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Teaching through a global pandemic: educational landscapes before, during and after COVID-19.

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Teaching through a Global Pandemic: Educational Landscapes Before, During and After COVID-19

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ABSTRACT

The coronavirus (COVID-19) pandemic has forced an unprecedented global shift within higher education in how instructors 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. Computing education traditionally focuses on experiential, in-person activities. The pandemic has mandated that educators reconsider their use of student time and has catalysed overnight innovations in the educational setting.

Even in the unlikely event that we return entirely to pre-pandemic norms, many new practices have emerged that offer valuable lessons to be carried forward into our post-COVID-19 teaching. This working group will explore what the post-COVID-19 academic landscape might look like, and how we can use lessons learned during this educational shift to improve our subsequent practice. Following a multinational study of computing faculty, this exploratory stage will identify practices within computing that appear to have been improved through exposure to online tools and technologies, and that should therefore continue to be used in the online space. In the broadest sense, our motivation is to explore what the post-COVID-19 educational landscape will look like for computing education.

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CCS CONCEPTS

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

KEYWORDS

COVID-19; coronavirus; computer science; computing education; online education; pandemic; recovery; resilience; teaching

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1 INTRODUCTION

1.1 Evolving Landscapes in Response to COVID-19

At the time of writing, mid-2021, we are still in the midst of the COVID-19 global pandemic. While some provisions have been made to facilitate a safe return of students to campus, most teaching is still conducted online, as has been the case for the totality of the current academic year for many institutions. This educational shift has acutely impacted subjects which, traditionally, benefit from in-person activities such as guided labs, experiential learning activities, and tutorials. These traditionally in-person activities have been augmented through the use of various technologies and innovative pedagogies to facilitate the transition to an online environment over the course of the academic year.

Before the pandemic, prior work explored concerns experienced by students transitioning into higher education [61, 62, 79, 81]. However, students transitioning into higher education during the COVID-19 pandemic encountered an entirely new learning, teaching, and assessment reality, especially with respect to their experiences of "emergency remote teaching" in 2020 [15, 60, 74, 80]. In parallel, the rise of online and hybrid coursework and programs has brought with it investigations of online content delivery.

As a community, while we have undertaken pedagogical work to teach students in the online environment [19, 39], the current, pandemic-affected students are not traditional online learning students – rather, they are face-to-face students who have been forced to rapidly adapt to diverse online learning provision [74, 80]. It is thus important to capture and analyse both faculty and student experiences and innovations, so as to reflect on lessons learned from these to better inform emerging policies and practice as we move towards a post-COVID-19 educational landscape.

1.2 Looking Ahead

While COVID-19 precipitated many challenges, it also catalysed creative and innovative modes of engagement in higher education [15, 17, 35, 60, 67, 74, 80]. Some of the preexisting barriers to innovation were lifted to allow for a rapid transition to online teaching and learning. As such, evaluation of and exposure to new tools and learning techniques took place at a faster rate than ever before [60]. It is important that we capture the lessons learned from both students and faculty while the experiences remain fresh.

The objectives of this study were as follows:

(1) to conduct a review of the existing literature relating to the impacts of the pandemic on computing education;
(2) to conduct a multinational study of computing faculty to better understand the impact of COVID-19 on computing education; and
(3) to explore the results of the study to elicit best practices resulting from the impact of COVID-19.

2 BACKGROUND

Given that this is the first occurrence of a pandemic affecting computing education at a global scale, many have started to explore its effects. A growing body of literature is investigating changes in a number of areas relating to computing education and the effects each has had on both students and instructors. As a starting point, we explored the newly emerging literature to compile a review of the existing work to date. This review forms the backbone of the study and is used to inform areas to be investigated.

Due to the strict time-frame and focus on CS education research, we approached the literature by first selecting the major conferences (e.g. SIGCSE, ITiCSE, ICER, UKICER, Koli Calling, FIE and EDUCON) and journals (e.g. Transactions on Computing Education, International Journal of Higher Education Research, Higher Education Pedagogies, and Higher Education for the Future). Several sources outside of mainstream CS education were also included, for example publications in the domain of psychology, sociology, and industry, due to the psychological, sociological, and industrial and economic implication of the pandemic on students.

Next, this set of sources was searched for titles, abstracts or keywords related to *COVID-19*, including *COVID*, *coronavirus* and *pandemic*. This yielded an initial set of 80 publications that included full papers, abstracts, and case studies. From this, we used inductive reasoning to organise papers into main themes as follow:

- Pedagogy & practice
- Value changes
- Inclusion & diversity
- Community, belonging & wellbeing
- Academic integrity

Some papers were assigned to multiple themes as they contained discussions pertaining to those themes. Any papers that did not fit into these themes, or had no real substance relevant to the pandemic, were omitted (n=16).

2.1 Pedagogy and Practices

As a result of the global COVID-19 pandemic, many universities have moved their teaching, services, and/or support online. Changes that have taken place do not seem dramatically out of alignment with the pre-pandemic forecasts. In several instances, institutional directions were strengthened by this new reality. With respect to advances in online supports for those who may find it more challenging to access the campus, COVID-19 has not changed where we are going, but rather has dramatically altered our starting point [59]. Many instructors and researchers quickly adapted to the new circumstances of the COVID-19 lockdowns, shifting classes and approaches quickly to develop and test new methods of instruction.

2.1.1 Course structure and design. Some studies focused on structural changes to courses necessitated by remote instruction. In a postgraduate Social Networking course in the Information Engineering curriculum, Chan et al. [9] implemented a three-phase Action Research study. They sought to identify ways to facilitate collaborative learning among engineering students during physical isolation through use of social platforms. By the end of Phase 1 (February 2020), students interacted more actively online than in the physical environment. By the end of Phase 2 (March 2020), class participation rates increased (80% to 95%) and class blogging became an important tool for collaborative learning. In Phase 3 (March – April 2020), students were invited to reflect on their collaborative learning experience in accordance to the social network analysis results obtained from their Python programming assessments. The findings indicate that class blogging practice along with the synchronous online sessions enhanced students' collaborative learning and participation.

In a survey of 214 UK computer scientists conducted shortly after the onset of COVID-19, Crick et al. [15] report positive impacts of learning, teaching, and assessment such as resilience of digital infrastructure, increased staff support, and opportunities for flexible learning. Negative impacts highlight that the technologies adopted at some institutions do not support shared mental representations necessary for effectively teaching key computer science topics such as programming, as well as more collaborative topics such as robotics and group software projects. The findings highlight concerns about institutions adopting top-down "one-size-fits-all" approaches to moving teaching online, without evaluating

disciplinary-specific challenges, and such decisions may not always be driven by appropriate pedagogic approaches.

Siqueira and Simion [65] surveyed 533 students in an inverted classroom across an active learning environment and traditional lecture hall. They found that before transitioning online, 83% of students in the active learning environment perceived an ease of collaboration compared with 25% of those in the traditional lecture hall. When both groups transitioned online due to COVID-19, the active learning group perceived the online mode as less collaborative. Specifically, 52% of the active learning group and 47% of the traditional lecture hall group reported the online collaboration options as "awkward."

Zhu et al. [82] describe the pedagogical design of a basic engineering online course. The design includes lecture breaks, content distribution, interaction, and strategies to manage the learning process before, during and after the lectures. It makes use of Rain Classroom, a smart teaching tool plug-in that allows for PowerPoint integration with WeChat (a free and popular messaging application used by students). The tool was used to evaluate student learning by sending questions during live online lectures, providing instant feedback on draft student submissions (e.g. graphs, equations, short videos) and automatic collection of all learning data before, during, and after the lectures. The findings highlight that in order to sustain student engagement and motivation over longer periods of online learning, additional methods must be integrated into a blended teaching and learning mode.

In June 2020, Bizot et al. [5] conducted a survey of CS faculty on the transition to online learning. They distributed the survey through Computing Research Association (CRA) and SIGCSE listservs and received 450 responses spanning public and private institutions. They found that a majority of faculty surveyed found it hard to implement their preferred teaching style (74.6%) and more time consuming to teach remotely (65.6%). Of those who used active learning before moving online, 34.9% reported discontinuing the practice while 64.7% reported continuing the practice and adapting their methodology. Similarly, 38.6% of faculty who employed pair programming in their pre-pandemic courses reported discontinuing the practice while 61.4% reported continuing while making adaptations. When asked about their students, most faculty agreed recorded lectures were better than in person for at least some of their students: 63.6% selected that their students' "ability to watch recorded lectures at a different time than class time" was better, while 63.1% agreed that students being able to re-watch lecture portions to better understand the material was helpful.

Thiry and Hug [72] surveyed 918 undergraduate students across 14 computing departments in Hispanic-Serving Institutions in late spring 2020 about the transition to online learning. Most students found help from faculty to be effective (84%) despite the transition. Certain aspects of learning, such as effective group work, were not considered as effective during this period of remote education, in spite of the fact that students were still exhibiting high levels of collaboration.

Escobar [22] discusses the impact of swapping assessment strategies in response to the pandemic, where an exam was swapped for performance tasks. While this is originally seen as a threat to validity of the study, it serves to show that the reaction to the pandemic has been exceptionally agile and adaptable. Furthermore, it was noted that although the students had to abruptly change from a more traditional classroom modality to an online synchronous learning environment, a large number of students successfully completed the course and examination requirements with scores that reflect a deep understanding of the core concepts of the course, regardless of the modality of delivery. This adaptability of learning was also commented on in a subsequent study [57], which focuses on a change in delivery format and identifies the importance for consistency in academic integrity.

2.1.2 Tool development and use. Many instructors found themselves grappling with new tools and technology, and researchers took the opportunity to identify where changes to practice that integrated these tools and platforms bore advances. Richard [37] described how Spike (used as a knowledge acquisition phase in Scrum to learn or determine work needed to solve a software issue) was implemented through Zoom and Padlet discussion forums as a group practice that enabled students to investigate problems, develop concepts, identify tasks, and collaboratively share the outcomes of each Spike in their interdisciplinary Game Design course. Their findings suggest that including teaching practices such as Spike in a blended mode may enhance student engagement and learning.

Whalley et al. [75] evaluated how connected technologies impacted higher education during COVID-19 and how they may continue to change patterns in the future. They note that while lectures can easily be delivered online, there is an ongoing challenge in providing quality - and addressing auxiliary items such as assessment, practicals and tutorials. This is echoed by Lishinski et al. [38], who reported that 40% of students found the shift to online teaching somewhat or very difficult, 50% found it was somewhat or very easy, and 10% were undecided. However, students were more aligned in a belief that online delivery was not as effective as in-person instruction. Students surveyed by Farghally et al. [25] found online office hours significantly less useful than in-person hours and felt less supported by their instructors, and prerecorded asynchronous lecturers less useful than face-to-face learning opportunities. There were mixed responses from students regarding uncontrolled online exams, which some found to be more stressful.

GatherTown's online space was also the foundation for innovation. Latulipe [35] implemented an interactive classroom space in GatherTown to facilitate team-based active learning during class. This online space provided similar mechanics to the physical classroom, where students could work privately with their group members at a table while free to interact with students in other groups and the learning assistants. Markel and Guo [41] reported on the experiences of undergraduate TAs in two CS courses pre-COVID and during COVID: an interactive software design course, in which students develop a web-app for a client; and a Unix-based computational tool course centered on lab assignments. They recommended investigation of avatar-based and "town-based" systems (e.g. GatherTown) to reduce bandwidth and potential student self-consciousness in online environments, and to provide a sense of ambient awareness. They also suggested that, Where capacity allows, round-the-clock TA virtual office hours can help online courses serve populations around the world despite timezone differences.

They found that, in the online environment, more students participated in asking questions and providing feedback compared to face-to-face, where a few, frequent voices were most dominant. Additionally, they noted that students found the flexibility of the online environment helped students coordinate and offered opportunities to communicate outside of class time (e.g., by "staying after" in a Zoom meeting). By comparison, they found that the face-to-face classes benefited from the shared context (same devices, screens, and face/eye contact) and ambient awareness, which enabled them to notice background events and allowed instructors to take the "pulse" of a course by walking around the room.

2.2 Value Changes

The values of students and teachers alike have been challenged by the pandemic, and in some cases have shifted. These values have also played a role in response to changes in the learning environment.

Toker [73] presents a set of underpinning core values for both educators and students, indicating that these cores values are directly linked to learners' application of knowledge. The study notes that educators bring both professional and personal values to the workplace, directly impacting their students' value development. It is argued that educators need to be aware of this responsibility of transferring these values to future generations, and future formations of society.

