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The rapid move to online mathematics support: changes in pedagogy and social interaction

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ABSTRACT

The dramatic changes brought on by the COVID-19 pandemic have changed the way in which mathematics and statistics support is offered. Students and staff have been presented with new opportunities and challenges. One-on-one interviews were conducted late in 2020 with 23 students and staff who had experience with fully online mathematics and statistics support. The interviewees were from University College Dublin, Ireland, and Western Sydney University, Australia. Utilising thematic analysis, five themes around online mathematics and statistics support common to both universities were identified. In this paper the three themes related to *connection* are explored; they are pedagogical changes, social interaction, and appreciation of mathematics and statistics support. These themes highlight the need felt by both students and staff for mutual connection. The paper concludes with a discussion on the repercussions of this study for future considerations of effective online mathematics and statistics support.

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1. Introduction

The enforced closure in March 2020 of many university campuses due to the COVID-19 pandemic resulted in major changes and developments in how students and educators interact. In particular, academic support systems such as mathematics and statistics support (MSS), have had to adapt in real time to changes in teaching, learning, assessment and engagement, among other factors, in order to best preserve the student support that existed, and was so successful, for those who engaged with it before the pandemic hit.

In this paper we outline the context of MSS both online and in-person, before and during the pandemic. We then analyze the experiences of students and tutors in the wholly online environment focussing on central themes of changed pedagogy and social interaction.

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2. Literature review

2.1. Mathematics and statistics support

Mathematics and statistics support in universities is free, optional assistance for students with mathematics and statistics which is not part of scheduled classes and is not taken for credit (Lawson et al., 2020; MacGillivray, 2009; O'Sullivan et al., 2014).

MSS was in the past seen to be primarily for engineering and the physical sciences, however these days MSS is provided for, and used by, students from many disciplines and at many different levels, including postgraduate students (Lawson et al., 2020; MacGillivray, 2009). Such support has become business as usual in most universities in Australia (MacGillivray, 2009), Ireland (Cronin et al., 2016), the UK (Grove et al., 2020) and the USA (Mills et al., 2020). Lawson and Croft (2021) note that the rise of dedicated student support centres has been slower in continental Europe and Liebendörfer et al. (2017) reported in 2017 that, while most German universities offer bridging courses, there are not many support centres.

In Australia and Ireland, formal MSS has existed for many years (Cronin et al., 2016; MacGillivray, 2009). This support was established in response to what is commonly called 'the mathematics problem' and its variants (Lawson et al., 2020). In Australia, decreasing levels of mathematics studied at secondary school (Barrington & Brown, 2014; Forgasz, 2006) coupled with an increase in the number of students taking on university study (Productivity Commission, 2019) led to an increased need for universities to provide mathematics learning support. The lack of prerequisites for many courses in many universities (e.g. Belward et al., 2011) exacerbates the problem as some universities admit students to degrees with a strong quantitative component without considering their mathematical knowledge or whether or not they have studied mathematics beyond age 16.

In Ireland there has also been concern about the declining mathematical performance of secondary school students and the lack of preparation of students for tertiary study (Gill et al., 2010; Hourigan & O'Donoghue, 2007). Recent mathematics curriculum reform and a bonus points[1] initiative for those choosing the higher level mathematics course at upper secondary school have seen the number of students taking higher mathematics increase steadily – from 15.8% in 2011 to 32.9% in 2019. However, concerns now exist around students who may not be suited for higher mathematics but persevere for the bonus points, as this increase in uptake has not been matched by an increase in mathematical proficiency (O'Meara et al., 2020).

In both countries the primary provision of MSS has been the drop-in model, in which students access assistance from an expert tutor of their own volition. Often students seek one-on-one help with their mathematical/statistical queries, though it is not unusual for small groups of students to access such support. Many studies have evaluated the effectiveness of MSS and most have found a link between the use of MSS and benefits to students in a plethora of ways, for example, improved retention, grades, confidence and employment prospects (Matthews et al., 2013).

