0=Strongly Disagree, 10=Strongly Agree), plotted against % of respondent's pandemic online courses taught asynchronously (yellow) and synchronously (purple).

Similarly, Figure 18 represents the histogram of student agreement with the statement *"Learning through the pandemic has improved my study skills"* (see Appendix A, question 16). The mean agreement was 4.895, and the median was 5.

An investigation into the relationship between undergraduate student respondents' agreements with their study skills improving and the proportion of online courses taught synchronously vs. asynchronously showed a positive correlation between improved study skills and the proportion of synchronous courses, as shown in Figure 19. This relationship was statistically significant, with a linear model showing predictive power of the proportion of classes taught synchronously on the ratings (t-value = 2.657, p-value = 0.00859).

An additional statement, *"My dependency on instructors / learning supports has increased during the pandemic"* (see Appendix A, question 17) was posed to survey participants and the histogram of their agreement can be seen in Figure 20. The mean agreement score was 3.739, while the median was 4.

Investigating the relationship between increased reliance on instructors and study supports and the proportion of online courses taught synchronously vs. asynchronously showed no difference by modality (see Figure 21). This was confirmed by a linear regression model which showed no significant predictive power of modality on ratings (t-value = 0.655, p-value = 0.513).

To understand students' perception of their study skills, we asked them to describe the study skills they are lacking going forward (see Appendix A, question 22). Students' free-form comments highlighted several themes regarding concentration, time management, communication, and assessments.

Participants in the study highlighted a lack of concentration and focus with some commenting for both online classes and the

return to in person teaching. *"In online classes, I struggle to pay attention properly, which is not an issue I have with in-person lectures"* (P29, undergrad 1). In contrast, *"being able to pay attention in class [face to face], was much easier to watch a video and pause when I need to take notes. I always fall behind with note taking during class"* (P53, undergrad 2). Overall, the participants highlighted a need to improve their concentration skills and noted that the pandemic had impacted this ability – *"focusing on lectures and paying attention in class, watching videos all day has reduced my attention span massively"* (P79, undergrad 2).

The difficulty with concentration was often combined with a lack of time management or scheduling skills. The pandemic brought into focus the difficulties of scheduling and finding a balance between work/study and life – *"[lack] the ability to organise my own time and create a clear divide between my study/work time and my free time"* (P146, undergrad 3). Participants were also aware that their skills had changed - *"since everything was online and I could access the slides and videos at any time, I don't feel like I have been making a consistent studying routine for the last 2 years"* (P157, grad 5+). Time management was very closely aligned to difficulties with motivation and procrastination with students highlighting the difficulties faced when trying to use one space for leisure, sleep and study.

Students were also aware of the impact on their social skills and networking opportunities, both with their peers and professors. This was closely linked to more general communication skills with one comment summing this up — *"The pandemic really put brakes on communication skills"* (P11, undergrad 3).

The return to face-to-face delivery has brought some new issues to the surface particularly around assessment with many students worried about their ability to study for closed book exams and memorize topics. This was summarised by P55, undergrad 3 who stated *"since almost all tests during the pandemic were open-book due to being online, I'm worried that I'm worse at studying for tests and exams." "All online courses let us access our notes during tests/exams. So I didn't have to fully memorize all my notes. If any courses don't allow us to do that now, I feel that I will struggle to remember my notes clearly enough"* (P64, undergrad 3).

7.3 Discussion

Participants were neutral regarding the relationship between their study skills and the pandemic. They neither felt that their study skills prepared them for the pandemic, nor felt that the pandemic improved their study skills. The literature showed that students' study skills improved significantly during the emergency online instruction at the beginning of the pandemic [32, 71]. However, we did not find more follow-up work examining students' study skills in the period that followed.

Online learning encouraged instructors to find new ways of offering help to students. However, our survey responses suggest that participants weakly disagree with the statement that their dependency on instructor and learning supports increased during the pandemic. This contradicts some of the literature on virtual office hours showing that virtual office hours were significantly more utilized than in-person office hours [22, 30]. Prior work highlighted several benefits of virtual office hours, such as providing access to students from underrepresented groups and attracting more students with low confidence and low enjoyment in solving CS problems. The one downside of virtual office hours is longer interactions and wait times. Going forward, it would be beneficial if instructors held both in-person and virtual office hours so that students can benefit from the equitable access afforded by the virtual office hours and the shorter wait times provided by in-person office hours.

8 COMMUNITY BUILDING

8.1 Prior Work

Several studies acknowledged that while studying remotely during the pandemic, it was important to build academic communities of students and faculty in order to provide a sense of belonging. Being part of the academic community impacts how students feel in terms of being able to answer their academic-related daily issues and worries and the practices they engage in to face them [17].

The literature covering community building and sense of belonging for CS students studying remotely during the pandemic is relatively limited. During that time, faculty in many cases focused their efforts on the teaching element of online delivery. No-one could be sure how long the emergency remote teaching would last, and with that, which aspects of the university experience needed to be adapted. Many faculty members lacked experience with online modes of instruction and with the development of effective strategies for building community online [8]. It has now become clear that ensuring a sense of belonging and encouraging community building has a positive effect on students studying both online and in-person. Lewis et al. [37] reported that faculty teaching CS courses at their university have now focused more of their attention on techniques to foster peer-to-peer relationships online, and see the study of the effects of such efforts as an important avenue for future work.

Mooney and Becker [46] surveyed undergraduate computing students over a three-year period between 2017 and 2020, asking about their sense of belonging. The researchers found that "COVID-19 had a larger impact on the sense of belonging of all students in the space of a few months than we otherwise observed over the two prior years". A student's sense of belonging is often boosted by informal messages in classrooms, which are not easily transferred into virtual classrooms [40].

Lewis et al. [37] examined UCSD computer science students' connection to their peers in Spring 2020 compared to Fall and Winter 2019. In the majority of courses the number of peers that students felt comfortable reaching out to had significantly dropped after the transition online. The study found that for some of the later courses the drop was smaller, as students in these courses may already have existing social networks. Social support is important in introductory computing courses where students do not yet have their own networks, as well as in online courses more generally [37].

Students' sense of belonging is an important construct to monitor and evaluate. During the move to emergency remote teaching during the pandemic, students lost many of the aspects of the learning experience that can improve their sense of belonging [72]. For many students, the degree of interaction with the instructor and

involvement in classroom socialisation are important social aspects of their university experience. In addition to student-staff rapport, student-student interactions are an important component of community building for students [6, 20].

Traditionally, students assemble and interact before, during, and at the conclusion of a class session, leading to organic opportunities for social interactions [42]. Tice et al. [66] suggested that the development of student-instructor relationship and student-student relationships can be supported by opening up time at the start of online classes for students to spend connecting and socialising. Majewska and Vereen [41] found that by allowing time and space at the end of online live classes, numerous students remained in the virtual classroom for an additional 10-30 minutes past the end of class to ask questions related to the course, share their thoughts, and discuss their online study experiences.

As another way to initiate informal conversation, some faculty used polling tools with questions designed with the intention to facilitate camaraderie among students [8]. However this method was not evaluated by CS students in any studies we found.

Informal peer support is valuable to students so that they can relate their own experience with learning computing to those of their peers. It was especially important for students studying online to realize they were not the only ones struggling with learning to program [40]. Peer support in in-person classes can be transmitted by facial expressions and informal oral communication including smalltalk, which do not translate as well to the virtual world.

Lohiniva and Isomottonen [40] considered which activities and situations improved collaboration and communication. A reduction in peer support and the will to help others were observed in the virtual setting, with one respondent stating "The fact that you don't know... that I can't even connect the name with the face and who is who, and who are these people... so I couldn't be bothered helping others with their problems" [40].

However, Thiry and Hug [65] found that nearly three quarters of CS students in their study reported that their interactions with peers and study groups outside of class helped their learning during the spring 2020 campus closures. They found that students judged informal peer interaction as more helpful to their learning than faculty-directed group assignments. During remote teaching, some students used their initiative to form themselves into study groups (or micro-communities) with other students that they already knew which increased their study motivation [40] .

Faculty can also establish online peer support groups. Though many faculty randomly assigned students to breakout rooms in online classes, some faculty members divided students into smaller groups with the intention of allowing collaborations and more personal enduring connections. Faculty noted that the smaller groups allowed students to establish camaraderie with classmates. Tice et al. [66] mentioned that, in their experience, keeping the groups persistent each week enabled students to develop friendships even during the strictest lockdown phases.

However some CS student feedback gathered by Messmer and Berkling [44] was that natural study group formation was preferred, rather than forced group formation in breakout rooms in classes for example. One student from this study said "People have to be motivated to get to know others themselves, otherwise it won't work. There is no time in the lecture to get to know each other".

In the absence of face-to-face opportunities for social connection with peers, during remote learning instructors of online courses are therefore encouraged to investigate how they can provide an appropriate platform for interactions between students [41] with the aim to develop supportive learning communities [40].