Fan [24] consolidates a broad spectrum of research that looks at issues regarding values in education through a series of exploratory studies on small groups. This study shows that there is a need to establish a more widely shared construct of values to develop a stronger theoretical basis for further research. The sudden shift in educational practice due to the pandemic resulted in a need for core aspects of higher education (such as teaching, assessment, and curriculum design) to become more agile and adaptable between online and face-to-face contexts [26]. The COVID-19 pandemic, and the subsequent national lockdowns, presented a unique shift in focus away from the previous institutional, community and culture-led values, by presenting institutions with a common challenge affecting both educators and learners [17, 22, 57], ranging from the accessibility of the methods of delivery to a focus on academic integrity and the needs for multi-modal and flexible learning environments [2, 15, 77].

Finally, in a study by Watermeyer et al. [74], a minority of respondents felt positive results could come from the sudden transition to online education. Some respondents noted that underlying assumptions about teaching and learning had been challenged, highlighting the expertise and importance of practitioners in the field of academic technology. Others expressed concern that this large-scale digitization would lead to further commoditization, "dumbing down", and automation of higher education, as well as the disproportionate impact on early-career academics, erosion of work-life balance and the loss of opportunities afforded by being in a shared physical space (e.g. counselling time with students). However, respondents also appreciate the flexibility of working from home, and felt that at least for some in the academic community, online education was more inclusive and helped community members connect in new ways. In particular, it created a level playing field by forcing some traditional, established academics to explore online educational technologies for the first time.

2.3 Inclusion and Diversity

In diverse learning spaces, it is important to cultivate an inclusive culture in which students feel confident to speak up, ask questions, raise concerns and learn from their mistakes alongside their peers in a safe environment. There were a number of global events leading up to the pandemic that directly impacted institutions and students; for example, the increased political polarisation in many countries has heightened the sense of isolation and loneliness amongst international students, and natural disasters associated with the shift in climate change have interrupted several teaching activities in developed countries [11, 34]. Furthermore, the Black Lives Matter movement has largely been a catalyst for institutions to reflect on their policies and institutional practices and start having conversations around diversity, inclusion and racial inequality [20, 29, 78].

As part of a SIGCSE panel, Brown et al. [8] discussed the combined impact of COVID-19 and racism on the computing community. During their discussion, the panel acknowledged the existence of structural and institutional racism integrated in educational systems and presented recommendations for combating those practices including calling on organisations to issue anti-racism statements, committing to the cause and removing barriers that impedes the participation of Black members with the computing community, and providing unconscious bias training.

One strategy to address under-representation or low performance with diverse groups has been to design preparatory or out-of-class courses that target specific groups. As the pandemic stretched resources, literature is emerging that reveals some of the impacts of these efforts. Despite rapidly growing numbers of Black female students studying Advanced Placement Computer Science Principles in Alabama (2007: n=3; 2020: n=754, with a further 637 underrepresented students), Escobar et al. [22] note that there are still concerning statistics with regards to successful completion. In response, they designed a preparatory experience to address the lack of engagement which they hypothesised accounted for the under-performance. Despite the impact of the pandemic, the authors reported that for the most part, the students continued to do well and meet the goals they set. However, they also reported a drop-out rate of 10%. The results showed that the extra attention to engagement led to a significantly higher qualifying rate (87.5%) than the regional (statewide) sample (55.3%).

Negative experiences in terms of drop-out rates have emerged. In 2021, McDonald and Dillon [43] explored the experience of moving a girls' coding club online, stating that the pandemic caused "[...] coding clubs to either close altogether or limit their activities to what they can do online. Because low-income communities depend on resources provided by these very institutions, the impact of their closing disproportionately impacts teens living in poverty". Despite documenting a wide range of positive practice shifts to move the coding club online, the authors note that attendance dropped by 50%, largely attributed to loss of clear lines of communication and confusion over the status of the course.

Branco et al. [6] designed an outreach program with the objective of encouraging children and young adults from various Brazilian communities into computing. Since its inception, the project introduced a total of 45 workshops and 94 courses dealing with unplugged coding activities, programming, and robotics. In a self reported survey, out of a total of 2639 students, 54% identified as male while 46% identified as female. While these numbers seem encouraging, there was a drop in enrollment during the pandemic from 611 students in 2019 to 428 in 2020.

During the first summer of the pandemic, Begel et al. [4], in collaboration with Clemson University Spectrum Program, developed a virtual game software development camp over Zoom specifically targeting students with autism spectrum disorder as many of those students struggle with communication and social interaction, anxiety caused by changes to their surrounding environment, and attention deficiency [21]. The researchers used pair programming as a methodology to foster teamwork and collaboration skills [18] and employed a block based programming environment (MakeCode Arcade [4]) to teach the students. At the end of the 13 day camp, the students reported "improved programming skills, increased confidence in communication, and better experiences working with others".

In an attempt to overcome the physical and distance challenges enforced by COVID-19, Brinkley et al. [7] described incorporating remote participatory design in the delivery of an inclusive design course focusing on accessibility. During the term, the students were assigned to create an autonomous vehicle technology solution with accessibility considerations as part of their final project. The deliverables included an app, a website, and the interior design of the vehicle layout with ergonomics in mind. The students collaborated with three older adults with a mean age of 86.7 years living in a senior facility, with two reporting a disability, for design ideas and feedback. The sessions were held individually over the phone and Zoom. While the students successfully completed the tasks, they reported issues with logistics, decreased efficiency, and increased workload as part of the design process.

In developed and developing countries alike, students requiring educational accommodations for disabilities also face difficulties due to lack of accessibility of newer technologies. More broadly, the psychological impacts of purely online education were noted as a concern. The authors suggest several ways that opportunities for the future have emerged in the wake of the pandemic. Whalley et al. [75] point out that tutoring, collaboration, and discussion do not require physical travel and can accommodate students who are sick or dealing with other personal issues through digital homes in Zoom, Teams, Hangouts, and similar video platforms. Networked learning and delivery enable knowledge sharing, teamwork, and other forms of cooperation from a distance. E-learning could bring educational programs within reach of many potential students from disadvantaged populations - who cannot easily move to a university - and also provide opportunities for post-graduate work. Institutions could benefit from an explicit teaching policy that advocates for active learning and support for blended learning models, along with continuing professional development support for new approaches to instruction. Pokhrel and Chhetri [56] also identified opportunities in the new educational landscape. They noted that the pandemic resulted in the exploration of technology for use in the classroom, and that it required instructors to be more creative in developing curricula.

Coleman et al. [13] described their mid-pandemic efforts of reaching out to the parents of marginalised and underrepresented student groups who comprised mainly Black and Latina middle school girls as part of an outreach project fostering computing. Pre-pandemic, emails in English and Spanish were used to engage with the parents, however, the authors resorted to using SMS and phone calls as well to support communications, which parents found effective.

In their review of COVID-19 teaching literature, Pokhrel and Chhetri [56] identified several challenges the pandemic has brought in education. For students from indigent or disadvantaged backgrounds, especially in developing countries, network connectivity can be expensive and difficult to procure, and technological devices may be unaffordable. As noted by Whalley et al. [75], higher education becomes "unreal" to those from disadvantaged backgrounds, and institutions need to address cultural differences and provide support for differences.

2.4 Community, Belonging and Wellbeing

Beyond students, faculty were also affected by the ramifications of the COVID-19 pandemic, leading to hardship, but also innovation in ways to address inclusion, diversity and belonging during tough(er) times. There were several spontaneous initiatives by computer science educators to create international communities to support academics who often feel ill-equipped or helpless about their approaches to support their students' mental well being. The objective is to create resources accessible to both students and academics and share positive experiences [1].

Furthermore, while dependence on online technologies through the pandemic is clear, face-to-face access to instructors remains invaluable. Piech et al. [55] observe that while MOOCs have become established as one option for online teaching, they suffer terrible completion rates. As campuses shut down in response to the pandemic, their project investigated the potential for volunteer teachers to complement online courses by giving students access to a teacher and a reasonably-sized cohort of students. They recruited 907 section leaders that met their criteria, covering all except 3 time zones and a range of 64 different languages. While the focus of the project was investigating the feasibility of this approach, the results were promising, and perhaps a potential pathway to reaching more diverse and underrepresented student groups even after the pandemic.

Finally, there was also an impact on the teachers themselves in terms of their career stability. In a recent study, the Organisation for Economic Co-operation and Development (OECD) explored the impact of the pandemic on the international scientific research communities [53]. While Microsoft focused on the impact of COVID-19 on the Computer Science Research Community specifically [47], there is little research exploring the effect on CS practitioners with respect to their career stability and progression [17].

While there is more to learn of what is happening in the post-COVID-19 educational landscape within computer science, early works are starting to emerge with recommendations towards the future. Marchant et al. [40] conducted a qualitative study to reflect on the lived experiences of primary school staff (responsible for

students aged between three and eleven) in Wales with respect to the immediate school closures and reopening to identify future recommendations. Results of survey responses identified several recommendations including focusing on the mental health and well-being of students and staff, protecting staff breaks to promote positive workplace practices, and providing pastoral care. A 2020 initiative by Microsoft [41] is recommending designing an experiential learning environment that combines video conferencing, online messages and screen sharing to increase collaboration and combat accessibility and physical barriers. We expect many more works to follow. As such, practitioners should aim to design various collaborative activities in which students work towards a mutual goal as it creates a sense of camaraderie or belonging. The following section presents an overview of the emerging literature in this space in the light of the pandemic. "Belonging" is defined as "…the experience of personal involvement in a system or environment so that persons feel themselves to be an integral part of the system of environment" [30]. Hagerty et al. [30] believe that belonging "can further influence the level of involvement and attachment an individual has to a community or group. It has been also accounted for psychological and physical well-being of individuals".

There are various factors contributing to fostering a sense of belonging amongst computer science university students. Mooney and Becker, who have been investigating the issue prior [48] and during [49] the pandemic attributed various factors including: students' experiences and background (specifically race, gender, financial hardship, and SAT scores) [32], campus climate (which includes colleagues [68] and teaching faculty [27]), physical [69] and virtual [31] environments, and full-time and part time enrollment [33].

In 2021, Moudgalya et al. [51] used qualitative instruments to study students' sense of belonging in introductory CS courses from 21 universities. The findings show nuanced correlations with respect to students' race, gender, and learning environment. Their work shows a positive association between students' sense of belonging and academic outcome with respect to increased motivation, achievement, developing interest in pursuing computing, and persistence in the field [10, 36, 42, 71].

Work by Stout and Write [70] has shown that LGBTQ+ students are more likely to consider leaving the field. Research by Mooney et al. [50] investigated the perceived differences in the sense of belonging between men and women in computing subjects, with women reporting that they felt out of place. This sentiment was echoed by first generation [3] and low income students. Solomon et al. [66] reported that Black women feel that they don't belong in CS, and in 2020, Nguyen and Lewis [52] concluded that competitive enrollment policies negatively affected first year students' sense of belonging.

Falkner et al. [23] explored viewpoints of female academics and postgraduate students in computer science and reported experiences of the imposter phenomenon [12] in high achieving women. Michell et al. [46] reported that many women are being chased away from the field to work in administrative jobs. The authors in [45] call for creating a socio-ecological framework that targets gender inequality in computing. Gonzales et al. [28] note that 60% of surveyed LGBTQ+ students exhibited mental health issues during the pandemic, and call for rapid intervention from higher education institutions.

The sudden closure of campuses undoubtedly had effects broadly across all students. However, the range of effects can vary greatly depending upon which group of students are considered. In a 2021 study by Thiry and Hug [72], an investigation into the Hispanic experience was conducted.The results showed that students expressed great anxiety, frustration, and difficulty in focusing academically with 75% reporting greater stress, 66% reporting increased anxiety, and 40% experiencing mental health issues. Women were disproportionately affected and more likely to experience multiple mental health challenges. Many students reported increased financial hardship with 33% struggling to meet basic needs such as buying food and covering living costs. Technical challenges also played a role with students reporting the need to share computing resources with family members (20% having hardware that was too old to cope with online teaching platforms and video conferencing) and unreliable internet connection (with some 10% having no internet connection at their home).