There are many ways in which MSS is delivered. There is considerable evidence in recent literature that drop-in and one-on-one bookable MSS are the most common modes of support. A 2018 survey of MSS in England and Wales found that in 96% of institutions MSS included drop-in support or one-on-one support by appointment, with 55% offering

both modes of support (Grove et al., 2020). In Ireland in 2015, 88% of institutions offered drop-in MSS and 44% offered support by appointment (Cronin et al., 2016). In Scotland in 2017 the most common forms of support were drop-in and on-on-one support (Ahmed et al., 2018). Lawson et al. (2020) note the importance of the tutors in these forms of one-on-one support, with Johns and Mills (2021) pointing out that one-on-one tutoring allows tutors to work with each student in their Zone of Proximal Development (Vygotsky, 1978).

There is a wide variety of other forms of MSS including bridging courses, supplementary instruction and workshops, pre-assessment problem-solving workshops, small group sessions, student worksheets, commercial online tutoring programmes, online revision modules, online question and answer services and the use of internet resources (Bressoud et al., 2015; Grove et al., 2020; Jackson, 2020; Johns & Mills, 2021; Lawson et al., 2020; Rylands & Shearman, 2018). Some support is embedded within teaching (Grove et al., 2020) and indeed informs teaching (Cronin, 2019; Cronin et al., 2019; Cronin & Meehan, 2020).

Online MSS has not been as common as face-to-face support, however it is not new (Cronin & Breen, 2015). Johns and Mills (2021) report that one-on-one online MSS has existed since the early 2000s, although the majority of MSS is on campus. Online support can be synchronous via video or using text; or asynchronous, perhaps using a discussion board. In Australia, before COVID-19, Jackson and Johnson (2013) used online tutoring software together with face-to-face support, Rylands and Shearman (2015) reported on the use of both online software and face-to-face workshops and Dzator and Dzator (2020) offered drop-in and bookable MSS face-to-face as well as online support. In the survey of England and Wales already mentioned (Grove et al., 2020), 23% of institutions offered online live MSS, the majority for less than one hour a week.

In March 2020, the COVID-19 pandemic resulted in the closure of university campuses around the world, and thus the closure of face-to-face MSS. Almost all universities in the UK and the USA reported on by Hodds (2020) and Johns and Mills (2021), respectively, moved to offering support online. Two problems mentioned with online MSS were issues with internet connections, and difficulties communicating mathematical notation with not all students and staff having appropriate equipment (e.g. a tablet). Both studies, as well as Mullen et al. (n.d.), found that in most cases the use of MSS decreased after the move from face-to-face support to online support.

Face-to-face interactions between students and tutors, which typically included being in the same room and working together at a table or board, were replaced, sometimes overnight, with wholly online MSS, often with limited institutional technological support. New ways of online communication, teaching and formative assessment were used by staff who largely had no experience or training in online MSS, changing how they and students interact and how learning and teaching occurred.

2.2. Online pedagogy

In transferring their practice from face-to-face to online environments, teachers had to rethink how they interact with their students and the extent to which familiar 'campus-based' pedagogical strategies can be effectively employed in virtual learning spaces. Mathematics teachers, in particular, strived to map their established 'ways of doing' onto the multifarious digital platforms that support online learning (examples given in Trenholm

& Peschke, 2020 include student-led learning, use of discussion and collaboration, 'free and extemporaneous' communication of symbolic notation and diagrams, non-verbal messaging, and well-timed question-response-feedback cycles). A concern is that this process does not always respect the *transformational* nature of the transition, and that the re-contextualized use of essentially unaltered traditional pedagogies might not be the best response (Carrillo & Flores, 2020).

The discipline dimension of this problem goes further. In Trenholm (2013), Trenholm notes the effect of the epistemology of different disciplines on pedagogical development (citing the work of Lattuca & Stark, 1995, where cummulative, linear and tightly structured knowledge growth in the natural sciences is distinguished from the recursive, reiterative and loosely-structured patterns of development in the humanities; and where pedagogical approaches focus on concepts and principles (natural sciences) as opposed to effective thinking (humanities)). This has implications for mathematics educators struggling to adopt the 'de-disciplined', uniform approaches to online teaching and assessment imposed on them from higher faculty or institutional levels (Trenholm, 2013). Moreover, it overlooks discipline-specific challenges in mathematical education such as the hierarchical nature of concept development, the predominance of abstraction and the need for strict adherence to principles of logic and proof.