It can be challenging to address important social aspects of the university experience when planning and delivering remote teaching [21]. Some of these important facets of delivery cannot always be adequately replicated in virtual learning environments, particularly for synchronous communication.

Forums and discussion boards on Learning Management Systems (LMS) are commonly used in online courses to facilitate social interactions and community building, yet their asynchronous nature and lack of real-time dialogue can make them feel forced and artificial, and it is easy for students to disengage from them [40, 41].

Some CS students in a study by Messmer and Berkling [44] stated that online events to encourage social interaction are no substitute for naturally engaging with fellow students. However, an online community that emulates or improves on-site interaction is not a natural occurrence and has to be specifically fostered.

Messmer and Berkling [44] also found that the LMS platforms prevented CS students in their study from working in their preferred ways. For example, they were restricted from uploading materials to certain content areas on their own initiative, and from creating their own course rooms for collaborative working and sharing of information.

Several studies found Discord and Slack to be popular tools for students to communicate with each other both inside and outside of class [5, 21, 40]. Use of this type of communication tool enabled constant interaction via multiple channels. Discord has also been used by faculty to communicate with students [44] and with tutors [45, 69].

Discord as a technical platform is an appropriate starting point for an online learning community [44, 45, 69]. Prior to the pandemic, Mock [45] studied how CS students were using Discord for socialising, finding study partners, and other community-building activities. Vladoiu and Zoran [69] found that Discord helped tremendously by contributing to building a resilient community during the pandemic.

Gama et al. [21] experimented with an approach to stimulate more intense online social interactions among students in an elective course. They utilized a hackathon format for the development of the students' project. Hackathons involve the synchronous collaboration among team members toward a common goal. In a traditional hackathon participants are intensively collocated, which had to be adapted for an online scenario. The researchers found that the voice channels and screen sharing features of Discord helped to create a sense of virtual collocation for students to socialize, work and learn together synchronously, and solve problems collaboratively [21]. The students reported that they found it exciting and motivating as they felt closer to each other, immersed in the same working environment.

Messmer et al. [44] felt that even the naturally grown learning environment for their CS students on Discord lacked some aspects of social presence. They built in some of these missing elements by using bots that provide more structure, modes of overcoming shyness, and informal means for communicating. The bot designs

were verified using a student survey and will be evaluated in future work.

Latulipe and De Jaeger [34] used Gather.town with CS students who reported that they liked the interactivity and social connection aspects of this platform. Students reported making friends in the Gather.Town CS1 classroom, similar to in-person, team-based CS1 classes.

Thiry and Hug [65] reported that faculty arranged co-curricular club meetings and workshops online to continue to provide professional development activities during the pandemic. They found that, even though for some the pandemic slowed progress for the development of student communities, for others it created opportunities to improvise and include students who may not otherwise be able to attend activities in-person.

8.2 Results

Figure 22 shows the histogram of undergraduate student agreement with the statement "I was able to find meaningful communities/groups for learning during the pandemic" (see Appendix A, question 18). The mean agreement score was 3.29 and the median was 3.0. This indicates that the majority of students were not able to find meaningful communities of learning, and supports the literature findings indicating that more work is needed in this area.

Ability to find community may be strongly impacted by opportunities for interacting with other students, which may be more prevalent when classes meet online synchronously. To investigate this relationship, we plotted student responses to the 'finding community' question against the percentage of their online courses that were taught synchronously vs. asynchronously (Appendix A, Question 10). This is shown in Figure 23. This result was confirmed statistically using a linear regression model, which showed the proportion of online courses taught synchronously was predictive of experience ratings (t-value = 2.911, p = 0.00398).

Some of the free-form comments from the qualitative data analysis supported the existing literature about students' need for connection and social interaction. *"It seemed that all you did was just sign on, listen and then leave. The sea of black boxes didn't allow you to connect and have the in-person feeling"* (P110, undergrad 4).

The connection between social interaction and learning was also referenced. *"Learning isn't just swallowing material. Being able to interact with other students, even if not for the express purpose of revision often leads to better learning when discussing material casually"* (P150, undergrad 4).

Another comment specifically mentioned peer support. *"Peer to Peer learn. Is something that I always thought really help since you needed to really understand the topic to teach it to someone"* (P110, undergrad 4).

The difficulties with finding meaningful learning communities was explicitly referenced in the student feedback data. A postgraduate student commented *"It was hard to find meaningful communities/groups for learning since I didn't get a chance to meet my classmates in-person"* (P67, grad 2). The literature review findings regarding the importance of online student communities were supported by some survey comments we received too. *"It would be nice to have a stronger sense of community through online experience in the virtual space for times like the pandemic"* (P232, undergrad 2).

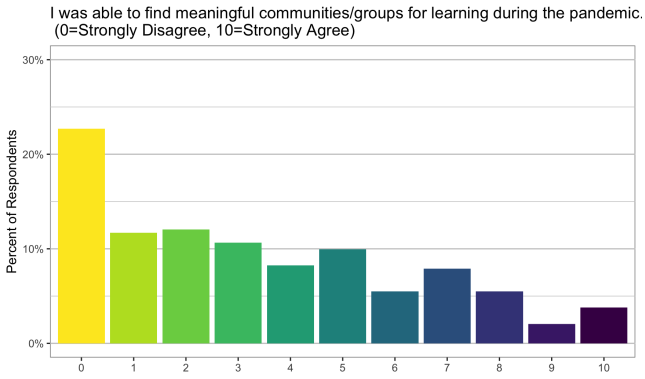

Figure 22: Histogram of undergraduate survey respondents' agreement with "I was able to find meaningful communities/groups for learning during the pandemic." (0=Strongly Disagree, 10=Strongly Agree).

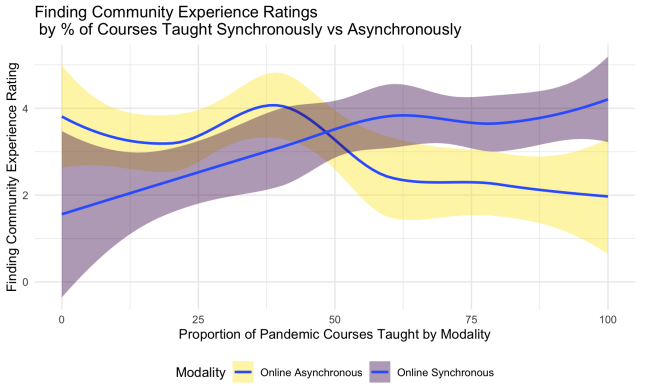

Figure 23: Survey respondents' level of agreement with "I was able to find meaningful communities/groups for learning during the pandemic." (0=Strongly Disagree, 10=Strongly Agree), plotted against % of respondent's pandemic online courses taught asynchronously (yellow) and synchronously (purple) during the Pandemic.

8.3 Discussion

Both the literature review and the results from our survey confirm the importance of building communities for students to support both their learning and the social aspects of their studies. Some research reported that the creation of online communities allowed some students to participate who otherwise wouldn't have [65]. The literature discussed above does highlight some positive benefits to community building during online learning, and since we did not ask respondents directly about whether they had positive experience around community building during the pandemic, we cannot rule this out. However, the majority of research demonstrates the difficulties of community building during the pandemic as opposed to in non-pandemic situations, and the student comments from the current study did not refer to any positive examples of community building from their experience. The comments primarily addressed

the lack of community they experienced and the respondents' desire for more of it when studying online.

It is understandable that social aspects of community building were not factored in from the start of the pandemic-related emergency remote teaching, as there were many other important and more immediate functional aspects to consider at the time, and faculty could not foresee how long this new way of teaching and learning would last. However, over time indications emerged that students' health and well-being were being affected by the unexpected move to online learning. Several student respondents in our study referred to their feelings of isolation. A sense of belonging has been conceptualized as a key component of a sense of community [43], and can provide a protective role for individuals' mental health and well-being [17].

There is now recognition of the importance of academic community building but more work is needed to alleviate the problem for CS students studying both online and in-person. It is suggested that going forward the social and community building aspects of learning should be factored into online teaching and instructional plans at an early stage.

9 MODALITY PREFERENCES

9.1 Prior Work

The impact of COVID-19 will continue to become evident in higher education institutions in the short, medium and long term. Whether it be for students, staff, our methods of delivery, assessment or institutional policies, the changes we make will revert, remain and distort as we unpack and come to terms with our new normal. Understanding student preferences for the modality of our course offerings is fundamental on this journey.

Different modalities of teaching have been explored during 'normal' circumstances where there is time for them to be planned, prepared and developed over time. However, the emergency move to online learning did not allow institutions to take full advantage of the benefits and possibilities offered by online or hybrid formats [28].