2.5 Academic Integrity

The literature of academic integrity in computing education has long focused on tasks, such as homework and assignments, that students are expected to carry out in their own time and unsupervised. Well before COVID-19, there has been mention in the literature of problems with academic misconduct in online, unsupervised, exams [63]. However, the bulk of the literature on the topic has dwelt on take-home tasks. A 2016 ITiCSE working group [64], exploring the question of academic integrity in programming education, appears to have focused entirely on such assessment items, making no mention at all of examinations or in-class tests. Anecdotally, this focus on the integrity of take-home programming tasks is balanced by an understanding that even if dishonest students benefit from inappropriate assistance in these tasks, they will be found out when they take a final examination, face-to-face and supervised.

Very recent literature shows a change of focus. In computing education, as in many other areas of education, the major change in assessment has been the migration of tests and final exams to an online delivery, generally unsupervised. In 2021, this has led to passing mentions of "the impact on formal examinations and assessment" [16], and also to full papers, such as one describing an examination template (albeit in a probability course for computing students) that permits the generation of a unique examination for each online student [58].

To address challenges in the use of traditional front-facing web cameras for remote proctoring (limited field of view, opportunities for academically dishonest behavior, and frequent student interruptions due to loss of eye contact in existing front-facing systems), Stapleton and Blanchard [67] ran a pilot of the use of profile (side) camera arrangements during remotely proctored assessments to investigate the practical feasibility of the approach. They describe the approach, which included a setup certification quiz and iterative feedback to students, finding that more than 99% of students successfully completed the camera setup. They note that their future work will investigate the efficacy in such systems of decreasing student interruptions by developing machine learning-based data sets for profile camera arrangements that are independent of eye

contact, and also in decreasing incentives to engage in dishonest behaviors.

2.6 Post-Pandemic Futures

At the time of writing, the pandemic is still ongoing, and much of the current effort is focused on recovery and easing up of local and national restrictions, which should have a positive impact on education. We present a snapshot of the current state of the literature, which shows that while the pandemic has caused great disruption, there have been real advances in many areas relating to teaching and learning. Many of the perceived pre-pandemic futures which were initially posited to take a number of years were implemented overnight in many institutions.

As universities begin their phased return to campus, we will begin placing a greater emphasis on the future and what each institution will become. While we recognise that not all institutions have had the same experience, through the literature and exposure with the wider community [60, 80], we have been made aware of many changes of practice, several of which were seen as positive. It is important to gain a wider understanding of the impact that COVID-19 has had on computing education and how it will affect education as we transition to a post-pandemic future.

3 METHOD

To understand the impact of COVID-19 on computing education teaching practices, assessment strategies, and technology usage, we conducted an international survey aimed at Computer Science faculty in higher education institutions. This study allowed for large-scale data collection aimed at enabling quantitative analysis, with a selection of open response questions to allow deeper probing of issues, challenges, and successes. 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 study co-authors. The study was conducted during June and July of 2021.

3.1 Survey

The survey employed in this study was built by the authors of this working group, drawing from the background research and literature review. Key themes were identified in line with the literature review presented above. To frame this study, we therefore considered key areas with the most potential for significant growth and change during the COVID-19 transition to remote learning:

- pedagogy and practices
- technology use
- assessment practices and their connections with academic integrity

3.2 Recruitment

We recruited participants 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 others.

Responses were anonymous, though potentially indirectly identifying, since respondents were asked to indicate the name of their institution and its location, along with their career stage as part of the demographic information collected.

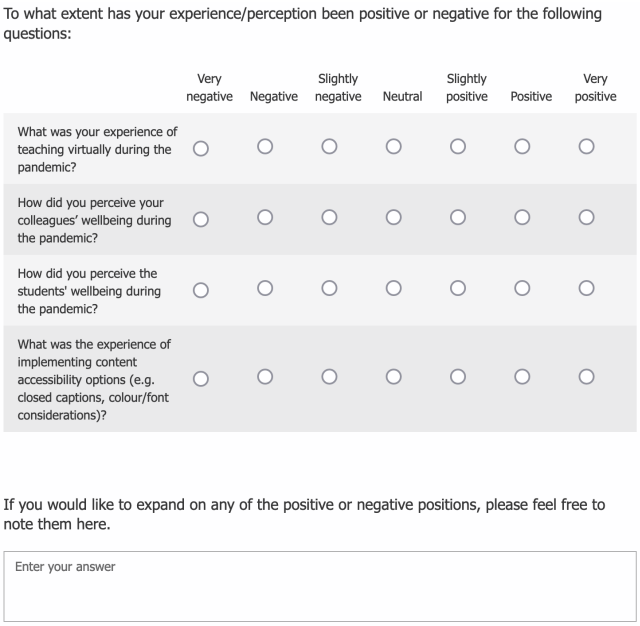

Figure 1: This question from Section 2 of the survey probes the valence (positivity/negativity) of respondent's experience and their perceptions of their colleagues' and students' teaching and learning experiences during the pandemic.

The survey was hosted as a Microsoft Forms survey at Dalhousie University, and access was provided via a public link. The survey took approximately 15 minutes to complete if all questions were answered. No compensation was provided to survey respondents.

3.3 Survey Questions

The survey consisted of 31 questions, broken down into the following six sections: *Demographics*, *Pedagogy & Practice*, *Teaching Styles*, *Technology Use*, *Assessment Practices & Academic Integrity*, and *Post-Pandemic Plans*. Most sections consisted of a set of Likert-style or checkbox-style questions presented in a tabular format followed by one or two open response questions. For example, Figure 1 shows a question table for rating the valence of pandemic teaching and learning experiences, with an open response followup. The survey questions focused on pedagogy and practice, efficacy of common teaching styles during the pandemic, use of technology during the pandemic, assessment practices, and academic integrity issues. Screenshots of a few questions are included to illustrate question style and presentation. The complete set of questions is included as Appendix A.

3.3.1 Demographics. The demographics questions collected information about the institution and geographic location of the respondent, as well as their years of teaching experience, the size of classes they taught during the pandemic, and the relative weight of teaching duties as a proportion of their overall duties.

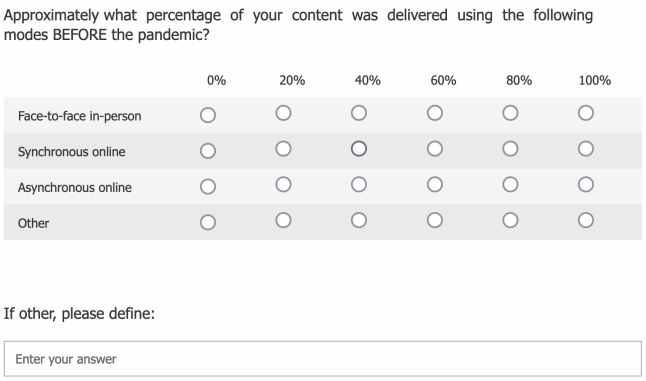

Figure 2: This question asks respondents to identify the percentage of their teaching done face-to-face, online synchronously, online asynchronously, or in some other modality.

3.3.2 Pedagogy Practices. The second section of the survey probed pedagogical practices during the pandemic. The first question set asked about the percentage of content delivered 'face-to-face', 'online synchronously', or 'online asynchronously' before, during, and projecting forward post-pandemic, see Figure 2. This section also contained a valence rating question set about the respondent's experience teaching during the pandemic (see Figure 1, and their perception of their colleagues' and students' experiences teaching and learning during the pandemic. This was followed by four sets of Likert-type questions that asked respondents to rate their level of agreement with statements relating to their (and colleagues') pedagogical preparation, skill development, use of teaching assistants, and institutional support for teaching activities during the pandemic. The final Likert-type question set focused on perceptions of various aspects of student learning during the pandemic, such as duty-of-care to students, student adaptation to online learning, students participating from different time zones, technology access barriers, and social learning opportunities.

3.3.3 Common Teaching Styles. The third section of the survey asked respondents to indicate which common teaching styles were used during the pandemic and would be likely to be used after the pandemic, or are approaches that the respondent didn't use during the pandemic but might use after the pandemic. The styles listed for consideration were 'flipped classroom', 'direct instruction', 'problem-based learning', 'small groups', and 'pair programming'.

3.3.4 Technology Use. In the fourth section, we asked respondents about various types of technology, whether or not they had used this technology during the pandemic, and whether or not they would consider using it post-pandemic. The technology types we asked about were: lecture content dissemination through institutional LMS, YouTube, or other avenues; document collaboration (e.g. Google Docs, Jamboard, Miro, etc.); online IDEs (e.g. Codio, Mimir, CS50, Codeshare, etc.); formal communication tools (e.g. Discussion Fora, Piazza, Teams, Slack, etc.); informal communication tools (e.g. Slack, Discord, Facebook, WhatsApp, etc.); CS-specific interactive learning platforms (e.g. Runestone Interactive, zyBooks, etc.); real-time interactive quizzing, etc. (e.g. Kahoot, Poll Everywhere, iClicker, etc.); autograders (e.g. Mimir, Codio, CodeHS, etc.); gamification tools; and accessibility technologies (e.g. Screen readers, closed captions, etc.). We followed this up with some open response questions about what technologies the respondent's institution made newly available during the pandemic, or what technologies the respondent wanted to use but could not, due to institutional constraints. We also asked about how concerns related to accessibility and equitable access impacted the respondent's teaching technology choices.

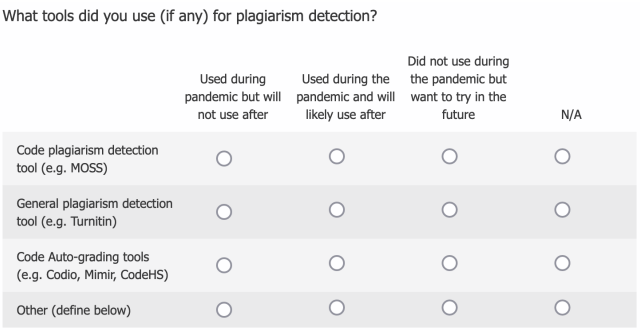

Figure 3: This question asks respondents to identify mechanisms used to detect plagiarism during pandemic teaching.

3.3.5 Assessment Practices and Academic Integrity. The fifth section of the survey focused on how assessment practices changed due to online teaching and how respondents and their institutions attempted to enforce academic integrity. The first question set in this section asked about use of remote proctoring, timed assessments, and plagiarism detection, whether these approaches were used during the pandemic and whether they will continue to be used post-pandemic. The second set of questions focused on tools use for plagiarism detection during the pandemic, see Figure 3. The third set of questions asked about practices the respondent used to promote academic integrity. For each set of questions in this section, respondents had an opportunity to describe other practices employed, beyond those listed.

3.3.6 Concluding Questions. The final section asked respondents to reflect on the impact of the pandemic on their teaching practice and the teaching practice of colleagues at their institution. The last two questions were open-ended, forward-looking questions about what new online teaching approaches or teaching innovations the respondent adopted during the pandemic and will continue to use in the future.

3.4 Analysis

We calculated averages and differences of averages for closed survey question responses, but no cell counts of less than five will be presented to protect the privacy of participants. To compare before-pandemic and post-pandemic delivery approaches, we used the Wilcoxon Signed-Rank Test, as the data did not follow a normal distribution [76], and we also calculated effect size [54]. Open responses were analyzed qualitatively in a somewhat ad-hoc approach loosely based on thematic analysis [14].

Country	Count
UK	44
USA	39
Canada	26
Australia	12
Ireland	9
South Africa	8
Sweden	7
New Zealand	5
Nigeria	5
Belgium	4
Germany	4
Finland	2
Brazil	1
Chile	1
Czechia	1
France	1
Italy	1
Jordan	1
Singapore	1
Zambia	1

Table 1: Count of survey respondents by country (n=173)

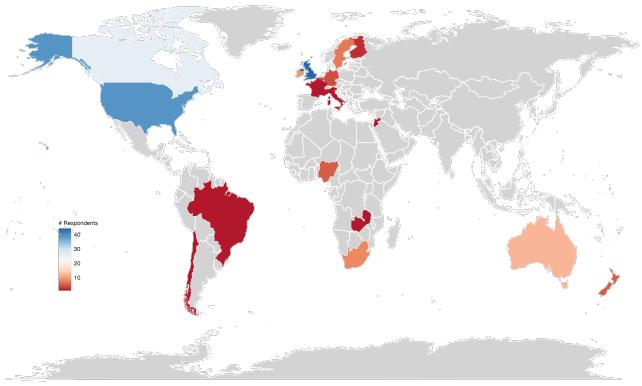

Figure 4: Locations of survey respondents visualised by global region

Teaching experience (years)	Respondents
0–5	32 (18%)
6–15	61 (34%)
16+	86 (48%)

Table 2: Teaching experience of respondents (N=179)

Work activities (25%+ workload)	Respondents
Teaching	165 (48%)
Research	93 (27%)
Administration	88 (25%)

Table 3: Work activities that represent 25% or more of respondents' workload (N=180)

Class size	Respondents
Small (< 50)	118 (43%)
Medium (50 – 100)	54 (20%)
Large (100 – 200)	63 (23%)
Large (200+)	40 (14%)
N/A	1 (1%)

Table 4: Sizes of classes that respondents taught during the pandemic (N=180)

4 RESULTS AND DISCUSSION

This section will discuss the gathered data, grouped by survey section. Within each section, individual results will be discussed. The purpose of this approach is to start understanding any underlying nuances in the data. Within the section, direct quotations from responses are identified by respondent number, e.g., R73.