From a practical point of view, teachers have less access in online teaching spaces to the sometimes subtle cues from students indicating discomfit, confusion, waning engagement or, on the positive side, moments of insight or 'ah-ha' comprehension (Bork & Rucks-Ahidiana, 2013; Lowe et al., 2016). In Smith et al. (2008) mathematics is cast as a 'foreign language', making it ill-suited to instruction in online environments which offer fewer opportunities for corrective feedback and 'multi-modal immersion' than face-to-face settings. The idea that the conceptual landscape of mathematics is different from that of 'soft-knowledge' disciplines (Lattuca & Stark, 1995), and that it is more difficult for students to navigate it online compared to face-to-face, has inspired discussion of students' discipline-specific preferences for in-person learning (Otter et al., 2013). But as online education evolves, and protocols and manuals for expert use of learning technologies such as web conferencing (see Levy, 2020 for example) continue to improve, it is possible that some of these concerns will fade.

Profiles of students who are best suited to online learning – particularly those undertaking mathematical study – typically refer to concepts such as self-sufficient, self-directed, self-disciplined, self-motivated, self-organized and independent among others (Gaytan, 2015; Heyman, 2010; Ituma, 2011; Jaggars, 2014; Ludwig-Hardman & Dunlap, 2003; O'Neill et al., 2004; Otter et al., 2013; Protopsaltis & Baumi, 2019; Xu & Jaggars, 2013). Common to all of these is the notion that in order to succeed in online environments, students must be able to regulate their own learning (Broadbent & Poon, 2015; Martin et al., 2020). But not all students possess self-regulatory learning capabilities upon entry to university, and so it is likely that, in the absence of appropriate pedagogies, those who do are privileged (Reinhold et al., 2021).

As mentioned above, attempts to transfer face-to-face pedagogies to online settings often assume that all that is needed is a mere re-deployment of skills and principles rather than the development of new, transformed approaches that privilege the digital media through which they are actualized (Coupland et al., 2016; Trenholm et al., 2016). This presents a challenge and, perhaps, an opportunity: how can the best of the 'old' methods

and philosophies be re-purposed for use in the 'new' context in such a way that students' mathematical development is optimized and continues to be the central educational focus? A related challenge is one of standards and measurement (and their effects on teaching): how can 'depth of understanding' in mathematics be measured in a standardized way across all modalities so that it is sensitive to achievements not directly amenable to commonly-used assessments? (Coupland et al., 2016)

2.3. Social interaction

The theme of social interaction has featured prominently in discussions of online education since the early to mid 1990s. At this time many of the theories developed to define and understand distance education were updated to accommodate the emerging 'computer-mediated' (and networked) educational world (Garrison, 1993; Jonassen et al., 1995). Studies considered the role of social relationships and group cohesion in enabling meaningful collaboration online, particularly dialogue in activating the 'cognitive processes necessary for deep learning and information retention' (Kreijns et al., 2003, p. 335, and see Johnson & Johnson, 1987 for a broader discussion of socially-mediated learning). Today, the ubiquity of online learning has led researchers to examine what has been lost and gained in the transition from face-to-face to digital modalities, especially as it relates to 'live' interaction and communication (Meehan & Howard, 2020; Trenholm, 2013). An interesting perspective offered by Trenholm and Peschke (2020) is that – per McLuhan's aphorism 'the medium is the message' (McLuhan, 1964) – the internet has fundamentally transformed the 'what' and 'how' of teaching and learning, meaning that efforts to simply re-direct or re-assemble traditional face-to-face approaches are doomed to fail (Trenholm & Peschke, 2020).

Teachers' and students' expectations have grown with the development of online learning technologies: if opportunities for dynamic, immediate, human-to-human communication are considered essential to high quality online learning, student success and retention, then what is being done to make these available? (Bower et al., 2015; Heyman, 2010; Protopsaltis & Baumi, 2019). This is true also of informal social interaction, where students see value in study-related conversations with their peers and teachers outside of timetabled classes (Meehan & Howard, 2020), and where the loss of opportunity for 'human exchange' is considered a distinct disadvantage (Cassibba et al., 2021). The provision of an online learning community is seen as important for students in creating a 'feeling of connectedness', a sense of belonging and a resource for knowledge construction and growth (Händel et al., 2020, p. 2). From the teachers' point of view, little research has been done on the 'lived experience' of practitioners interacting with each other (online or face-to-face) in collegial communities (Grove & Croft, 2019), a situation this paper aims to address.