Institutions can employ several delivery modes, such as in-person face-to-face, remote, and hybrid. The default delivery method for most higher education institutions before the pandemic was in-person, with both the student and the teachers in the same physical location for the delivery of the class [68]. This face-to-face delivery enhanced learning due to the interpersonal contact between students and academic staff and between students and their peers. Students benefit from self-learning, low costs, convenience, and flexibility [1].

These in-person sessions often fall into two main categories within computer science education: lectures and lab activities. Lectures are delivered live, with supplementary materials, often in the form of PowerPoint presentations, videos, audio, demonstrations, or a combination thereof [23]. The interactive nature of this modality relies on discussions, feedback and Q&A to confirm student understanding. Lab sessions consist of more practical, hands-on computer science components, such as programming, which depend on specific software packages or hardware. During these sessions, students participate in the real-time execution of a practical exercise, either individually or in groups [23].

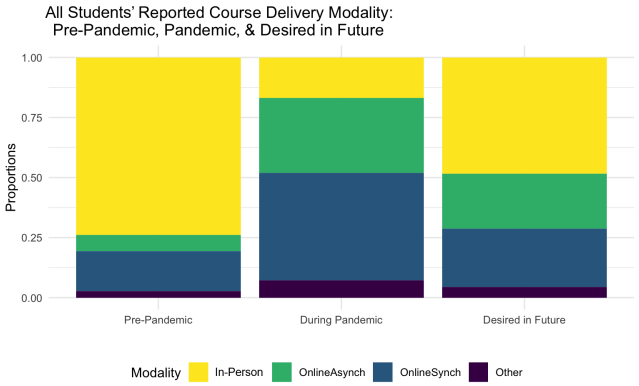

Figure 24: Reported course delivery modality for all students: pre-pandemic, pandemic and desired in future courses.

During the pandemic, students expressed a preference for hybrid learning. Zhou and Zhang [77] studied the pandemic's impact on students' learning experiences in the USA one year after the outbreak began. They found that hybrid was the optimal among the three delivery modes (in-person, hybrid, and remote) since students received sufficient support from the campus interactions and this mode simultaneously had the lowest anxiety level.

Several studies compared students' perceptions of different online learning delivery modes and found that students preferred online synchronous delivery to asynchronous delivery [3, 50]. For instance, Peimani and Kamalipour [50] reported that students found it more helpful to attend live online lectures than to watch prerecorded videos. Similarly, Aristovnik et al. [3] found students preferred real-time video conferences over available video recordings.

Many factors influence students' satisfaction with online learning. Kovačević et al. [33] highlighted the importance of interaction with peers and previous positive experiences of digital platforms. In their study of 337 participants, Singh et al. [61] found that additional activities such as participation in clubs, internships and jobs had a significant impact on students' choice of teaching and learning mode.

9.2 Results

Part of the study conducted for this working group explored the modality of courses offered before, during, and after the pandemic (see Appendix A, questions 8, 9, 10, 20, 21). During the pandemic, nearly all participants experienced a move away from in-person instructional delivery. The current experience of higher education is a mixture of in-person, online asynchronous and online synchronous with in-person being the nominate method. The study revealed differences in both the experiences and preferences of undergraduate and graduate students as shown in Figure 24.

Graduate students had more exposure to online delivery methods pre-pandemic than did undergraduates, as seen in Figures 25 and 26. During the pandemic the experience of both groups is very similar, however, looking to the future there are some differences. Undergraduate student have increased their desire for the online asynchronous and online synchronous modalities with the most

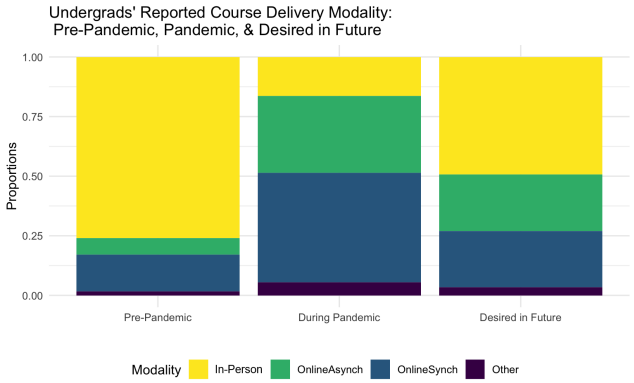

Figure 25: Undergraduate respondents' reported course delivery modality: pre-pandemic, pandemic and desired in future courses.

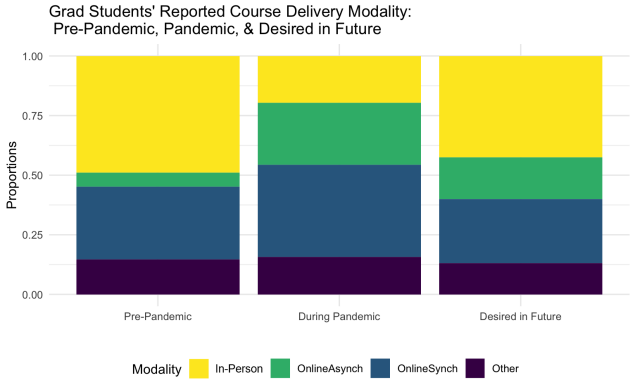

Figure 26: Graduate respondents' reported course delivery modality: pre-pandemic, pandemic and desired in future courses.

significant difference being in online asynchronous. Graduate students show a decrease in the in-person and online synchronous modalities with online asynchronous increasing in popularity.

Figure 27 shows the proportion of each modality that respondents would like to see in the future, based on respondents' self-declared gender identity. This shows that non-binary participants have a preference for more online courses than respondents who identify with as a man or a woman, and woman-identifying respondents expressed the least interest in online asynchronous courses in the future.

Some participants were positive about learning online with one commenting – *"online learning pattern is a meaningful exploration, even after the pandemic, we should use more online learning instead of in-person learning, it's efficient, cost-saving and provides wider institution options for students"* (P5, grad 2). The benefits of recorded session were a popular observation with playback options such as double-speed and replay helping students with their learning and time savings on their commute to campus. Others were less supportive, describing their online experience as *"the sea of black boxes"*

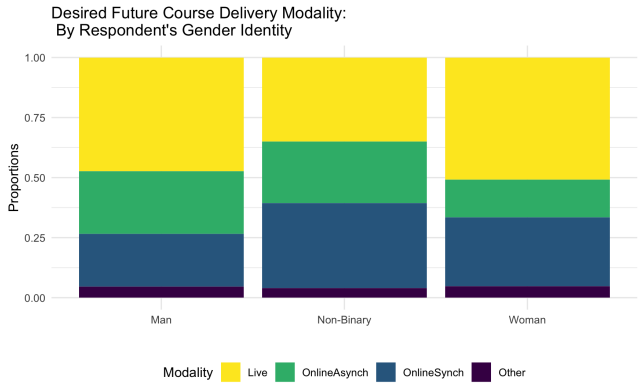

Figure 27: Desired proportion of course modalities in the future, by gender identity of respondent.

(P110, undergrad 4), their learning experience being *"significantly worse than any other time"*, *"pathetic"* (P16, undergrad 2) and one participant stating that *"this cannot replace the in-person education system"* (P1, grad 5+).

The lack of personal contact, *"just sign on, listen and then leave"* (P110, undergrad 4) and the detrimental impact on mental health with participants feeling isolated – *"I felt negatively impacted by being isolated from peers and by the lack of studying independently in small groups which is key to understanding the content well"* (P145, undergrad 5+).

Some were more critical of their face-to-face experience – *"in-person learning is objectively worse and needs to be eliminated from computer science education"* (P14, undergrad 4) and others found benefits in studying online – *"I'm more productive, lessons are far more enjoyable, I save money, I have the ability to push myself further with my coursework than I can with on campus classes"* (P72, undergrad 3).

9.3 Discussion

The pandemic has allowed CS students to experience alternative instructional modalities which they would otherwise not have experienced. Very little data exists on students' future preferences, and this is a key strength of this work. Unfortunately, the participants were exposed to these alternative modalities during the stressful and unique life event of a pandemic. This forced institutions into rushed online delivery and the challenges and best practices may differ from those who voluntarily study online [10]. We must be mindful of the circumstances of this experience and consider if exposure to online synchronous and asynchronous methods during 'normal' times would have resulted in a different set of responses.

The vast array of comments from survey participants makes it difficult to identify common themes but what emerged are the differences and an understanding that CS students at all levels are individual, with competing demands and different experiences, perceptions, and options. The future of CS education needs to respond in a hybrid manner, combining face-to-face and online delivery. This was summed up by one participant – *"the opportunity to gather*

and learn face-to-face, while having the content accessible and online when needed" (P32 undergrad 3).

10 DISCUSSION

The final question on our survey asked students to describe what they felt their future educational experience should look like (see Appendix A, question 25). 160 of the 304 respondents shared comments in answer to that prompt. Their answers touch upon all of the themes investigated in this work.