4.1 Demographics

A total of 180 responses were collected in June and July of 2021 from various institutions located in 20 countries as shown in Table 1. The majority of responses were from the West (Europe, the Americas and Australasia) and, as such, do not reflect the educational landscape worldwide. This can be seen when the locations of respondents are visualised (see Figure 4). In the future, we aim to extend our reach to global respondents.

Respondents overwhelmingly (161) gave their institution level as university. Five indicated community college, three indicated high school, and 11 did not respond to this question.

Table 2 shows a breakdown of the responses based on teaching experience. The majority of respondents had over 16 years of experience (86), followed by between six and 15 years (61). The remaining respondents had no more than five years of experience (32). From the responses, it can be inferred that a large portion of respondents are aware of, or have experience in, various teaching methods to accommodate students virtually or in physical spaces.

Not surprisingly, most of the respondents were involved in teaching activities (n=165), followed closely by research (n=93) and administrative tasks (n=88) as shown in Table 3.

With the exception of a single respondent, all respondents have undertaken teaching activities during the pandemic with various class sizes, as shown in Table 4.

4.2 Pedagogy and Practice

Figures 5, 6 and 7 show a breakdown of different teaching delivery modes before the pandemic grouped into three categories: face-to-face or in-person, synchronous online, and asynchronous online.

4.2.1 Face-to-Face, In-Person Delivery of Teaching. Unsurprisingly, most of the teaching activities happened in-person before the pandemic. Nearly half of the respondents (49%) taught fully face-to-face pre-pandemic, and another 34% reported teaching face-to-face 80%

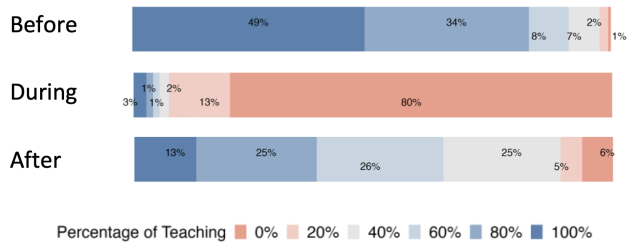

Figure 5: Respondents' estimated share of FACE-TO-FACE IN-PERSON teaching before, during and after the pandemic.

of the time, and 8% of respondents reported teaching face-to-face 60% of the time. Only a handful of respondents, 6%, 2%, and 1%, reported teaching at a rate of 40% of the time, 20%, or none respectively.

For the most part, movement restrictions during the pandemic have forced the teaching delivery mode to shift towards synchronous or asynchronous online activities. Only 5% of respondents reported teaching in-person 60%, 80%, or 100% of the time, whereas the rest either reduced it to a minimum of 20% of their teaching time as reported by 13% of respondents or none at all by 80% of them.

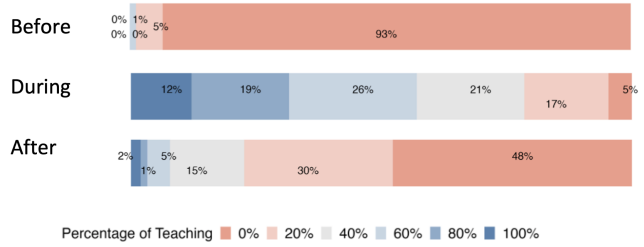

Figure 6: Respondents' estimated share of SYNCHRONOUS ONLINE teaching before, during and after the pandemic.

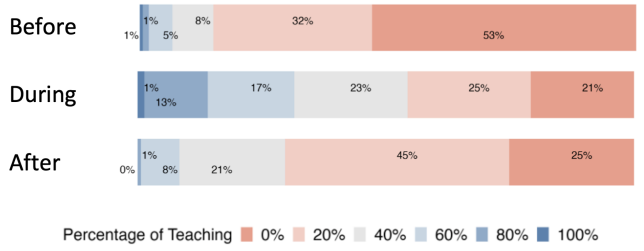

Figure 7: Respondents' estimated share of ASYNCHRONOUS ONLINE teaching before, during and after the pandemic.

4.2.2 Synchronous and Asynchronous Online Delivery of Teaching. Pre-pandemic, synchronous online activities were rarely implemented: 87% of respondents did not practise them at all, 9% applied them 20% of the time, 1% for 40% of the time, and 3% for more than half of the time (60%).

Similarly, before the pandemic, 41% of respondents reported not using asynchronous online activities for teaching, 39% used them 20% of the time, and 10% used them 40% of the time. Higher than that of synchronous online activities, this could be explained by the posting of supplementary material or recordings of live lectures online to complement live delivery. However, a few responses reported relying on asynchronous delivery 60%, 80%, and even 100% of the time by 6%, 1%, and 3% of respondents respectively.

During the pandemic, synchronous activities appear to be more popular than asynchronous activities, with 57% of respondents performing them at least 60% of the time, whereas asynchronous teaching at that rate was utilized by only 31% of respondents respectively.

This could be attributed to the fact that preparing asynchronous activities requires additional resources that are not at the disposal of respondents within a short time-frame. In addition, many faculty may not have had the required experience – technical or pedagogical – or the pressing need to learn them prior to the pandemic. As such, delivering content live would be a logical convenient solution to many. It is also possible that for some instructors, delivering content asynchronously would lack the live interaction with students that is often seen as the rewarding and interesting part of teaching. During the pandemic, many things were changing very quickly. As such, allowing for and retaining some familiarity in classroom structure may have been desirable by either the instructor or the institution.

4.2.3 Other Modes of Teaching. There were few responses in the 'other' category, and in elaborating on this choice, respondents explained their use of asynchronous delivery:

- Annotated slides for download (R25)
- Videos used by others for teaching (R124)
- Readings and assignments (R151)

In the 'other' category, respondents elaborated on their answers of teaching in-person exclusively or using blended teaching instead of specifying other modes of delivery. For example, one respondent commented "The class was synchronous, but I made it possible to complete the course in a fully asynchronous manner as well" (R7). The hybrid approach was popular amongst other respondents as well:

- There was a hybrid mix of face-to-face and synchronous online. Students basically made their own call on which approach to use, and it was flexible during the pandemic (R10)
- Students were given the option to attend synchronously or watch videos of the synchronous class (R18)
- Hybrid: in-person and synchronous online simultaneously (R37)
- Via text messaging on Microsoft Teams aside from email and forum support (R120)

4.2.4 Trends Going Forward. Overall, it is interesting to notice that the majority of respondents relied on a combination of modes rather than exclusively committing to one method.

As the academic year progressed, there seemed to be a shift in the teaching mode towards either in-person or synchronous:

- This has changed across the pandemic timeline – initially we flipped all face to face teaching online, now we are back to running face to face workshops (other than when in lockdown) (R76)
- Fall semester was 100% synchronous online, but Spring was 40% in-person (although most students connected synchronously online) and 60% synchronous online (R131)
- During the spring 2021 semester, one of my courses had a face-to-face option (for two sections). Approximately one-third of the class signed up for it, but by the end of the semester ALL had moved to the synchronous online version, even though I was still required to teach in a classroom (in case they decided to show up). (R177)

When comparing against participants' pre-pandemic delivery approaches, we found that their delivery aspirations post-pandemic shifted away from face-to-face delivery and toward online synchronous and asynchronous delivery. Before the pandemic, participants reported that, on average, 84% of their delivery was face-to-face (σ = 21%), while post-pandemic, the average face-to-face delivery aspiration was 59% (σ = 27%), and this difference was significant (p<0.001, Z=9.7) with a large effect size (r=0.51).

Likewise, before the pandemic, participants reported lower use of online synchronous (μ = 3%, σ = 10%) and asynchronous (μ = 16%, σ = 22%) delivery, compared to their post-pandemic plans for synchronous (μ = 18%, σ = 23%) and asynchronous (μ = 25%, σ = 22%) delivery, which were also significant (synchronous: $p < 0.001, Z = 7.5$; asynchronous: $p < 0.001, Z = 5.8$) and had a medium effect size (synchronous: $r = 0.40$; asynchronous: $r = 0.31$).

When asked about how they hope to be teaching post-pandemic, 64% of respondents want to spend at least 60% of their time teaching face-to-face (see Figure 5), which shows a desire to be back in physical classrooms interacting in person. However, this number is smaller than the 91% of respondents who were teaching at least 60% of the time face-to-face pre-pandemic. This demonstrates that the time spent teaching online (either synchronously, asynchronously or in some hybrid of the two) has led to some instructors wanting to continue teaching online in the future, if only for some classes or for some activities.

Figure 6 shows that 30% of respondents want to teach online synchronously 20% of the time (compared to 5% pre-pandemic), and 23% of respondents want to teach synchronously online at least 40% of the time (compared to 1% pre-pandemic, see Fig. 7). The proportion of respondents who want to teach online asynchronously is also substantial, with 45% wanting to teach asynchronously 20% of the time (compared to 32% pre-pandemic), and 30% wanting to teach asynchronously 40% or more of the time (compared to 7% pre-pandemic).

As the academic year progressed, the acceptance of online teaching activities is slightly on the rise between 20% and 40% (Figure 6 and Figure 7). Respondents indicate that there is an increasing level of confidence with integrating online teaching activities, and that they provide a number of benefits to the overall teaching experience. There are also other reasons, such as the rise in COVID-19 cases in some countries, transportation and mobility issues, and climate change concerns, that make this mode of teaching desirable.

Teaching during the pandemic has abruptly forced many instructors to reflect on their current teaching practices and think of ways of improving them as we return to a new sense of normalcy. For example, one respondent commented: "My lectures have been video recorded and shared with students for several years. I would continue to do this but would not go as far as to ensure that ALL in-class/synchronous activities could be done asynchronously" (R7). Another respondent talked about taking advantage of educational technologies to support teaching activities: "Much greater emphasis on real-time ed-tech; e.g. polling, work boards, online meeting spaces for workgroups; applying to the classroom the interactive techniques acquired while teaching online" (R55). This was echoed by others who will be using hybrid activities in the future to support remote attendees:

- Hybrid/Flexible: face-to-face but with remote attendees (R72)
- Complicated to respond to this as we will have offshore students for a couple of years (at least) (R174)
- The F2F content will also be delivered online for overseas students (R180)

4.2.5 Teaching Experience and Perception of Practice. Figure 8 shows the range of teaching experience and perceptions during the pandemic. In terms of the experience of teaching, there is an almost normal distribution of opinions, with about half of respondents answering on the positive side and half on the negative side. Perhaps of most interest is that only 7% replied *neutral*, indicating the polarising effects the pandemic has had on teaching experience. Of more concern are the items regarding colleagues' and students' wellbeing during the pandemic. Both follow a similar distribution that is highly skewed to the negative side, with a total of 70% responding *slightly negative*, *negative*, or *very negative*. When looking at the two distributions, there is a clear shift further to *very negative* for students' well being (14%) compared to colleagues' well being (10%). Finally there was a largely *neutral* reaction to the item regarding the experience of implementing accessibility options (39%) with similar distributions on the positive and negative sides.

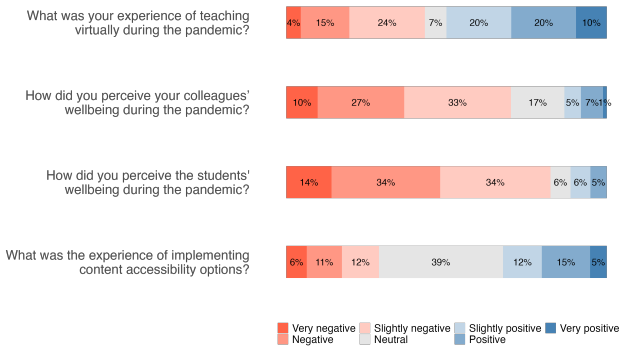

Figure 8: Respondents' experiences and perceptions during the pandemic

The questions in this group were followed by an open-ended question inviting participants to expand on any of their responses.