Instructional design and teaching practice are informed by frameworks validating the central role of social interaction in online education (see Arbaugh et al., 2008; Benson & Samarawickrema, 2009 for examples). In their survey of interaction and presence in online learning environments, Kyei-Blankson et al. cite two theories of distance education that 'have been advanced in the discussion of effectiveness of online courses' (Kyei-Blankson et al., 2019, pp. 48–50). Interaction is a primary element in both of these: Transactional Distance (Moore, 1993), where interaction and perceived pedagogical distance are assumed to be inversely related; and Community of Inquiry (Garrison

et al., 2000), where 'social presence' is deemed critical. A third theory, Communities of Practice (Wenger, 1998), frames learning in terms of four interconnected social components – 'community (learning as belonging), identity (learning as becoming), meaning (learning as experience), and practice (learning as doing)' (Trenholm & Peschke, 2020, p. 3).

The construct of social presence is referred to frequently in the literature but is poorly defined (Lowenthal & Snelson, 2017). While many definitions assume the existence of a 'real person' who is (in some sense) 'there' in online communications, there is little consensus on precisely what this means (examples include non-machine, emotionally available, present and actively engaged) (Lowenthal & Snelson, 2017). Notwithstanding these definitional issues, there is evidence of a positive relationship between social presence (of teachers and peers) and student satisfaction with their online learning (Carrillo & Flores, 2020; Richardson et al., 2017). Related correlations highlight the value of social presence – manifested as meaningful feedback or fully engaged instruction, for example – in enabling students to feel less isolated and disconnected in their online study, but question the extent to which disembodied digital learning environments can provide the same level of 'socio-emotional information' as face-to-face settings (Paechter & Maier, 2010; Sorensen & Donovan, 2017).

There is much to be studied in this new environment. This paper explores the following research question:

What were the effects of the rapid change to fully online MSS on pedagogy and interactions among tutors and students?

3. Background

Western Sydney University (WSU) came into existence in 1989. It is a multi-campus university with more than half a dozen campuses in the west of Sydney, Australia. Many degrees can be studied on several campuses and students can, and do, study on more than one campus. In 2019 the university had approximately 50,000 students of whom 79% were undergraduates.

Mathematics and statistics support has been provided by the Mathematics Education Support Hub (MESH) for the last decade. MESH currently has the equivalent of just over five full-time staff and casual staff are also employed during the semester. MESH tutors would be classified as 'dedicated staff' according to the MSS staffing definition of Lawson et al. (2020, p. 1238). The university has offered MSS for over 25 years, though with fewer staff than at present.

There are no secondary school mathematics prerequisites for entry to WSU, so many students are mathematically poorly prepared for their studies. MSS is provided to all students regardless of discipline or subject[2] studied. Before the COVID-19 pandemic, MESH provided face-to-face support on six campuses. This support included refresher courses for students about to begin their studies at WSU, drop-in support in campus libraries and workshops run for specific subjects and student cohorts. For many years MESH has run an online answer service via a discussion board. Over the last decade MESH has built up comprehensive support materials which are available to all students via the learning management system and MESH web pages.

All MESH services ran fully online from the 18th of March 2020, the third week of a 15 week semester. One year later MESH has only just returned to running a few workshops on campus. From the point of view of the study reported in this paper, all MESH services were online for 28 weeks, which for the students in this study was just three weeks short of their full academic year.

University College Dublin (UCD), Ireland, founded in 1854, is one of Europe's leading research-intensive universities and Ireland's largest university with over 33,000 registered students. It is consistently the university-of-first-choice among school leavers in Ireland.

The UCD Mathematics Support Centre (MSC) was established in 2004. Due to demand, since 2015 only students from preparatory, first- or second-year subjects may access the MSC. In these past five years the MSC received 29,707 student visits from over 400 subjects across all six colleges of the university – Arts and Humanities, Business, Engineering and Architecture, Health and Agricultural Sciences, Social Sciences and Law, and Science. The majority of these visits emanate from the library drop-in one-on-one service. In addition 'Hot Topic' sessions for groups of students, similar to the workshops at MESH, are offered.