Some respondents wrote about their experiences with virtual learning intertwined with their health and well-being as a basis for what they wanted to see happen in their schooling going forward. One undergraduate who entered university in 2020 did not have a frame of reference to pre-pandemic higher education so they couldn't imagine what their future educational experience would look like. Other accounts varied. *"Being in the classroom/lecture hall is much more engaging than staring at a screen"* (P171, undergrad 3). One expressed their wish to move forward with in-person classes because *"In person learning is still better for individuals that have learning difficulties such as ADHD, perhaps online classes are good for others but I struggled to maintain focus on online work"* (P62, undergrad 3). An undergraduate in their second year asked for *"more in-person classes [please,] online ones are just depressing"* (P152, undergrad 2). Another simply wrote *"i hope i find better ways to study"* (P19, undergrad 1).

Of the 160 students who gave an answer to this last survey prompt, the majority, 112, expressed an opinion on the preferred modality of their future education. 11 wanted all of their instruction and activities to be delivered online-only, 17 said that students should be given an option to choose, 32 asked for hybrid education (*"Face to face to collaborate, online to elaborate"* (P105, undergrad 3)). Another 43 participants were adamant that classes should be in-person-only.

Many students that asked for hybrid or in-person-only future modalities thought this should be how education moves forward because of the possibility to build community with others. *"Interacting with peers and instructors in person helps us learn important social skills that we can use as we work"* (P102, undergrad 2). *"Especially small classes such as tutorials and labs should be delivered in-persons as they enable getting to know your classmates in every one of your courses and working together with peers on lab/tutorial exercises and learning from each other"* (P145, undergrad 5+). *"I develop better relationships with my professors in person though, and I am unsure that can really be mimicked in an online environment. I do like my online professors, though what I have with my face to face professors is not really comparable."* (P117, undergrad 4). *"Encouragement to form groups with other students. That was lacking during the pandemic"* (P160, undergrad 4). One student put it very succinctly, *"I want to hang out with other students on campus between classes again"* (P55, undergrad 3).

Technology was also a big theme in the responses to the final survey question. The vast majority of participants mentioned recorded lectures, some going so far as to say that all activities should be recorded. *"Even before the pandemic, I really appreciated when an instructor would record their lectures in case someone was sick or missed a day, so I hope that continues"* (P213, undergrad 4).

Many survey respondents were wishing for greater accessibility to materials online to help with prep, note taking, and studying. Some said that we should leverage technology to make lectures more interactive and more collaborative. *"Future education should be Interactive"* (P302, undergrad 3). *"I think further learning benefits can be achieved by using digital devices in the classroom"* (P273, undergrad 3). *"Using emerging technologies to increase student learning. Things like AR/VR, new learning platforms, updated textbooks, etc. Also more experiential learning opportunities as that is how students actually solidify what they have learned in the class"* (P135, undergrad 4). *"I believe technology should increment the real, physical classroom in ways to promote Active Learning for all the students. Peer Instruction, which uses online quizzes with the help of clickers/smartphones, is a good example of this"* (P34, grad 3).

Study skills and supports were also addressed by respondents. Some respondents appreciated the changes in assessment during the pandemic and expressed the opinion that going forward classes should be more conceptual, assessments should be project based, and exams should be open book with internet access and focus on testing students' understanding rather than their *"ability to memorize something for one night"* (P115, undergrad 2). A respondent shared their thoughts that future educational experience should be *"better suited to the individual's learning style with a small percentage of taking them out of their comfortable learning style for exposure and growth"* (P227, undergrad 3). Another shared their opinion that *"we should also encourage in-person interaction between students, but in new innovative ways (pair-programming instead of lectures, for example)"* (P210, undergrad 1).

Several students mentioned that having some or all classes online would let them set their own pacing and could help save time that they'd otherwise spend commuting. Saved time was seen as having other benefits as well. *"Face-to-face classes are ESSENTIAL both for social and for the ease of exchanging information, but there is the possibility of some classes being online (synchronous/ asynchronous) makes life a lot easier because it gives us freedom and flexibility to better handle study schedules and circumvent the challenges of supporting ourselves with jobs and so on"* (translated from Portuguese, P36, undergrad 1). *"I would like lectures to be available online going forward as it makes higher education more accessible to working students and those with care-responsibilities"* (P210, undergrad 1).

Several respondents spoke about accessibility. Two wrote that future education should be *"Accessible for all through the incorporation of distant learning techniques we learned and developed over the pandemic"* (P107, grad 1); *"An environment where each person can be taught"* (P290, undergrad 3). Another shared that recorded lectures *"are great for students with learning disabilities as they can better adapt their studying to their individual needs"* (P145, undergrad 5+). As one student said, *"Our educational experiences should be flexible and easily adaptable to the needs of all students– pandemic related or not"* (P66, grad 1).

11 CONCLUSIONS

This work provides an insight into the experiences of computing students during the COVID-19 pandemic.

This paper presents contributions to the existing body of knowledge, including: i) a literature review exploring the impact of

COVID-19 on the student experience with a particular focus on six key themes; and ii) a survey that captured the experiences of 304 students regarding the impact of COVID-19 on their learning journeys.

Guided by the results of the survey, the authors of this paper would like to make some recommendations for future instructors. Recording lectures and making them available along with all other materials is something that students see tremendous value in and instructors should strongly consider implementing this. Instructors should contemplate offering virtual options to their in-person office hours as well. Strong consideration should also be given to the use of communication tools, allowing students to pose questions to instructors, TAs, and their peers; and answer questions from others. Being able to keep in touch with other students and faculty builds community, strengthens students' sense of belonging, and improves their sense of wellbeing. Furthermore, employing interactive quizzing tools and moving toward more experiential learning could boost student engagement. Students also expressed wanting more options on how to attend class. When offering online instruction to undergraduates, faculty should opt for the online synchronous modality for a better learning experience. Offering hybrid or fully online lectures could be beneficial in offering students flexibility but online classes should be kept small to prevent participants from feeling isolated and getting lost in the crowd.

11.1 Limitations

The remote nature of this working group presented a number of limitations that can be reflected on. First, the open coding/thematic analysis described in this paper happened organically, through discussions amongst the working group team. Whilst many of these points were captured and are discussed in the paper itself, due to the nature of the remote working group, it may be possible that some of the finer detail may have been missed. An Inter-Rater Reliability analysis was planned, but uncompleted due to timing issues.

Furthermore, the literature review itself was built by different subsets of the working group. Inevitably, this led to differences in what was documented, and how – leading to some gaps when considering quantitative data on papers analysed, returned, excluded, etc. Whilst much of this data was retrieved and replicated, it was not possible to do so on all counts.

The relatively late ITiCSE '22 working group commencement (mid-April) and compressed available time for the team to organize and complete work artificially imposed limitations on what could have been a survey with a much broader impact. Additionally, due to the remote nature of this working group, it took much longer than anticipated to get the correct ethical clearance from partner universities in order to run this study. This limitation is one that was experienced during the partner working group in the previous year [58]. While mitigations were put in place to try and overcome this (e.g. having the survey mostly ready in advance of the working group, asking working group members to preemptively apply for ethical clearance before the start of work), the timescales within which the group operated meant that ethical clearance was granted mid-May. This led to a potentialEma limitation, where many students may have missed the call for participation due to the spring semester having ended.

We also note that responses related to adapting to technology may be biased. The survey itself was deployed online, and students who struggled with online technologies may have been less likely to see or respond to the survey due to the delivery modality. This may mean that we have missed responses from students who did struggle with adapting to online educational technology use. As with many voluntary surveys, it may be the case that students that are motivated to respond are not typical and may represent more engaged students, which can skew the results. The mix of student responses was not always very even: for example, most of the respondents from Japan are male, whereas most from Pakistan are female. This means direct comparisons between countries should be done with caution as there are multiple factors that could be influencing these differences; this is one of the reasons why we have not attempted to do this in this paper. By looking at gender differences across the whole data set, we believe confounding variables are less likely to be a factor; nevertheless, we cannot be sure that there are not hidden factors in the data, and conclusions should be viewed with this in mind.

Students have experienced education during a pandemic and for most this resulted in online delivery. This study draws conclusions from the data provided but we acknowledge that the participants were not experiencing online learning in normal times. Had their classes been switched to online in 'normal' circumstances the results could have been very different. Participants are also comparing face-to-face and online delivery methods without considering the circumstances in which these materials were uploaded and presented.

11.2 Future Work

This paper presents the experience of computing students when reflecting on their educational experience at various stages during the pandemic. There are a number of avenues for future work, which will be illustrated here. First, the authors are planning to conduct a version of this survey with a wider audience, capturing students from other subject areas. This would allow for comparisons to be made between and within fields, to acquire more granular data and better understand the nuances of the captured results.

Second, the authors are considering the possibility of exploring the same issues through an institutional lens. Whilst the existing studies have been from faculty and student viewpoints, it would be interesting and valuable to capture the administrative lens and better understand complications with regards to policy and program requirements.