The greatest number of responses to this question addressed academic workload. Respondents mentioned stress, fear, and damage, along with inadequacy of tools, resources, and working hours. The workload was variously described as unmanageable, overwhelming, huge, unsustainable, and having doubled or increased massively or unrealistically. The general impression was not just that changing to a different mode takes time, but that preparing materials for online teaching takes longer than preparing them for face-to-face teaching.

- Staff in general seemed to find that it took a lot more time to prepare materials for online delivery (R70)
- Preparation for online teaching takes a lot more effort and time, which wasn't accounted for .. and I didn't feel was appreciated by the department (R179)

One respondent mentioned that a few years ago, a suggestion of preparing asynchronous material for a course was met with an abrupt reassignment to a different course.

There were many observations regarding wellbeing and mental health, either of the academic staff or of the students.

- This year I have referred more students for crisis support from our mental health team than I have combined over my previous 6 years of teaching (R26)
- Despite repeated promises of support I never received any, despite multiple calls and messages (R53)
- From the students' perspective, it became very clear rather quickly the impact of the pandemic on their mental health, a large number of my students had to juggle unrealistic expectations from other instructors (including a lack of understanding and flexibility from those instructing) with their own personal (and family) safety (R54)
- Colleague wellbeing was largely overlooked during the pandemic. Any support was tokenistic. Senior management attitude evolved from supportive to critical during the academic year. Better support was provided by the trade union ... Learners have clearly suffered more and more from online learning fatigue as the year has progressed. (R66)
- A lot of students requested extensions for assessments due to mental health reasons (R70)
- Students were very stressed, had more difficulty learning and needed more support (R91)
- Staff wellbeing went out the window. The notion of 'value for money' was repeatedly touted, as were the financial implications of losing students. Retention was explicitly made the number one priority for academics. Research activity was explicitly ordered to cease unless it was funded ... I felt sorry for the students as they were having a terrible time of it all, and we saw a considerable increase in mental health problems ... Academic staff were left to their own devices, save for an early morning wellfullness meeting that clashed with emergency planning meetings every single week. (R92)
- It was still difficult for students to be in lockdown, we have a lot of international students who had never studied online before, and disliked it, and our poor team really battled stress and depression (R110)

Almost as many responses addressed a perceived drop in student engagement.

- Things got worse as time dragged on; initially students and I were more engaged, but we got weary over time (R9)
- Students were very burned out by the end of winter 2021. Attendance at lecture declined. (R11)
- A lot of students started to feel less motivated or disengage. The transition from having the opportunity to go into the university, attend face-to-face lectures/labs, meet new people/make friends, to suddenly not being able to go into university and to attend classes online / use online software etc was difficult for most people including staff. (R30)
- Difficult to teach certain subjects, difficult to discuss and share knowledge with the class, difficult to do group work properly, difficult to get students to engage, difficult to avoid one way delivery. Teaching to a blank black screen is extraordinarily challenging. If it went on for any longer than a trimester I would have resigned – it's too boring and uninvolving and unsatisfying. (R59)
- Often it was like drawing blood from a stone when trying to get them to engage with the content. I also think it was a lot easier for students to check out of the learning process; I believe that a lot of students would log on to show they have attended the session then walk away from their computer. (R62)
- I suspect that more students chose not to attend synchronous online classes than face-to-face classes, opting instead simply to view the recording of the session – or not (R73)
- The desire to meet synchronously declined as everyone adjusted to learning online – I think students got fed up with Zoom (R108)
- Needed a lot more script preparation to manage classes where students didn't talk or use cameras (R115)

A number of respondents mentioned missing the connection of face-to-face teaching, both for themselves and for the students.

- Lack of physical interaction prevented many of the intangibles of teaching. Things like hallway conversations, bumping into students in non-academic environments were lacking. (R10)
- Everyone (instructors and students) missed the personal connections that come from being in the same room and talking in person instead of through zoom (R36)
- Online lecturing doesn't allow for flexibility or adaptability in response to the class the same way as face to face (R117)
- If students asked questions in Zoom, I felt like I was engaging. If they didn't, I felt like I was talking to myself. (R178)

Some respondents made specific mention of struggling students.

- It was extremely difficult to identify/help struggling students (R113)
- The most negative aspect of teaching was not being able to see when students are struggling during online lab classes (R128)
- New (first year) students did not have the foundations to cope well with virtual learning – they did not have peer support groups in place (R145)

Respondents from developing countries were particularly concerned that their students might not have the resources to participate online.

- It was negative for students – particularly those who do not come from middle-class families (R161)
- It's quite difficult to teach a computer based module online due to most students not having the resources needed to follow along with the lecturer (R165)

On the positive side, some respondents saw advantages of the technology that they were newly required – or newly permitted – to use.

- I could live-code on one window and have a virtual whiteboard open next to it. In a classroom, this would require a more complicated setup than simply a projector and a blackboard. (R35)
- It did have its advantages: being able to share screens with students who were all over the world, and still help to review code etc (R70)
- I found that teaching virtually greatly facilitated material creation (R95)
- The virtual delivery mechanism used for synchronous sessions, Microsoft Teams, offered automatically generated closed captions. Whilst not perfect, these were good enough. (R118)
- The most positive aspect was the use of an online platform that the students chose and were comfortable with, namely Discord (R128)
- I think in Computing we are luckier than most, we use new software all the time and try new things. To me, it was interesting and I was eager to explore new ways of doing things. (R140)

Additionally, a couple of respondents mentioned the support that they were given by their institutions.

- The university provided resources to aid in captioning videos as needed (R2)
- I have a supportive faculty which provided closed captioning support and a small army of TAs which made it possible to teach under these conditions (R91)

4.2.6 Pedagogical Skills. One of the major themes of the pandemic for teaching staff was the rapid demand to change their practice and adopt new skills. Teaching staff mostly agreed that their pedagogical skills helped to prepare them for the transition (combined 78% on the positive side), as shown in Figure 9. This clearly underpins the importance of pedagogical training throughout a teacher's career. The challenge of transitioning into a new teaching reality appears overwhelmingly to have had a positive effect on improving teaching staff's perceptions of their pedagogical skills, with 77% of respondents falling on the positive side. Furthermore, respondents had a similar distribution towards their colleagues' pedagogical skills improving, although there is a larger neutral component in the distribution. Unsurprisingly, in light of the positive responses to the former items, respondents are mostly in agreement with the plan to continue improving their pedagogical skills going forward from the pandemic (94%).

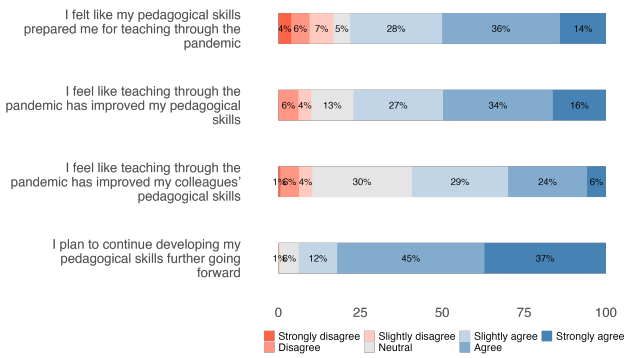

Figure 9: Respondents' opinions on their pedagogical skills during the pandemic

4.2.7 Opinion on Institution. Figure 10 shows an overall positive response on the institutions' response to the pandemic; with 64% of respondents indicating that they had an increase in opportunities to develop their pedagogical skills, 55% indicating that their institution increased the importance given to teaching, and 51% indicating that their institution would maintain the importance given to teaching post-pandemic. This shows that institutions that typically may have focused their efforts towards research and other types of funding were starting to acknowledge a required focus on teaching as everyone navigated the pandemic.

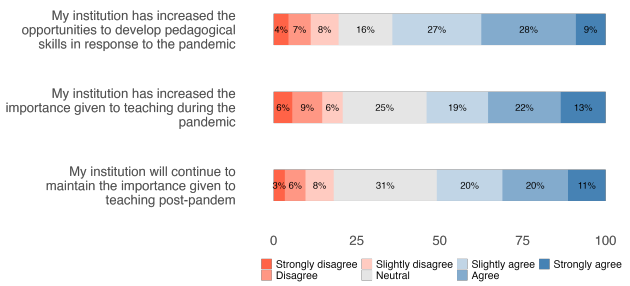

Figure 10: Respondents' opinions on their institutions during the pandemic

4.2.8 Opinion on Teaching Assistants. Whilst not all teaching faculty make use of teaching assistants (TAs), those who do generally value their contribution. Here we explore how dependency on TAs changed during the pandemic and how TAs were seen to adopt to pandemic teaching. The interest is on the effects the pandemic might have had upon their practice. Figure 11 shows the responses for two items concerning teaching assistants during the pandemic. In terms of increase in dependency upon teaching assistants, the most dominant single response was neutral (35%) followed by joint positive agreement (38%), indicating that there was some additional support required during the pandemic. There was an even more positive response to the teaching assistants' adaptation to the new circumstances, with 57% in agreement and 30% remaining neutral.

Perhaps both underline the fact that teaching assistants successfully provided extra help when required and also that they adapt well to the changing circumstances.

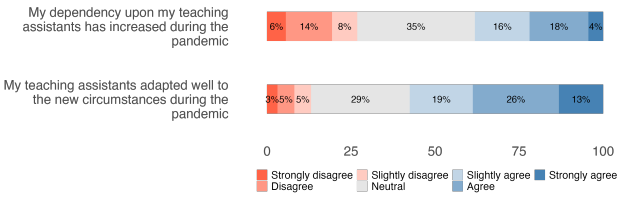

Figure 11: Respondents' opinions on teaching assistants during the pandemic

4.2.9 Opinions on Students. Perhaps one of the greatest concerns throughout the pandemic was its impact on the student experience. Whilst there will undoubtedly be many studies conducted in the wake of the pandemic to try to document this from the students' perspective, here the focus is on the perceptions that the teaching staff had of their students' experience. Figure 12 shows the perception to the student experience from the staff point of view. As is shown in the first stacked bar plot, there is only a negligible amount of disagreement with the increase in duty of care. The majority of respondents (83%) felt that this aspect increased during the pandemic. This follows from not being able to meet students face-to-face, which may have led to additional efforts to try to compensate (e.g. increased online office hours, new platforms for interaction, and so on). It could be posited that this shows an empathetic response from staff who recognized their own struggles in their students and thereby showed an increased concern about their welfare in these unusual times.

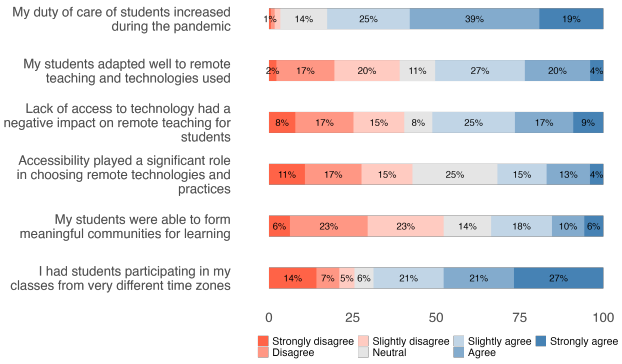

Figure 12: Respondents' opinions regarding their students during the pandemic

There was more of a mixed response in terms of how well students adapted to distance learning and its implications, with 51% of respondents leaning towards agreement with the fact that their students adapted well to remote teaching and the technology used, and 39% leaning towards disagreement. One of the implications of the transition is the access to adequate technology; respondents once again were split, with 51% agreeing that students had experienced significant and negative impacts, whereas 40% disagreed with this, perhaps reflecting the diversity of student home or other learning environments and their adequacy for handling remote teaching technologies. The extent to which accessibility concerns influenced technology decisions made by teaching staff seems to have been driven mainly by practicality and availability: 43% disagreed that there was an influence in their choices, 25% took a neutral position, and only 32% agreed that it played a part in their decision making.

The loss of campus-based learning for many led to a variety of digital solutions to plug the gap. Figure 12 shows that when it comes to staff opinions about whether students were able to form meaningful communities for learning, the majority are either in disagreement (52%) or neutral (14%), with only 34% having a positive opinion. Once again, this can be attributed to a loss of vision and awareness of what students were doing, especially as many digital communities may have been created (or not) to provide some virtual alternative. It is also possible that these communities were being formed outside of institutional channels (e.g. student Discord).