The MSC is staffed by 2–5 tutors at any given time with approximately 20 tutors hired each year. Tutors are predominantly postgraduate research students with no formal pedagogical training. Most MSC tutors also tutor regular tutorials and many go on to teach within tertiary or secondary education professionally. Also, final stage undergraduates serve as (near-)peer tutors for first-year MSC visitors.

Up to March 2020, apart from a short pilot using Slack.com during busy examination periods, the MSC had not offered any personalized synchronous online MSS.

The MSC started providing wholly online MSS from the 23rd of March, 2020 – Week 8 of the 12-week teaching Spring semester (January to May) of the 2019/20 academic year. The MSC was fully online for the Autumn semester of 2020/21 (September to December) when it ran from Weeks 3–12. In contrast then to MESH which had 28 weeks of wholly online MSS (three weeks short of a full academic year) the MSC provided MSS wholly online for a total of 14 weeks during the COVID-19 period of this study.

The pandemic has had a significant impact on MSS engagement at both institutions. At UCD the MSC drop-in figures decreased by 59% on the previous year's visits (4283 to 1762 visits) for the corresponding period (April–December 2020), while WSU drop-in service figures decreased by 46% and the MESH workshops had a drop of 23% for the same period (Mullen et al., n.d.).

4. Method

The data comprises of transcripts emanating from 23 one-on-one Zoom interviews conducted by the lead author in late 2020. A single set of questions was used for UCD and WSU, appropriately adapted for the student/tutor context – see Appendix. The questions were tested with non-participants of this study to ensure that they encouraged responses relevant to the research, without being too narrow.

Participants were recruited via email by the second author (WSU students and tutors) and the third author (UCD students and tutors) in October 2020. Students from WSU and UCD were sent the recruitment email if they had used MESH or MSC services after the transition to online MSS. Those emailed were $n = 890$ MESH users and $n = 397$ MSC users (231 of which were first-year students who only had access to the online MSC from

Table 1. The participants.

Participants	Background information	MSS experience
UCD students IS1–IS6	Mix of specialist and service mathematics: 3 first years, 3 second years	1 student had used on campus and online MSS; 5 had used only online MSS
WSU students AS1–AS7	All service mathematics: 5 first years, 2 second years	2 students had used on campus and online MSS; 5 had used only online MSS
UCD tutors IT1–IT6	Part-time tutors: 5 postgraduate students, 1 lecturer/tutor	Postgraduates had 3–7 semesters MSS experience, lecturer/tutor had several years of MSS experience
WSU tutors AT1–AT4	Dedicated tutors: 3 had postgraduate qualifications	3 had at least 5 years' MSS experience, 1 had over 2 years' MSS experience

when they started university in September 2020). Tutors, excluding the authors of this paper, from both MESH and the MSC ($n = 11$ and $n = 15$ respectively) were emailed and invited to participate as they had all tutored online for the entire period March to October 2020 of this study.

Seven WSU students (AS1–AS7), four WSU tutors (AT1–AT4), six UCD students (IS1-IS6), and six UCD tutors (IT1–IT6) participated. We acknowledge the convenience sample limitations but note that the student samples were diverse in terms of degree major, gender and age, that is recent school leavers or mature status. Background information about the participants is provided in Table 1.

Thematic, deductive, semantic coding (Braun & Clarke, 2006) was used to analyze interview transcripts. The coding framework was developed over four rounds as outlined in Mullen et al. (n.d.) and shown in Figure 1: Round 1 was to establish a basic coding framework which was developed in Rounds 2 and 3, concluding with a final review for consistency in Round 4. Throughout these rounds the primary coder, and lead author, was assisted by the co-authors to ensure: (a) the coding framework was expansive and well-defined; (b) the coding framework was consistent throughout all 23 interviews; and (c) the context of WSU tutors' and students' interviews was not misunderstood by the UCD-based interviewer. Through this multi-round, multi-coder process a robust coding framework was created to aid the theme development and identification process that constituted the final step of analysis. In each round coding was completed independently by the authors using methods outlined in Thomas (2006). Coding was then compared through discussion using an inter-rater reliability measure of at least 80% as outlined in O'Connor and Joffe (2020).