Finally, there would be value in running these studies with similar populations in years to come, to be able to make more longitudinal comparisons, and be able to make both comparisons and reflections on this unprecedented time.

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REFERENCES

[1] Zakaryia Almahasees, Khaled Mohsen, and Mohammad Omar Amin. 2021. Faculty's and Students' Perceptions of Online Learning During COVID-19. *Frontiers in Education* 6 (2021). https://doi.org/10.3389/feduc.2021.638470

[2] M. Amzalag, N. Shapira, and N Dolev. 2021. Two Sides of the Coin: Lack of Academic Integrity in Exams during the Corona Pandemic, Students' and Lecturers' Perceptions. *J Acad Ethics* 20 (2021), 243–263. https://doi.org/10.1007/s10805-021-09413-5

[3] Aleksander Aristovnik, Damijana Keržič, Dejan Ravšelj, Nina Tomaževič, and Lan Umek. 2020. Impacts of the COVID-19 Pandemic on Life of Higher Education Students: A Global Perspective. *Sustainability* 12, 20 (2020). https://doi.org/10.3390/su12208438

[4] Esteban M. Aucejo, Jacob French, Maria Paola Ugalde Araya, and Basit Zafar. 2020. The Impact of COVID-19 on Student Experiences and Expectations: Evidence from a Survey. *Journal of Public Economics* 191 (2020), 104271. https://doi.org/10.1016/j.jpubeco.2020.104271

[5] Bridget Benson, Paul Hummel, and James Mealy. 2021. Comparing Techniques for Building Community and Promoting Inclusion in a Virtual Engineering Classroom. In *2021 IEEE Frontiers in Education Conference (FIE)*. IEEE, 1–9. https://doi.org/10.1109/FIE49875.2021.9637419

[6] Marianne C Bickle and Ryan Rucker. 2018. Student-to-Student Interaction: Humanizing the Online Classroom Using Technology and Group Assignments. *Quarterly Review of Distance Education* 19, 1 (2018), 1–56.

[7] Kristi L Boardman, Stephanie A Vargas, Jami L Cotler, Dmitry Burshteyn, et al. 2021. Effects of Emergency Online Learning during COVID-19 Pandemic on Student Performance and Connectedness. *Information Systems Education Journal* 19, 4 (2021), 23–36. https://files.eric.ed.gov/fulltext/EJ1310048.pdf

[8] Katrina Borowiec, Deoksoon Kim, Lizhou (Jo) Wang, Julie Kim, and Stanton Wortham. 2021. Supporting Holistic Student Development Through Online Community Building. In *Online Learning*. Boston College, USA, 125–155. https://doi.org/10.24059/olj.v25i4.2882

[9] Kathryn Bridson, Jeffrey Atkinson, and Scott D. Fleming. 2022. Delivering Round-the-Clock Help to Software Engineering Students Using Discord: An Experience Report. In *Proceedings of the 53rd ACM Technical Symposium on Computer Science Education V. 1* (Providence, RI, USA) *(SIGCSE 2022)*. Association for Computing Machinery, New York, NY, USA, 759–765. https://doi.org/10.1145/3478431.3499385

[10] Alexander Brooks, Caroline Hardin, Jennifer Scianna, Matthew Berland, and Laura Hobbes Legault. 2021. Approaches to Transitioning Computer Science Classes from Offline to Online. In *Proceedings of the 26th ACM Conference on Innovation and Technology in Computer Science Education V. 1* (Virtual Event, Germany) *(ITiCSE '21)*. Association for Computing Machinery, New York, NY, USA, 81–87. https://doi.org/10.1145/3430665.3456366

[11] Wenjun Cao, Ziwei Fang, Guoqiang Hou, Mei Han, Xinrong Xu, Jiaxin Dong, and Jianzhong Zheng. 2020. The Psychological Impact of the COVID-19 Epidemic on College Students in China. *Psychiatry Research* (2020). https://doi.org/10.1016/j.psychres.2020.112934

[12] Maria Chierichetti and Patricia Ryaby Backer. 2021. Student Experiences after the Move to Fully Online Instruction: A Case Study of One Large Public Institution. In *2021 IEEE Frontiers in Education Conference (FIE)*. IEEE, 1–9. https://doi.org/10.1109/FIE49875.2021.9637354

[13] Igor Chirikov, Krista M Soria, Bonnie Horgos, and Daniel Jones-White. 2020. Undergraduate and Graduate Students' Mental Health during the COVID-19 Pandemic. (2020). https://escholarship.org/uc/item/80k5d5hw

[14] Rachel C Conrad, Amanda Koire, Stephanie Pinder-Amaker, Cindy H Liu, et al. 2021. College Student Mental Health Risks during the COVID-19 Pandemic: Implications of Campus Relocation. *Journal of Psychiatric Research* 136 (2021), 117–126. https://doi.org/10.1016/j.jpsychires.2021.01.054

[15] Kimberly Cook-Chennault, Danielle Cummings, Marcus Anthony, Tejaskumar Balar, Laura Uzzell, Sheryle Boone, and Crystal Watson. 2021. What Informal Learning Programs Teach Us About Adaptation to Contactless and Remote Learning Environments. In *2021 IEEE Frontiers in Education Conference (FIE)*. 1–8. https://doi.org/10.1109/FIE49875.2021.9637140

[16] Sarah Elaine Eaton and Kristal Louise Turner. 2020. Exploring Academic Integrity and Mental Health during COVID-19: Rapid Review. *Journal of Contemporary Education Theory and Research v4 n1 p35-41* (2020). https://doi.org/10.5281/zenodo.4256825

[17] Ciro Esposito, Immacolata Di Napoli, Barbara Agueli, Leda Marino, Fortuna Procentese, and Caterina Arcidiacono. 2022. Well-being and the COVID-19 pandemic. *European Psychologist* (2022).

[18] Simon Evans, Erkan Alkan, Jazmin K Bhangoo, Harriet Tenenbaum, and Terry Ng-Knight. 2021. Effects of the COVID-19 Lockdown on Mental Health, Wellbeing, Sleep, and Alcohol Use in a UK Student Sample. *Psychiatry research* 298 (2021), 113819. https://doi.org/10.1016/j.psychres.2021.113819

[19] Department for Education. 2021. Safeguarding and Remote Education. https://www.gov.uk/guidance/safeguarding-and-remote-education Last accessed: 2022-08-30.

[20] Brandi N Frisby and Matthew M Martin. 2010. Instructor-Student and Student-Student Rapport in the Classroom. *Communication Education* 59, 2 (2010), 146–164. https://doi.org/10.1080/03634520903564362

[21] Kiev Gama, Carlos Zimmerle, and Pedro Rossi. 2021. Online Hackathons as an Engaging Tool to Promote Group Work in Emergency Remote Learning. In *Proceedings of the 26th ACM Conference on Innovation and Technology in Computer Science Education V. 1*. 345–351. https://doi.org//10.1145/3430665.3456312

[22] Zhikai Gao, Sarah Heckman, and Collin Lynch. 2022. Who Uses Office Hours? A Comparison of In-Person and Virtual Office Hours Utilization. In *Proceedings of the 53rd ACM Technical Symposium on Computer Science Education V. 1* (Providence, RI, USA) *(SIGCSE 2022)*. Association for Computing Machinery, New York, NY, USA, 300–306. https://doi.org/10.1145/3478431.3499334

[23] Francisco García-Peñalvo, Alfredo Corell, Víctor Abella, and Mario Grande-de Prado. 2021. *Recommendations for Mandatory Online Assessment in Higher Education during the COVID-19 Pandemic*. 85–98. https://doi.org/10.1007/978-981-15-7869-4_6

[24] Jean-Luc Gaudiot and Hironori Kasahara. 2020. Computer Education in the Age of COVID-19. *Computer* 53, 10 (2020), 114–118. https://doi.org/10.1109/MC.2020.3011277

[25] Rolando Gonzalez, Hanne Sørum, and Kjetil Raaen. 2022. Emergency Digital Teaching during the COVID-19 Lockdown: Students' Perspectives. *Education Sciences* 12, 3 (2022). https://doi.org/10.3390/educsci12030152

[26] Suzanne R. Hawley, Jyothi K. Thrivikraman, Noemi Noveck, Theresa St Romain, Mary-Jon Ludy, Lucy Barnhart, Winnie SS Chee, Ming Jung Cho, Megan HZ Chong, Chen Du, Jenifer I Fenton, Pao Ying Hsiao, Richard Hsiao, Laura Keaver, HeeSoon Lee, Wan Shen, Lai Chang-Chi, Kuo-Wei Theng, Wei-Chin Tseng, and Robert Tucker. 2021. Concerns of College Students during the COVID-19 Pandemic: Thematic Perspectives from the United States. *Asia, and Europe. J. Appl. Learn. Teach* 4 (2021), 11–20. https://doi.org/10.37074/jalt.2021.4.1.10

[27] Rune Hjelsvold, Shaun S Nykvist, Madeleine Lorås, Abdullah Bahmani, and Andreas Krokan. 2020. Educators' Experiences Online: How COVID-19 Encouraged Pedagogical Change in CS Education. In *Norsk IKT-konferanse for forskning og utdanning*. https://eprints.qut.edu.au/207024/

[28] Charles B Hodges, Stephanie Moore, Barbara B Lockee, Torrey Trust, and M Aaron Bond. 2020. The Difference Between Emergency Remote Teaching and Online Learning. https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning Last accessed: 2022-08-24.