Finally, 68% of respondents reported that they experienced students visiting their classes from very different time zones, suggesting that a lot of students who expected to travel to a university, some in another country, were forced to remain at their home address, leading to a possible disadvantage based on unfavourable time zones. While this is not the case for all universities, the challenge of engaging from varied time zones is noteworthy. In universities with high international student populations, especially in circumstances where the primary international population from which a student body was drawn was geographically quite distant, students could be working up to 12 hours off of their home time zone in order to engage synchronously.

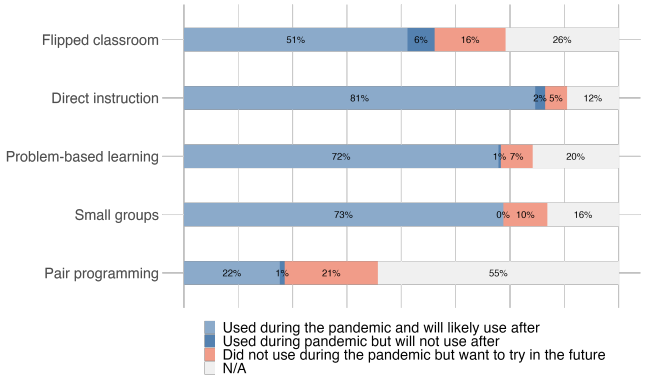

Figure 13: Respondents' uses of different teaching styles during and after the pandemic

4.2.10 Use of common teaching styles, during and after the pandemic. Figure 13 shows whether respondents used a particular style of teaching during the pandemic and if they will continue to use it afterwards, as well as styles that they did not use during the pandemic but would like to use in the future. In terms of not using

the teaching style after the pandemic, there is little data here to suggest much change. For the flipped classroom style, 6% responded that despite using it during the pandemic, they would not use it afterwards. Given the awkward nature of managing small group discussions online and the need for student preparation in a time when there was a lot of confusion and other competing concerns, perhaps this approach might have been difficult to manage remotely; however, 17% indicated that they would like to try this style in the future. Pair programming was the style that the greatest number indicated they would like to try in the future, with 22%; however, it was also the least used during the pandemic, and also owing to its domain-specific nature, the most not applicable (N/A) response.

4.3 Use of Technology during the Pandemic

4.3.1 Technologies Used. As seen in Figure 14, most respondents who used a certain technology during the pandemic stated that they would continue using it afterwards. For example, 97% used online lecture dissemination and 89% intend to continue using it after the pandemic. Likewise, 82% used formal communication tools, such as discussion forums, Piazza, and Microsoft Teams, during the pandemic, and 78% will continue their use.

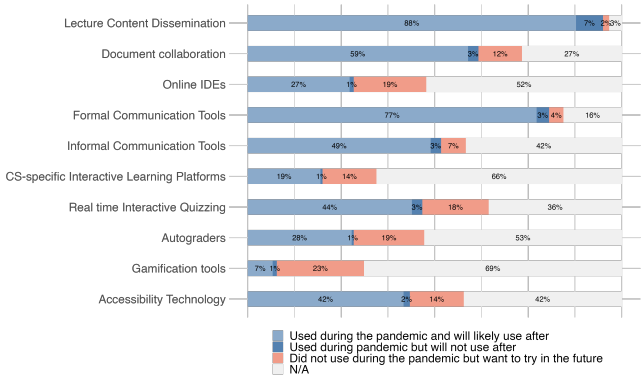

Figure 14: Respondents' uses of technology during and after the pandemic

4.3.2 New Technologies Offered by Institution. Three open-ended questions asked whether any tools were made newly available by the institution during the pandemic, whether institutional constraints prevented respondents from using certain tools, and whether accessibility constraints affected tool choices.

In terms of tools made newly available, by far the most common type of tool was software for meetings and/or video conferencing, including Zoom (n=41), Microsoft Yeams (n=25), Collaborate (n=6) and Webex (n=5). Other tools such as Discord, FlipGrid, Gather.Town were mentioned, but with very small numbers (n<=3).

Video recording and video hosting software was mentioned either specifically or generically by ten respondents, with five explicitly mentioning Panopto.

A number of respondents mentioned learning management systems or similar software, though they might not have intended to suggest that their institutions introduced this software in response to the pandemic.

Other types of software, with no more than five mentions per type, were question-and-answer software (Kahoot, Wooclap, iClicker Cloud); grading software (Crowdmark, Gradescope, Web-CAT); remote-access software such as virtual machines; interactive whiteboard software; assessment software; and presentation software.

Four responses mentioned software specific to particular tasks or courses, and two mentioned custom-made software.

In addition, eight respondents mentioned being given pertinent hardware: headsets, microphones, cameras, enhanced classroom equipment, drawing tablets, and monitors; and one high-school respondent indicated that pupils were given iPads and were assisted with Internet connectivity if required.

To understand institutional constraints, respondents were asked if they were prevented from using any particular technologies. Notably, institutions seemed to open doors to tools at a pace beyond anything seen pre-pandemic. Of the 106 responses, 37% reported no institutional constraints on technology use or adoption, while 55% reported some type of institutional constraint on technology use. The two most common reasons for constraints on technology choice related to privacy and security concerns (mentioned in 10% of responses) and lack of tech support (mentioned in 10% of responses). Financial limitations and budget cuts were other common institutional constraints, mentioned in 7% of responses.

Some participants commented that the institution determined what technologies would be used and instructional staff did not have much choice in the matter, as demonstrated by the comments "Tools were chosen at the institutional level and imposed on teaching staff, with the single exception that we were permitted to choose between zoom and blackboard collaborate for synchronous classes" (R73). Similarly, R117 reported that "The institutes chose the formal communication channels to assure consistency with learners. We could not used teams/whatsapp, the faculty were only authorised to use e-mail, Moodle, Panopto, Zoom." The most common technologies that were mentioned as not being allowed due to institutional constraints were Zoom (31%), Microsoft Teams (10%), and various plagiarism detection or auto-grading systems (5%).

Respondents were asked whether the need for accessibility and equitable access affected tool choice and implementation. Of the 127 responses, 76 respondents (60%) said that these considerations were at play in technology choices, with 12 respondents noting that such considerations are standard. For example, R155 noted, "I've been tending to accessibility for years, the pandemic didn't change that." However, there were 35 respondents (28%) who answered no, indicating that accessibility and equity were not considerations in tool/technology choice. Sixteen respondents reported that technology decisions were made by others within the institution, with two noting that such decisions were "above my pay grade" (R82, R92). In terms of equity, four respondents mentioned that tool choice was impacted by students participating in remote courses from China where certain web-based applications were not accessible, and so other tools were chosen in order to ensure that those students could participate. Five respondents mentioned a lack of time to fully investigate more accessible or equitable tools. For example, R95 noted "there was often more work on my side in ensuring that any shortfalls in the technology were resolved such that they did not negatively impact accessibility needs." While some participant

Type	Count
Viva	7
Ethical appeal to students	3
Assessment design	3
Individualised questions	3
Randomised questions/Exams	3
Extra video content	2
Coursework diary	2
Code of conduct	2
Screen sharing	1
Exam removal	1

Table 5: Other tools used to help enforce academic honesty in assessments during and after the pandemic

comments expressed surprise at the question, answering "We always made sure the tools we used were accessible" (R1) and "of course" (R121), other participants indicated that they didn't see a real need, noting "I did not have any accessibility issues, but I have not had a blind or deaf person in CS yet" (R102) and "Indeed, but accessibility and equitable access was not a major constraint as the student diversity was light" (R148).

4.4 Assessment Practices and Academic Integrity

4.4.1 Tools Used to Enforce Academic Honesty. Figure 15 displays the reported use of tools to detect academic dishonesty. Most (75%) did not report using a remote proctoring service, and those that did were divided on whether they would continue using it after the pandemic. Of those who used it, 40% (10% overall) stated that they would not use it after the pandemic. An interesting trend is that a similar number of respondents (11%) stated that they would like to try it in the future.

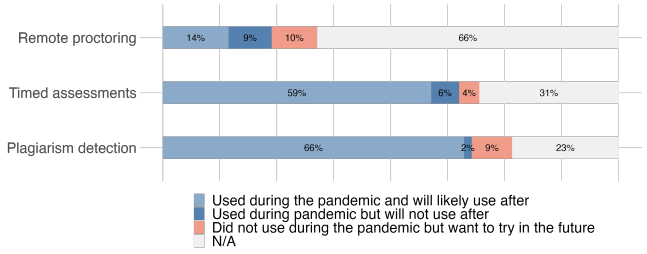

Figure 15: Tools used to help enforce academic honesty in assessments during and after the pandemic

Of 29 participants selecting 'other', three responses did not answer the prompt, and one listed a remote proctoring solution (covered previously). Some respondents listed multiple other technologies, so counts sum to more than 100%, as shown in Table 5.

4.4.2 Tools Used to Detect Plagiarism. Figure 16 shows the reported use of plagiarism detection tools. Most (56%) report using a general plagiarism tool during the pandemic, while 33% specify the use of plagiarism tools specifically for code. Overall, respondents using

Type	Count
Custom Tools	7
Urkund	2
Online Searches	2
IP Analysis	1
Vivas	1
ProctorU	1
Online IDE history	1
Swedish natoinal system	1

Table 6: Other technologies used to help detect plagiarism during and after the pandemic (n=16)

these tools intend to continue their use after the pandemic; only 1% reported that they would stop using them in the future. The survey results do not convey an increase in the use of plagiarism detection due to the pandemic, but does indicate that those respondents using them throughout will continue to do so.

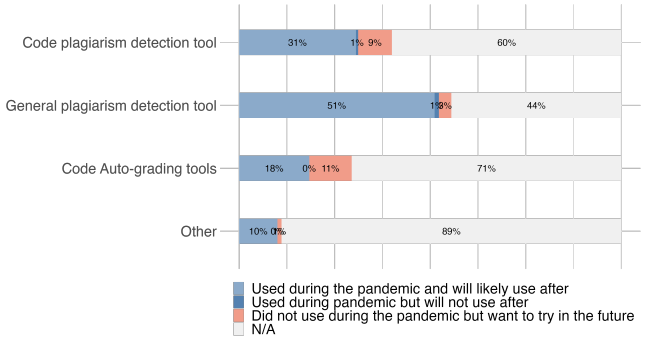

Figure 16: Tools used for plagiarism

Of 24 respondents selecting 'other', eight did not answer the prompt. Some respondents listed multiple other technologies, as shown in Table 6.

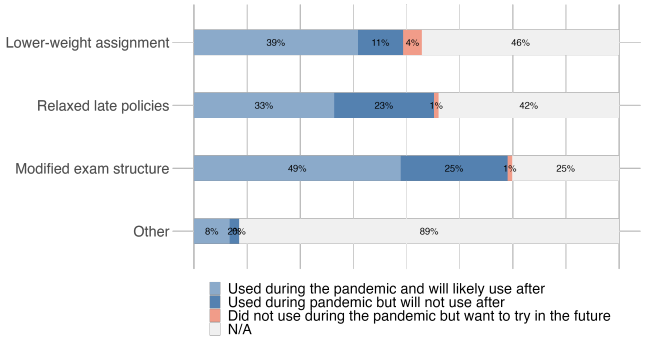

Figure 17: Practices used to promote academic integrity during and after the pandemic

4.4.3 Academic Integrity. Figure 17 shows the reported practices used to promote academic integrity during and after the pandemic.

Type	Count
Viva	3
Low-stakes, frequent assessments	3
Ethical appeal to students	2
Long exam windows	2
Assessment questions on honesty	2

Table 7: Other practices used to promote academic integrity during and after the pandemic

Several instructors and institutions made changes to their exam structures (in some cases removing them entirely, or replacing them with appropriate practical coursework) which may have benefited the course development and its learning outcomes. Most respondents with modified exam structures (49% overall) show that these structures were something they would retain post-pandemic. There is a similar pattern for those who relaxed course late policies or lowered assessment weights. Of 26 participants selecting 'other', two did not answer the prompt. Some respondents listed multiple other technologies, as shown in Table 7.

Other suggestions, each from a single respondent, include discussion of assessment, student videos, institutional leniency, code of conduct, new/fresh assignments, class explanation of detection process, communication, extra video content, staff and student training / development, unique assignments, assignment drops, fail grades not recorded, free repeat of course, higher order questions, open-book exams, project-based assessment.