Coding concluded with the identification of themes highlighted by this process. Key to this process was the detection of evidence highlighting any differences in the experience of tutors and students in the context of online MSS, while also attending to potential impacts of these experiences on MSS in post-COVID-19 settings. Similarly, attention was paid to any testimony of shared experiences both from tutor-student and Australia-Ireland perspectives.

5. Results

Five themes were identified as central to the shared experiences and perspectives of tutors and students in the online MSS context of the COVID-19 period of March to November 2020. These are *Usage of online MSS*, *Mathematics is different*, *Pedagogical changes*, *Social*

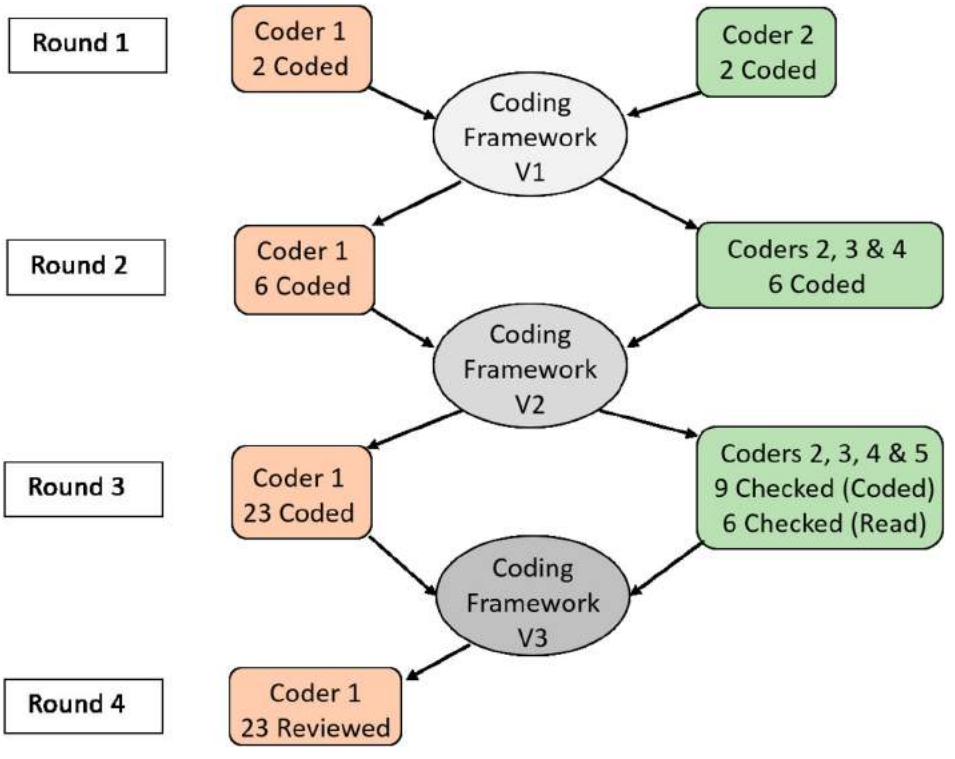

Figure 1. Creation of the coding framework over four rounds of coding with five coders for 23 interviews.

interaction, and the *Future of online MSS*. The themes and their subthemes are shown in Figure 2. Based on the research question, the third and fourth themes together with part of the first theme are now examined. A detailed discussion of the themes not covered in this paper can be found in Mullen et al. (n.d.).

5.1. Pedagogical changes

The pedagogical changes observed by tutors to have arisen from the rapid shift to online MSS yielded five subthemes (shown in the purple rectangular nodes in Figure 2). The tutors noted a reduced capacity to communicate with students online – especially via body language or other non-verbal exchanges – and see their work, either at all or as it was being written. This made diagnosing students' problems harder and complicated tutors' use of familiar in-person teaching strategies such as thinking time, guided questioning and treatment of misconceptions. These changes caused a shift among tutors to a more didactic teaching approach, one where they talked to students a lot more and answered their questions more completely than they would in in-person settings. The tutors found that having easier access to relevant learning resources online improved their confidence as well-informed teachers but that this came at a cost: students needed greater guidance in filtering out the best resources from the vast, uncurated, array of learning materials served up to them on the internet. Tutors also observed an increased willingness of students to communicate in online lectures and tutorials via chat, but this was not as visible in the MSS