[29] Rainer M Holm-Hadulla, Margaritha Klimov, Tilman Juche, Andreas Möltner, and Sabine C Herpertz. 2021. Well-Being and Mental Health of Students during the COVID-19 Pandemic. *Psychopathology* 54, 6 (2021), 291–297. https://doi.org/10.1159/000519366

[30] Andrew Jiang and Bogdan Simion. 2022. Help Supports during Online Delivery: Student Perception and Lessons Learnt from an Online CS2. In *Proceedings of the 53rd ACM Technical Symposium on Computer Science Education V. 1* (Providence, RI, USA) *(SIGCSE 2022)*. Association for Computing Machinery, New York, NY, USA, 105–111. https://doi.org/10.1145/3478431.3499369

[31] Katharine Kelly. 2022. Building on Students' Perspectives on Moving to Online Learning during the COVID-19 Pandemic. *The Canadian Journal for the Scholarship of Teaching and Learning* 13, 1 (Feb. 2022). https://doi.org/10.5206/cjsotlrcacea.2022.1.10775

[32] Sezen Korkmaz and İsmail Hakkı Mirici. 2021. Converting a Conventional Flipped Class into a Synchronous Online Flipped Class during COVID-19: University Students' Self-Regulation Skills and Anxiety. *Interactive Learning Environments* 0, 0 (2021), 1–13. https://doi.org/10.1080/10494820.2021.2018615

[33] Ivana Kovačević, Jelena Anđelković Labrović, Nikola Petrović, and Ivana Kužet. 2021. Recognizing Predictors of Students' Emergency Remote Online Learning Satisfaction during COVID-19. *Education Sciences* 11, 11 (2021), 693. https://doi.org/10.3390/educsci11110693

[34] Celine Latulipe. 2021. A CS1 Team-Based Learning Space in Gather.Town. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education* (Virtual Event, USA) *(SIGCSE '21)*. ACM, New York, NY, USA, 1245. https://doi.org/10.1145/3408877.3439587

[35] Kyungmee Lee, Mik Fanguy, Xuefei Sophie Lu, and Brett Bligh. 2021. Student Learning during COVID-19: It Was Not as Bad as We Feared. *Distance Education* 42, 1 (2021), 164–172. https://doi.org/10.1080/01587919.2020.1869529

[36] Kim S. Lee J, Jeong HJ. 2021. Stress, Anxiety, and Depression Among Undergraduate Students during the COVID-19 Pandemic and their Use of Mental Health Services. *Innovation in Higher Education* (2021). https://doi.org/10.1007/s10755-021-09552-y

[37] McKenna Lewis, Zhanchong Deng, Sophia Krause-Levy, Adrian Salguero, William G. Griswold, Leo Porter, and Christine Alvarado. 2021. Exploring Student Experiences in Early Computing Courses during Emergency Remote Teaching. In *Proceedings of the 26th ACM Conference on Innovation and Technology in Computer Science Education V. 1* (Virtual Event, Germany) *(ITiCSE '21)*. Association for Computing Machinery, New York, NY, USA, 88–94. https://doi.org/10.1145/3430665.3456315

[38] Xueyan Li, Ping Fu, Changyu Fan, Miao Zhu, and Min Li. 2021. COVID-19 Stress and Mental Health of Students in Locked-Down Colleges. *International journal of environmental research and public health* 18, 2 (2021), 771. https://doi.org/10.3390/ijerph18020771

[39] Alex Lishinski, Joshua Rosenberg, Michael Mann, Omiya Sultana, and Joshua Dunn. 2021. How CS1 Students Experienced COVID-19 In the Moment: Using An Experience Sampling Approach to Understand the Transition to Emergency Remote Instruction. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education* (Virtual Event, USA) *(SIGCSE '21)*. Association for Computing Machinery, New York, NY, USA, 1254. https://doi.org/10.1145/3408877.3439657

[40] Meija Lohiniva and Ville Isomöttönen. 2021. Novice Programming Students' Reflections on Study Motivation during COVID-19 Pandemic. In *2021 IEEE Frontiers in Education Conference (FIE)*. IEEE, 1–9. https://doi.org/10.1109/FIE49875.2021.9637367

[41] Ania A Majewska and Ethell Vereen. 2021. Fostering Student-Student Interactions in a First-Year Experience Course Taught Online during the Covid-19 Pandemic. *Journal of microbiology & biology education* 22, 1 (2021), ev22i1–2417. https://doi.org/10.1128/jmbe.v22i1.2417

[42] Joanne M McInnerney and Tim S Roberts. 2004. Online Learning: Social Interaction and the Creation of a Sense of Community. *Journal of Educational Technology & Society* 7, 3 (2004), 73–81. https://www.jstor.org/stable/jeductechsoci.7.3.73

[43] David W McMillan and David M Chavis. 1986. Sense of Community: A Definition and Theory. *Journal of community psychology* 14, 1 (1986), 6–23. https://doi.org/10.1002/1520-6629(198601)14:1<6::AID-JCOP2290140103>3.0.CO;2-I

[44] Gino Messmer and Kay Berkling. 2021. Overcoming the Gap of Social Presence in Online Learning Communities at University. In *2021 World Engineering Education Forum/Global Engineering Deans Council (WEEF/GEDC)*. IEEE, 563–570. https://doi.org/10.1109/WEEF/GEDC53299.2021.9657401

[45] Kenrick Mock. 2019. Experiences Using Discord as Platform for Online Tutoring and Building a CS Community. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*. 1284–1284. https://doi.org/10.1145/3287324.3293769

[46] Catherine Mooney and Brett A. Becker. 2021. Investigating the Impact of the COVID-19 Pandemic on Computing Students' Sense of Belonging. *ACM Inroads* 12, 2 (May 2021), 38–45. https://doi.org/10.1145/3463408 p. 617.

[47] Colin Moore, Lina Battestilli, and Ignacio X. Domínguez. 2021. Finding Video-Watching Behavior Patterns in a Flipped CS1 Course. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education* (Virtual Event, USA) *(SIGCSE '21)*. Association for Computing Machinery, New York, NY, USA, 768–774. https://doi.org/10.1145/3408877.3432359

[48] Nadia Najjar, Anna Stubler, Harini Ramaprasad, Heather Lipford, and David Wilson. 2022. Evaluating Students' Perceptions of Online Learning with 2-D Virtual Spaces. In *Proceedings of the 53rd ACM Technical Symposium on Computer Science Education V. 1* (Providence, RI, USA) *(SIGCSE 2022)*. Association for Computing Machinery, New York, NY, USA, 112–118. https://doi.org/10.1145/3478431.3499396

[49] Lígia Maria Soares Passos, Christian Murphy, Rita Chen, Marcos Santana, and Giselle Passos. 2022. Association of Positive and Negative Feelings with Anxiety and Depression Symptoms among Computer Science Students during the COVID-19 Pandemic. In *Anais do II Simpósio Brasileiro de Educação em Computação* (Online). SBC, Porto Alegre, RS, Brasil, 50–56. https://doi.org/10.5753/educomp.2022.19198

[50] Nastaran Peimani and Hesam Kamalipour. 2021. Online Education in the Post COVID-19 Era: Students' Perception and Learning Experience. *Education Sciences* 11, 10 (2021). https://doi.org/10.3390/educsci11100633

[51] Sumitra Pokhrel and Roshan Chhetri. 2021. A Literature Review on Impact of COVID-19 Pandemic on Teaching and Learning. *Higher Education for the Future* 8, 1 (Jan 2021), 133–141. https://doi.org/10.1177/2347631120983481

[52] Alfonso Abizaid Robert L. Gabrys Kim G. C. Hellemans Zachary R. Patterson Rebecca Prowse, Frances Sherratt and Robyn J. McQuaid1. 2021. Coping with the COVID-19 Pandemic: Examining Gender Differences in Stress and Mental Health Among University Students. *Frontiers in Psychiatry* 12 (2021). https://doi.org//10.3389/fpsyt.2021.650759

[53] Gili Rusak and Lisa Yan. 2021. Unique Exams: Designing Assessments for Integrity and Fairness. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education* (Virtual Event, USA) *(SIGCSE '21)*. Association for Computing Machinery, New York, NY, USA, 1170–1176. https://doi.org/10.1145/3408877.3432556