4.5 Concluding Questions

To conclude the survey, we asked respondents to give their general opinion moving forward from the pandemic. Figure 18 shows the opinions about the change caused by the pandemic at a personal level and a wider perspective of teaching at their institution. Both threads show a large amount of positivity, with 84% believing the changes have been positive for themselves, and a lower amount of 68% for the wider teaching staff at their institution. Perhaps this reflects that many of us have managed to navigate the pandemic teaching with an awareness of the individual benefits, however we have also been aware that others around us, for a variety of valid reasons, have not had as positive an experience.

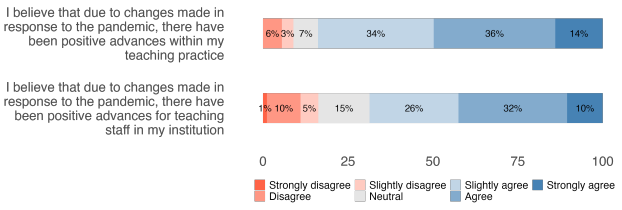

Figure 18: Respondents' general opinions going forward from the pandemic

There were two open-ended questions on new and innovative online teaching approaches that the participants intended to use in the post-pandemic space. To analyse these questions we applied a somewhat ad-hoc approach loosely based on thematic analysis, building themes and categories by organising the data into more abstract units of information [14]. The questions were optional, and our analysis does not include null responses or equivalent responses such as 'none' or the plaintive 'I would like things to go back to the way they were'.

Note that respondents typically mentioned one, or perhaps two, innovations or approaches in response to these questions. The analysis breaks down those responses into categories, but should not be taken as overall votes for those categories. For example, the 10% for online assessment in table 8 does not mean that only 10% of respondents favour continuing to use online assessments; it means that 10% of the responses explicitly mentioned online assessments as something that they would continue to use.

4.5.1 Teaching Approaches to be Retained. Table 8 summarises the themes and categories derived from the analysis of the responses to the first question, "What new online teaching approach do you intend to keep in the future?" The resulting themes and their categories are discussed below.

Flipped classroom. The highest number of responses (n=61) relate to using a flipped classroom approach to delivering course content online. Respondents observe that the flipped approach enabled students to schedule their own learning and that that they would continue to use a combination of (i) asynchronous: pre-recorded lectures / short videos and (ii) synchronous: online / face-to-face class time with instructor-led group and individual learning activities to emphasise key learning points. This theme is well captured in the following three responses:

- Pre-recorded lectures to make space for more meaningful and active learning/interactions during face-to-face time (R13)
- Keeping the asynchronous 'lecture', where students are engaging in active learning tasks rather than me talking at them for 50 minutes (R62)
- Chunking / breaking down the module content into appropriate and manageable pieces that fit with the concepts and are freed from the time slots associated with a lecture session. The chunks can be a combination of code, video, slides that rotate around a single topic, and may only be 15 minutes in length (R111)

There was also acknowledgement of the challenges associated with students not completing the asynchronous 'before the class' materials, and ensuring student engagement and participation.

Group-based learning and teaching. Participant responses related to how group work could be facilitated in both small and large online groups. The responses included a range of tools and activities for class group projects and project-based learning in an online environment as seen in the following responses:

- Supporting small groups of students via Microsoft Teams (R30)
- Use of jamboards for small group ideation (R56)
- Collaborative lectures to large groups (R67)
- Using tools like repl.it for group coding (R134)

Table 8: What new online teaching approach do you intend to keep in the future? (N=134)

Theme / category	Description	Count
Teaching approach	Teaching practices and approaches to online teaching and learning	
flipped classroom pedagogy	delivering course content online and using synchronous or face-to-face lectures to emphasise key learning points and to facilitate instructor-led class-based, group, and individual activities	61 (46%)
group-based learning	facilitating group work (e.g. groups for project-based learning, in-class group work, supporting small groups of students)	20 (15%)
teaching practices	practices used to support online teaching	12 (9%)
Assessments & tools	Assessment policies, instruments, and tools to support online teaching and learning	
office hours	online office hours	22 (16%)
online platform	online tools, platforms, and virtual environments	14 (10%)
online assessments	online assessment techniques and instruments to assess student knowledge	10 (8%)

Table 9: In a few words, describe an innovation or a new approach adopted during the pandemic that you will keep on using after (N=110)

Theme	Description	Number
Innovative teaching & learning practice	Teaching & learning practices, tools, and technologies	36 (33%)
Innovative assessments	Assessment methods, policies, and instruments	17 (16%)
Blended, hybrid, and flipped classrooms	Blended learning approaches	16 (15%)
Student engagement and interaction	Practices and activities to ensure students feel engaged	13 (12%)
Student wellbeing and community building	Supporting student wellbeing and building community support	9 (8%)
Professional development	Professional development in online learning and teaching	2 (2%)

Teaching practices. Responses included several practices such as collaborative coding, one-to-one online coding support sessions for students, "use of guided tutorials, linked to git repos, videos, and formative assessments" (R65), discussions in learning management systems and Discord servers, project demonstrations using WebEx/Zoom, Kahoot, and the use of Padlet and Poll Everywhere to assess student understanding and collecting student responses.

Office hours. Several respondents (n=22) reported that they intended to use online office hours to support instructor presence and accessibility in the online learning environment. Two participants said that they would provide both virtual office and in-person office hours and one mentioned providing additional support hours for students. Specific tools for office hours, such as Discord, were mentioned and planned to be used post-pandemic by three respondents.

Online platforms. In addition to the commonly used platforms such as Zoom and Microsoft Teams, respondents reported use of virtual meeting communities and spaces such as Gather.Town, Town Hall meetings, and Ed-Tech.

Online assessments. Responses included assessment strategies, policies and tools for administering online assessments and exams: offering online quizzes for CS1/CS2 courses, using Teams instead of jotters for homework, marking homework on OneNote, quizzes on iPads for starters and plenaries, open-book assessments, "eschewing exams for low-stakes formative assessments, relaxed late policies" (R35), administering "all or most of my night-time exams remotely" (R177), auto grading quizzes and assessments, and automatic testing of code solutions.

4.5.2 Innovations to be Retained. Table 9 summarises the main themes derived from the analysis of the results of the second open-ended question, "In a few words, describe an innovation or a new approach adopted during the pandemic that you will keep on using after".

Innovative teaching and learning. The highest number of responses (36) related to practices that incorporate participatory teaching methods, interactive learning, and strategic use of digital tools and technologies to collaborate, create, and share learning. Responses included a range of practices including using educational games, simulations, embedding quizzes in videos, techniques to record coding work, short bugbuster sessions for handling coding related questions, "recorded video presentation by students as code walkthroughs to accompany their code" (R111), "creating POGIL exercises on the Runestone platform" (R11), and creating structured learning activities. Responses on project-based practices included "mini project hands-on with class", "Google Jam Board for small in-class group work so that I can observe as students are working" (R15), and "weekly online standups for team projects and asking students to demonstrate their software live online" (R140). Further comments on using tools such as replit.com for group coding were noted. It was acknowledged that such tools make group projects and project-based learning very viable in an online environment.

Innovative assessments. Online exams were mentioned by many respondents: "short timed online tests" (R79), "online exams constructed from (i) a large pool of randomised multiple choice / true-false questions (ii) short written answers (iii) long written answers" (R139), and open-book exams. Respondents mentioned flexibility in allowing students to choose from "different combinations of assessments based on individual's preference" (R129), and "collecting student submissions in a publicly viewable forum on the school VLE seemed to result in a very valuable revision tool for many students" (R95). There was also acknowledgement of the need to move from high-stakes exams to low-stakes quizzes as "the total 'surface area' being tested is much larger this way, while simultaneously avoiding having students cram content for an exam. The relaxed nature of these quizzes also helps to reduce dependence on academic dishonesty arising from desperation" (R35). Grading practices such as clearer weekly participation scoring, automatic exam marking, using Google forms, and using tools such as Mimir for automated grading and feedback were mentioned. Approaches to marking final project vivas using a specialist web conferencing space and running online expos and poster demonstrations using streaming technologies and MURAL were also mentioned.

Blended, hybrid, and flipped classrooms. This theme relates to blended teaching and learning approaches where participants noted the use of live webcasting, recorded videos, and other forms of online technology to complement and enrich face-to-face instruction. The most common responses were generating more flipped classrooms and hybrid courses, "a mix between hybrid teaching methodologies and blended learning" (R54), "asynchronous resources/content to augment more traditional face-to-face learning and teaching resources" (R89), preparing more pre-recorded material – "pre-recording numerous small videos" (R127), "videos of worked examples, cutting lecture videos into smaller chunks" (R81), "video recordings to flip the classroom through video repositories and digital worksheets to keep track of student progress during lectures" (R58) – online discussion and interaction, and increasing independent student learning.

Student engagement and interaction. Some responses addressed the techniques and activities used by participants to improve student engagement and participation: "polling and Zoom breakouts were the most successful" (R55), "Zoom breakouts for student programming questions: the semi-private space increased participation from quieter students" (R75), and breakout rooms used to discuss case study questions "with responses recorded using a discussion forum so all groups had access to every group's answers" (R117). The use of chats allowing students to post questions anonymously, live-text chat questions during lectures, group chat, gamification and polls for engagement, and small group interaction on Teams were reported to have positive impact on improving student engagement.

Student wellbeing and community building. Participants acknowledged concerns related to the learning needs of students who are less likely to have access to digital resources and tools or a suitable online learning environment. Respondents also noted difficulties that some students experience and identified the need for monitoring student issues:

- as one student told me, treat us like humans (R88)
- provide routine 'monitoring point' type meetings with students (R44)
- enable controlled workflow, and encouraging student social interaction, community forming (R69).

One participant highlighted the need for faculty to "assist students to be accountable for themselves"(R88) as "students who are reluctant to speak up in class either via video, in chat, or to use online discussion forums did not realise that such behaviour – asking questions – was their main means of gaining help in these strange times" (R126).

Reliance on tools such as Discord for community building and supportive environment was also acknowledged. One participant identified the need for remote access infrastructure "using the CitrixVDA technology that allows students remote access to on-campus PC/equipment" (R175).

Professional development. Two participants recognised the need for professional development in the area of online learning and teaching. The benefits of scheduling regular meetings/sessions with colleagues to share tips and ideas on online teaching was acknowledged: "our faculty started regular meetings for staff teaching in the current semester that were part educational (a presentation by our educational developer) and part information sharing about our experiences teaching in the semester (new tools or techniques we're having success with, problems we're facing, etc.). This was extremely helpful and we intend to continue post pandemic" (R52).

5 RECOMMENDATIONS

We have identified a number of themes that have emerged from the analysis of the survey responses reported above, which serve as the basis for recommendations for teaching faculty, administrators and institutions to take note of as they start to make plans for what the post-pandemic educational landscape may look like.

1) Leverage technology in teaching: A high number of teaching faculty reported that the changes caused by the rapid transition online due to the pandemic have led to a number of positive changes to their teaching practice. Of the surveyed respondents, 89% intend to continue using online lecture dissemination for appropriate classes or activities following the end of the current teaching practices imposed by various local restrictions. More particularly, teaching faculty reported that leveraging certain technologies can add value to the classroom and lead to a better quality of teaching, with face-to-face sessions to emphasise the key learning points and facilitate group-based and individual activities. While some instructors employing flipped classroom pedagogies created pre-recorded content before the pandemic, the effort of pre-recording content videos has often been viewed as very labour-intensive and avoided by many instructors. However, the pandemic forced some instructors into this approach, and that then freed up time during class meetings for more meaningful interaction and active learning activities. This is demonstrated by R47: "It helped break the ice to get me to consider online and asynchronous methods, videos, etc. This will now be a part of my teaching going forward."

During the move to teaching online, many institutions opened their doors to tools at a pace beyond any seen pre-pandemic - teaching faculty mentioned that using such a wide variety of tools was improving their practice. For example, 78% of respondents indicate

that they see a need to continue using formal communication tools [44] in line with the changing landscape of the world of future employment for students, with many workplaces transitioning to remote working for the foreseeable future.

Despite the fact that many new tools were adopted during pandemic teaching, there are clear trade-offs when allowing faculty to choose their own educational tools and software. Not only does it take time to evaluate and select appropriate tools, but there are associated challenges for students that are then required to install, learn, and maintain these many tools. More importantly, institutions are obligated to ensure that their students' privacy is protected and take measures to properly assess the risks of adopted tools.

It is important that faculty and their institutions take time to reflect on the lessons learnt from teaching during the pandemic. Given the rapid rate and forced nature of the pandemic-induced changes, many aspects of teaching and learning have shifted. Understanding the impacts of these shifts will help identify approaches that we might wish to continue and allow for their possible inclusion within post-pandemic plans.