[54] Hasan Saleem, Boluwatife Akinola, and Celine Latulipe. 2021. Facilitating Team-Based Learning in Lecture Halls. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education* (Virtual Event, USA) *(SIGCSE '21)*. Association for Computing Machinery, New York, NY, USA, 1296. https://doi.org/10.1145/3408877.3439588

[55] Lauren S Schlesselman, Jeff Cain, and Margarita DiVall. 2020. Improving and Restoring the Well-Being and Resilience of Pharmacy Students during a Pandemic. *American Journal of Pharmaceutical Education* 84, 6 (2020). https://doi.org/10.5688/ajpe8144

[56] Angela A. Siegel and Mark Zarb. 2016. Student Concerns Regarding Transition into Higher Education CS. In *Proceedings of the 2016 ACM Conference on Innovation and Technology in Computer Science Education* (Arequipa, Peru) *(ITiCSE '16)*. ACM, New York, NY, USA, 23–28. https://doi.org/10.1145/2899415.2909581

[57] Angela A. Siegel, Mark Zarb, Bedour Alshaigy, Jeremiah Blanchard, Tom Crick, Richard Glassey, John R. Hott, Celine Latulipe, Charles Riedesel, Mali Senapathi, Simon, and David Williams. 2021. Educational Landscapes During and After COVID-19. In *Proceedings of the 26th ACM Conference on Innovation and Technology in Computer Science Education V. 2* (Virtual Event, Germany) *(ITiCSE '21)*. Association for Computing Machinery, New York, NY, USA, 597–598. https://doi.org/10.1145/3456565.3461439

[58] Angela A. Siegel, Mark Zarb, Bedour Alshaigy, Jeremiah Blanchard, Tom Crick, Richard Glassey, John R. Hott, Celine Latulipe, Charles Riedesel, Mali Senapathi, Simon, and David Williams. 2022. Teaching through a Global Pandemic: Educational Landscapes Before, During and After COVID-19. In *Proceedings of the 2021 Working Group Reports on Innovation and Technology in Computer Science Education*. Association for Computing Machinery, New York, NY, USA, 1–25. https://doi.org/10.1145/3502870.3506565

[59] Angela A Siegel, Mark Zarb, and Teri Balser. 2021. Learning from COVID. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education* (Virtual Event, USA) *(SIGCSE '21)*. ACM, New York, NY, USA, 1356. https://doi.org/10.1145/3408877.3439521

[60] Angela A. Siegel, Mark Zarb, Richard Glassey, and Janet Hughes. 2019. Perspectives on the Student Transition into CS1. In *Proceedings of the 2019 ACM Conference on Innovation and Technology in Computer Science Education* (Aberdeen, Scotland Uk) *(ITiCSE '19)*. ACM, New York, NY, USA, 168–169. https://doi.org/10.1145/3304221.3325540

[61] Mankirat Singh, Edward Clay, Yasser Salem, and Wen Cheng. 2021. Determining the Students' Preferable Learning Mode for both Traditional Classrooms Teaching Under Normal Situations and Forced Virtual Teaching in Quarantine Period. In *2021 IEEE Frontiers in Education Conference (FIE)*. 1–8. https://doi.org/10.1109/FIE49875.2021.9637466

[62] Changwon Son, Sudeep Hegde, Alec Smith, Xiaomei Wang, and Farzan Sasangohar. 2020. Effects of COVID-19 on College Students' Mental Health in the United States: Interview Survey Study. *J Med Internet Res* 22, 9 (3 Sep 2020), e21279. https://doi.org/10.2196/21279

[63] Patriel Stapleton and Jeremiah Blanchard. 2021. Remote Proctoring: Expanding Reliability and Trust. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education* (Virtual Event, USA) *(SIGCSE '21)*. ACM, New York, NY, USA, 1243. https://doi.org/10.1145/3408877.3439671

[64] SWGfL. 2022. Video Conferencing for Kids: Safeguarding and Privacy Overview. https://swgfl.org.uk/resources/safe-remote-learning/video-conferencing-for-kids-safeguarding-and-privacy-overview/ Last accessed: 2022-08-30.

[65] Heather Thiry and Sarah T. Hug. 2021. Sustaining Student Engagement and Equity in Computing Departments During the COVID-19 Pandemic. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education* (Virtual Event, USA) *(SIGCSE '21)*. Association for Computing Machinery, New York, NY, USA, 987–993. https://doi.org/10.1145/3408877.3432381

[66] Dianne Tice, Roy Baumeister, Joseph Crawford, Kelly-Ann Allen, and Alisa Percy. 2021. Student Belongingness in Higher Education: Lessons for Professors from the COVID-19 Pandemic. *Journal of University Teaching & Learning Practice* 18, 4 (2021), 2. https://doi.org/10.53761/1.18.4.2

[67] Tammy VanDeGrift. 2022. Post-Exam Videos for Assessment in Computing Courses: See and Hear Students' Thinking. In *Proceedings of the 53rd ACM Technical Symposium on Computer Science Education V. 1* (Providence, RI, USA) *(SIGCSE 2022)*. Association for Computing Machinery, New York, NY, USA, 230–236. https://doi.org/10.1145/3478431.3499273

[68] Ana Verde and Jose Manuel Valero. 2021. Teaching and Learning Modalities in Higher Education During the Pandemic: Responses to Coronavirus Disease 2019 From Spain. *Frontiers in Psychology* 12 (2021). https://doi.org/10.3389/fpsyg.2021.648592

[69] Monica Vladoiu and Zoran Constantinescu. 2020. Learning during Covid-19 Pandemic: Online Education Community, Based on Discord. In *2020 19th RoEduNet Conference: Networking in Education and Research (RoEduNet)*. IEEE, 1–6. https://doi.org/10.1109/RoEduNet51892.2020.9324863

[70] Akash R Wasil, Rose E Franzen, Sarah Gillespie, Joshua S Steinberg, Tanvi Malhotra, and Robert J DeRubeis. 2021. Commonly Reported Problems and Coping Strategies during the COVID-19 Crisis: A Survey of Graduate and Professional Students. *Frontiers in psychology* 12 (2021), 598557. https://doi.org/10.3389/fpsyg.2021.598557

[71] Mary Katherine Watson, Elise Barrella, and Kevin Skenes. 2021. Self-Directed Learning Readiness among Engineering Students during Emergency Online Instruction. In *2021 IEEE Frontiers in Education Conference (FIE)*. 1–5. https://doi.org/10.1109/FIE49875.2021.9637313

[72] Emma R Wester, Lisa L Walsh, Sandra Arango-Caro, and Kristine L Callis-Duehl. 2021. Student Engagement Declines in STEM Undergraduates during COVID-19-Driven Remote Learning. *Journal of microbiology & biology education* 22, 1

(2021), ev22i1–2385. https://doi.org/10.1128/jmbe.v22i1.2385
[73] Iman YeckehZaare, Gail Grot, Isadora Dimovski, Karlie Pollock, and Elijah Fox. 2022. Another Victim of COVID-19: Computer Science Education. In *Proceedings of the 53rd ACM Technical Symposium on Computer Science Education V. 1* (Providence, RI, USA) *(SIGCSE 2022)*. Association for Computing Machinery, New York, NY, USA, 913–919. https://doi.org/10.1145/3478431.3499313
[74] Mark Zarb, Bedour Alshaigy, Dennis Bouvier, Richard Glassey, Janet Hughes, and Charles Riedesel. 2018. An International Investigation into Student Concerns Regarding Transition into Higher Education Computing. In *Proceedings Companion of the 23rd Annual ACM Conference on Innovation and Technology in Computer Science Education* (Larnaca, Cyprus) *(ITiCSE 2018 Companion)*. ACM, New York, NY, USA, 107–129. https://doi.org/10.1145/3293881.3295780
[75] Mark Zarb and Angela A. Siegel. 2018. An Analysis of Pupil Concerns Regarding Transition into Higher Education. In *Higher Education for All. From Challenges to Novel Technology-Enhanced Solutions*, Alexandra Ioana Cristea, Ig Ibert Bittencourt, and Fernanda Lima (Eds.). Springer, 3–16. https://doi.org/10.1007/978-3-319-97934-2_1
[76] Mark Zarb, Angela A Siegel, Ric Glassey, and Janet Hughes. 2021. Becoming a CS1 Student in the Time of COVID. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education* (Virtual Event, USA) *(SIGCSE '21)*. ACM, New York, NY, USA, 1362. https://doi.org/10.1145/3408877.3439518
[77] Jiahua Zhou and Qiping Zhang. 2021. A Survey Study on US College Students' Learning Experience in COVID-19. *Education sciences* 11, 5 (2021), 248. https://doi.org/10.3390/educsci11050248
[78] Martha Zimmermann, Casandra Bledsoe, and Anthony Papa. 2021. Initial Impact of the COVID-19 Pandemic on College Student Mental Health: A Longitudinal Examination of Risk and Protective Factors. *Psychiatry Research* 305 (2021), 114254. https://doi.org/10.1016/j.psychres.2021.114254

A APPENDIX: SURVEY

The following contains the survey distributed to participants.

Survey Title: Impact of COVID on the Student Learning Experience

Research Participant Notification:

We invite you to take part in a research study exploring the experiences of higher education students through the COVID-19 pandemic. Please read this information carefully. By taking the survey and submitting your responses, you are giving the researchers your formal consent to the collection and use of your data.

Purpose of the research study: The coronavirus pandemic (COVID-19) has forced an unprecedented global shift within higher education in the ways that we communicate with and educate students. This necessary paradigm shift has compelled educators to take a critical look at their teaching styles and use of technology. Higher education traditionally traditionally focuses on experiential, in-person activities. COVID-19 has mandated that educators reconsider their use of student time and catalyzed overnight innovations in the educational setting. We are an international group of researchers investigating this impact, and how it will affect education as we transition to a post-pandemic setting. We would like to invite you to complete this survey, and/or share it across your networks.

This survey is completely anonymous and gathered data will only be used for the purpose of research. All questions in the survey are optional, and there is no impact for submitting an incomplete survey. The results of this research may also be published in professional journals or presented at scientific conferences, but any such presentations will report only aggregated findings, which in some instances may be illustrated by short, anonymous quotes carefully selected so as not to breach individual confidentiality.

Who can take part in the research study?: The project invites the any students in higher education through the COVID-19 pandemic. We are interested in the experiences of full-time or part-time students at any level of higher education.

What you will be asked to do: If you decide to participate in this research you will be asked to complete a short 20-30 minute survey about your learning experiences during the COVID-19 pandemic.

All reported data will be aggregated, and no participant will be identifiable. No individual data will be reported, except for some unidentified quotes from questionnaire answers that will be used to illustrate specific findings. You will not be identified in any reports or publications. By completing the survey, you are giving consent to the use and of the data gathered herein. Your participation is completely voluntary, and you are free to abstain from answering any question(s) for any reason.

If you decide to stop participating: You are free to leave the study at any time; if you choose to do so, simply close your browser. Should you withdraw, all gathered responses will be destroyed. Following submission of this survey, it will become impossible for us to remove your data because we are not collecting any identifying data that will tie you to your responses.

Questions: Please direct questions or comments to: Dr. Angela Siegel (siegel@dal.ca | Dalhousie University); or Dr. Mark Zarb (m.zarb@rgu.ac.uk | Robert Gordon University).

If you have any ethical concerns about your participation in this research, you may contact the Director, Research Ethics, Dalhousie University at (902) 494-1462, or email: ethics@dal.ca. If you do, you may cite our research project REB file 2022-6090.

Consent Decision: Completion of the survey beyond this section indicates your agreement to this statement of informed consent.

Research Team This study is being conducted by the following researchers as part of an ITiCSE 2022 Working Group:

Angela Siegel (Dalhousie University, Canada)
Mark Zarb (Robert Gordon University, UK)
Emma Anderson (Northumbria University, UK)
Brent Crane (Dalhousie University, Canada)
Alice Gao (University of Waterloo, Canada)
Celine Latulipe (University of Manitoba, Canada)
Ellie Lovellette (College of Charleston, USA)
Fiona McNeill (University of Edinburgh, UK)
Debbie Meharg (Edinburgh Napier University, UK)

Questions:

(1) Program of study:
    - Undergrad
    - Masters
    - PhD
    - other (free response item)
(2) Field of study / Major (free response item)
(3) Current year of study (for selected program):
    - Year 1 / Freshman
    - Year 2 / Sophomore
    - Year 3 / Junior
    - Year 4 / Senior
    - Year 5+
(4) Institution Name (free response item)
(5) Institution Country (free response item)
(6) What is the average class size you took during the pandemic?
    - Small (<50)
    - Medium (50-100)
    - Large (100-199)

- ○ Very Large (200+)
- ○ N/A - I didn't study during the pandemic

(7) When were you first a student at your institution?
- ○ Pre-2020
- ○ 2020
- ○ 2021
- ○ 2022 onwards

Section: BEFORE the Pandemic - University life pre-2020

(8) Approximately what percentage of your classes were delivered using the following modes BEFORE the pandemic?
(a) Live face-to-face (in-person)
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%
(b) Live online (synchronous)
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%
(c) Online class (no live component, asynchronous)
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%
(d) Other
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%

Section: DURING the Pandemic - University life 2020 to 2021

(9) Approximately what percentage of your classes were delivered LIVE FACE-TO-FACE (IN-PERSON) DURING the pandemic?
- ○ 0% (ALL ONLINE)
- ○ 20%
- ○ 40%
- ○ 60%
- ○ 80%
- ○ 100% (ALL IN-PERSON)

(10) *(question appears only if response to question 9 was less than 100%)* Approximately what percentage of your NON-FACE-TO-FACE (i.e. not in-person) classes were delivered using the following modes DURING the pandemic?
(a) Live online (synchronous)
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%
(b) Online class (no live component, asynchronous)
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%
(c) Other
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%

(11) *(question appears only if response to question 9 was less than 100%)* How was your **experience of learning virtually** during the pandemic?

0	1	2	3	4	5	6	7	8	9	10
Very negative										Very positive

(12) *(question appears only if response to question 9 was less than 100%)* How was your experience of **adapting to new technologies used for learning** during the pandemic?

0	1	2	3	4	5	6	7	8	9	10
Very negative										Very positive

(13) How was your experience of **access to technology and Internet** during the pandemic?

0	1	2	3	4	5	6	7	8	9	10
Very negative										Very positive

(14) How was your **mental health / personal wellbeing** during the pandemic?

0	1	2	3	4	5	6	7	8	9	10
Very negative										Very positive

(15) My **study skills prepared me for learning** through the pandemic.

0	1	2	3	4	5	6	7	8	9	10
Strongly disagree										Strongly agree

(16) **Learning through the pandemic has improved my study skills.**

0	1	2	3	4	5	6	7	8	9	10
Strongly disagree										Strongly agree

(17) My **dependency upon my instructors and/or learning supports** has increased during the pandemic

0	1	2	3	4	5	6	7	8	9	10
Strongly disagree										Strongly agree

(18) I was **able to find meaningful communities/groups for learning** during the pandemic.

0	1	2	3	4	5	6	7	8	9	10
Strongly disagree										Strongly agree

(19) If you have any thoughts on your **learning experience during the pandemic**, please share: (free response item)

Section: NOW and Going Forward - University life 2022 onwards

(20) Approximately what percentage of your classes are delivered using the following modes **NOW**?
(a) Live face-to-face (in-person)
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%
(b) Live online (synchronous)
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%
(c) Online class (no live component, asynchronous)
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%
(d) Other
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%

(21) Approximately what percentage of your classes **WOULD YOU LIKE** to be delivered using the following modes **GOING FORWARD**??
(a) Live face-to-face (in-person)
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%
(b) Live online (synchronous)
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%
(c) Online class (no live component, asynchronous)
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%
(d) Other
○ 0% ○ 20% ○ 40% ○ 60% ○ 80% ○ 100%

(22) Which **study skills do you feel you are lacking going forward**? (free response item)
(23) Which of the following **learning tools would you like to see used going forward**?
   (a) **Document collaboration** (Google Docs, Jamboard, Miro, ...)
      ○ N/A ○ No ○ Maybe ○ Yes
   (b) **Recordings of lectures** (YouTube, Panopto, ...)
      ○ N/A ○ No ○ Maybe ○ Yes
   (c) **Communication Tools** (Slack, Discord, Teams, WhatsApp, ...)
      ○ N/A ○ No ○ Maybe ○ Yes
   (d) **Interactive Learning Platforms** (zyBooks, Runestone Interactive, ...)
      ○ N/A ○ No ○ Maybe ○ Yes
   (e) **Real-time Interactive Quizzing** (Kahoot, Mentimeter, Poll Everywhere, iClicker, ...)
      ○ N/A ○ No ○ Maybe ○ Yes
(24) Have you been taught using **innovations or new teaching and learning approaches** that you want to see continued or being used more widely going forward? (free response item)
(25) What do you feel your **future educational experience should look like**? (free response item)

Section: Demographic Data

As with all questions, these fields are entirely optional. These demographic questions will help us to understand if student experiences varied based on these factors. Demographic data will not be compared at an institutional level nor used for identification purposes.

(26) Are you a racial or ethnic minority student in your program (Black, Hispanic, Indigenous, etc.)?
   ○ Yes
   ○ No
   ○ Unsure
   ○ Prefer not to respond
(27) What gender do you identify with?
   ○ Woman
   ○ Man
   ○ Non-binary
   ○ Prefer not to respond
   ○ Prefer to self-describe (free response item)

Submit button

Confirmation page

Thanks!
Your response was submitted.