Oftentimes there has a focus on "going back to normal" or "to the way things were". However, the authors would argue that the "new normal" must look different to the educational landscape pre-pandemic, and capturing and reflecting on the lessons learnt from this experience is an important step towards understanding what this might look like. Despite the many hurdles that the pandemic has laid in our paths, we have learned many new skills on the way to clearing them. It is important that we capitalize on these new understandings as we move into the future of teaching and learning so that all the work behind us was not wasted.

2) Support teaching faculty and student well-being: Teaching faculty reported that mental health and well-being for both their colleagues and their students was negatively affected due to the changes made in response to the pandemic. On top of the stress and fear caused by the global situation, they reported an overwhelming and unsustainable workload as well as having to use tools that were inadequate for the job. P73 noted "Many of my colleagues were damaged by the additional workload." P92 described myriad issues related to workload, wellness, unrealistic expectations and tokenistic support: "Staff well-being went out the window. Every axe at the coalface! There was considerable pressure to adapt in a very short amount of time, introducing "blended" learning materials and deploying new tools like Microsoft Teams. The notion of "value for money" was repeatedly touted, as were the financial implications of losing students...The fundamental problem with delivering classes in lockdown was the poor internet connections used by staff and students - it wasn't tenable...students were granted considerable levels of support and services, whereas academic staff were left to their own devices, save for an early morning wellfullness meeting that clashed with emergency planning meetings every single week."

It is imperative that faculty and students are supported in their mental health. In particular, both should be empowered with choice where possible: teaching faculty should be able to choose the best tools, environment, and method of teaching, and students should be consulted on how they feel they get added value to their learning journeys. P140 positively described the benefits of tool choice and learning about different tools: "..people shared what they were using and new ways of doing things. I never got to try them all but there were some interesting discussions. We used Discord and online whiteboards and Zoom, Kahoot, Teams - all sorts of things." P128 noted the benefits of giving students choice: "Some CS students really liked the online provision of content...The most positive aspect was the use of an online platform that the students chose and were comfortable with, namely Discord."

3) Nurture Computing Education research: The survey was mainly distributed through SIGCSE and ITiCSE mailing lists, so it can be posited that it has reached a large number of teaching faculty with an interest in pedagogical research. Faculty responded that they felt their understanding of pedagogy helped prepare them for a smoother transition to online teaching at the start of the pandemic. This clearly underpins the importance of pedagogical training as part of a typical faculty member's career path. While general pedagogical training provided by most university centers for teaching & learning is of value, it is often offered in a discipline-agnostic way and largely aimed at faculty from disciplines that are less tech reliant. Typically, Computer Science faculty won't need as much training on how to use basic tools. The specific pedagogical challenges within Computer Science point to a clear need for Computing Education research to inform CS-specific pedagogical training. This is an opportune time to nurture what should be an inevitable growing interest in the field of Computing Education for both faculty and their institutions.

6 CONCLUSIONS AND FUTURE WORK

This paper provides an initial body of work that starts to capture the perception from teaching faculty of how the COVID-19 pandemic has impacted the educational landscape in computing, and what the next stages might be as institutions start to consider what the post-pandemic educational landscape might look like. This paper presents a number of contributions to the existing body of knowledge, including: i) a comprehensive literature review on the COVID-19 shift; ii) a survey that aimed to capture the experiences of teaching members regarding the impact of COVID-19 on their teaching practice; and iii) an analysis of the self-reported experiences of 180 teaching faculty within computer science.

6.1 Limitations

Due to the complex nature of remote working, as well as the very remote nature of the working group and the working world at the time of the study, it took much longer than anticipated to get the correct ethical clearance from the partner universities in order to run this study. This meant that the survey was released later than expected, which led to two limitations: i) there was a tighter window for participants to complete the survey; and ii) some participants may have missed the call for participation due to the northern Summer timing.

Furthermore, while analysing the responses, it became increasingly clear that for some categories, knowing what the respondents taught before and during the pandemic may have provided additional context to their responses, particularly those centered around technology use and perception. Additionally, responses to the survey question that asked about what common teaching styles instructors will use after the pandemic that they didn't use during the pandemic were ambiguous to interpret, as some of the techniques

listed might have been used pre-pandemic, and in those cases they would not actually be a new style/technique for the instructor - this was likely the case with pair programming, which was harder to facilitate in remote teaching.

There may be some discrepancy to the responses to any questions that have asked participants to reflect on their perception of 'during' and 'after' the pandemic. At the time of the survey, most countries were firmly in the 'during' stage - but the 'after' goalposts were (and still are, at the time of writing) very unfixed and subject to loose interpretation.

Perhaps the most significant limitation can be clearly seen in Figure 4: Perhaps unsurprisingly, many of our responses were centered around locations where the SIGCSE and ITiCSE communities have the most reach. While attempts were made at reaching outside of these communities, these were not always successful. E-mails, as well as the included survey, were always circulated in English, despite the destination country. This may have prevented some from filling it in, or distributing it further. While this limits the international reach of our analysis, it does give us a comprehensive view into the countries that are represented. We would welcome the opportunity to do better, and would welcome assistance in reaching underrepresented communities so that we can archive their experiences.

6.2 Future Work

This paper presents the self-reported experiences of computing teaching faculty when reflecting on their teaching practice before, during and after the pandemic. There are a number of avenues for future work: firstly, to run the survey with population groups that were not represented in this analysis in order to accurately archive and reflect on a wider set of experiences. Furthermore, the authors would like to look to conduct follow-up interviews in order to capture a richer data set of their experiences not constrained to questions on a survey.

Finally, it is important to capture a wider range of experiences: there is value in understanding how the pandemic has impacted decision-making by the administration of computing departments. It is also vital to understand the experience of people whose educational journeys have been most impacted by the pandemic: the students. Capturing both these perspectives would add a rich layer of understanding to the current analysis, and would give a stronger indication as to how best to implement the recommendations set out in this paper.

APPENDIX A: THE SURVEY

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.

The project invites people who taught computing courses during the COVID-19 pandemic. We are interested in the experiences of full-time, part-time, and contract teaching members (university, college, or high school).

If you decide to participate in this research you will be asked to complete a short online survey about your teaching 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.

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.

Demographics

- Institution level
- Institution name
- Institution location
- Stage of career:
  - 0-5 years teaching experience
  - 6-15 years teaching experience
  - 16+ years teaching experience
- Which of the following would you feel are 25%+ of your expected workload in this position? (tick all that apply):
  - Research
  - Teaching
  - Administration
- What is/are the class size/s you taught during the pandemic? (tick all that apply):
  - Small (<50)
  - Medium (50-100)
  - Large (100-199)
  - Very Large (200+)
  - N/A - I did not teach)

Pedagogy & Practice

Each of the questions below was set to a 6-point Likert scale, with the options 0%, 20%, 40%, 60%, 80%, 100%.

- Approximately what percentage of your content was delivered using the following modes BEFORE the pandemic?
  - Face-to-face in-person
  - Synchronous online
  - Asynchronous online
  - *Other (please define)*
- Approximately what percentage of your content was delivered using the following modes DURING the pandemic?
  - Face-to-face in-person
  - Synchronous online
  - Asynchronous online
  - *Other (please define)*
- Approximately what percentage of your content was delivered using the following modes GOING FORWARD from now?
  - Face-to-face in-person
  - Synchronous online

  - Asynchronous online
  - *Other (please define)*

The question below was set to a 7-point Likert scale, ranging from Very Negative to Very Positive, with free-text space to comment further.

- To what extent has your experience/perception been positive or negative for the following questions:
  - What was your experience of teaching virtually during the pandemic?
  - How did you perceive your colleagues' wellbeing during the pandemic?
  - How did you perceive the students' wellbeing during the pandemic?
  - What was the experience of implementing content accessibility options (e.g. closed captions, colour/font considerations)?

The question below was set to a 7-point Likert scale, ranging from Strongly Disagree to Strongly Agree, with free-text space to comment further.

- To what extent do you agree or disagree with the following statements on SKILLS
  - I felt like my pedagogical skills prepared me for teaching through the pandemic
  - I feel like teaching through the pandemic has improved my pedagogical skills
  - I feel like teaching through the pandemic has improved my colleagues' pedagogical skills
  - I plan to continue developing my pedagogical skills further going forward
- To what extent do you agree or disagree with the following statements on your INSTITUTION
  - My institution has increased the opportunities to develop pedagogical skills in response to the pandemic
  - My institution has increased the importance given to teaching during the pandemic
  - My institution will continue to maintain the importance given to teaching post-pandemic
- To what extent do you agree or disagree with the following statements on your TEACHING ASSISTANTS
  - My dependency upon my teaching assistants has increased during the pandemic
  - My teaching assistants adapted well to the new circumstances during the pandemic
- To what extent do you agree or disagree with the following statements on your STUDENTS
  - My duty of care towards students has increased during the pandemic
  - My students adapted well to distance/remote learning and all the technologies used
  - Lack of access to technology and Internet had a significant and negative impact on virtual teaching for my students
  - Accessibility considerations (screen readers, closed captions, WCAG 2.1, etc) played a significant role in choosing remote teaching technologies and practices
  - My students were able to form meaningful communities/groups for learning
  - I had students participating in my classes from very different time zones

Efficacy of Common Teaching Styles During the Pandemic

Each of the questions below was set to a 3-point Likert scale, with the options *Used during pandemic but will not use after*, *Used during the pandemic and will likely use after* and *Did not use during the pandemic but want to try in the future*. A *N/A* option was also provided.

- For each teaching style, choose the appropriate column to indicate whether usage of that teaching style happened
  - Flipped classroom
  - Direct instruction
  - Problem-based learning
  - Small groups
  - Pair programming

Use of Technology During the Pandemic

Each of the questions below was set to a 3-point Likert scale, with the options *Used during pandemic but will not use after*, *Used during the pandemic and will likely use after* and *Did not use during the pandemic but want to try in the future*. A *N/A* option was also provided.

- For each technology, choose the appropriate column to indicate whether usage of that technology happened
  - Lecture Content Dissemination (e.g. YouTube, LMS, ...)
  - Document collaboration (e.g. Google Docs, Jamboard, Miro, ...)
  - Online IDEs (e.g. Codio, Mimir, CS50, Codeshare, ...)
  - Formal Communication Tools (e.g. Discussion Fora, Piazza, Teams, Slack, ...)
  - Informal Communication Tools (e.g. Slack, Discord, Facebook, WhatsApp, ...)
  - CS-specific Interactive Learning Platforms (e.g. Runestone Interactive, zyBooks, ...)
  - Real time Interactive Quizzing, etc. (e.g. Kahoot, Poll Everywhere, iClicker, ...)
  - Autograders (e.g. Mimir, Codio, CodeHS, ...)
  - Gamification tools
  - Accessibility Technology (e.g. Screen readers, closed captions, ...)

The following questions were free-text:

- Were there any tools newly made available to you by your institution during the pandemic?
- Were there any tools that you could not use due to institutional constraints?
- Did ensuring accessibility and equitable access affect tool choices and implementation?

Assessment Practices and Academic Integrity

Each of the questions below was set to a 3-point Likert scale, with the options *Used during pandemic but will not use after*, *Used during the pandemic and will likely use after* and *Did not use during the*

pandemic but want to try in the future. A *N/A* option was also provided.

- Which tools did you employ (if any) to enforce academic honesty on assessments?
  - Remote proctoring
  - Timed assessments
  - Plagiarism detection
  - *Other (please define)*
- What tools did you use (if any) for plagiarism detection?
  - Code plagiarism detection tool (e.g. MOSS)
  - General plagiarism detection tool (e.g. Turnitin)
  - Code Auto-grading tools (e.g. Codio, Mimir, CodeHS)
  - *Other (please define)*
- What practices did you employ overall to promote academic integrity (beyond catching violations)?
  - Lower-weight assignment
  - Relaxed late policies)
  - Modified exam structure
  - *Other (please define)*

Conclusion/Going Forward

Each of the questions below was set to a 7-point Likert scale, ranging from Strongly Disagree to Strongly Agree.

- To what extent do you agree or disagree with the following statements on the future going forward...
  - I believe that due to changes made in response to the pandemic, there have been positive advances within my teaching practice.
  - I believe that due to changes made in response to the pandemic, there have been positive advances for teaching staff in my institution.

The following questions were free-text:

- What new online teaching approach do you intend to keep in the future?
- In a few words, describe an innovation or a new approach adopted during the pandemic that you will keep on using after

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