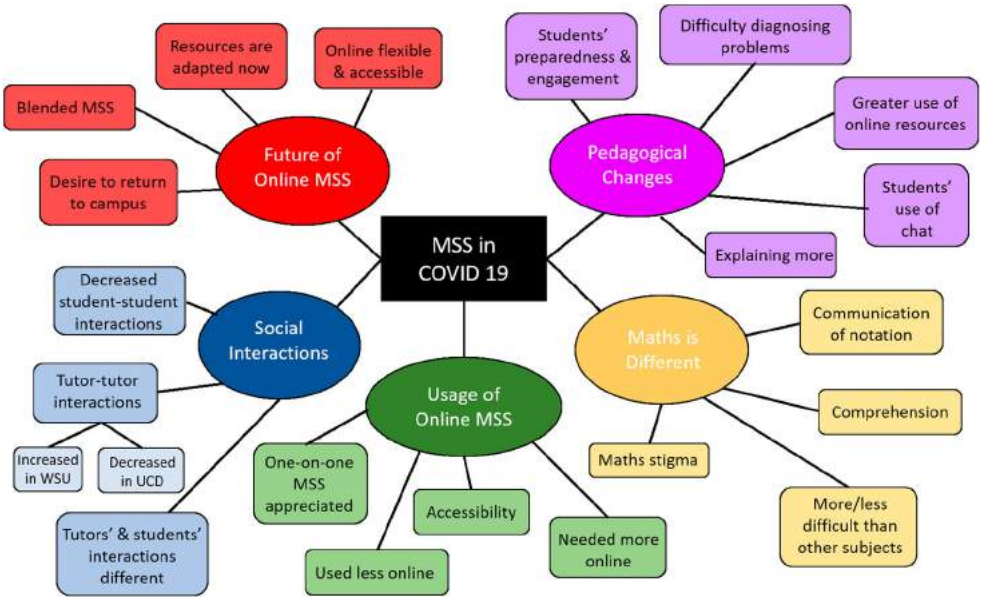

Figure 2. The five themes and their subthemes as identified via analysis of interviews.

context. On the question of students' preparedness and engagement when studying online, UCD and WSU tutors' highlighted different experiences. UCD tutors found that students were often more prepared for online MSS sessions but some were taking less notes in online lectures. WSU tutors pointed out the difficulties of engaging students in group work. These pedagogical challenges and benefits associated with online mathematics tutoring will now be explored in further depth.

5.1.1. Difficulty diagnosing problems

One of the greatest challenges tutors identified regarding online teaching was the loss or lack of body language or non-verbal communication. Students in UCD and WSU tended to turn their cameras off (if they had a camera) during online support interactions and tutors found this limited their ability to interpret students' level of understanding. IT2 explained how a student's facial expression clearly portrays how much they understand an explanation:

> You can tell very easily face-to-face when they're having issues, even when you are describing something to them and they're lost, it shows in their face very quickly, whereas if they're just saying "yes" in their voice you can sometimes catch it; but probably not always.

AT3 discussed the loss of connection with their students online and how not being able to see the student or their mathematical work is difficult:

> I just feel like I'm not really connecting with the student. If they suddenly get something and understand it, I'm not receiving the message that they have understood it. And if they have not understood, it's much harder to identify what it is that they're not understanding when I can't see their working.

This issue of not being able to identify student's precise misunderstandings without seeing students' work was echoed by IT1 who also noted that they felt less comfortable online with the 'thinking time' they give students.

> [I]n face-to-face teaching, if you ask them a question it's a lot easier to leave that silence and let them think it out. Whereas online, if I ask them a question and they don't respond, I assume technology errors … It's a lot easier to write things out with the students face-to-face and see their thinking. Whereas when online, unless they're writing it out and showing it to me, which means you probably have to take something else off the screen, I can't see where they've gone wrong.

Tutors and students had trouble communicating mathematics with each other without pen and paper. Due to technological difficulties, among others, tutors were less able to see students' work and this led to awkward situations.

> some students are more technology savvy than others. Some students really struggle with sharing, sharing notes, sharing different things, and students can get away with stuff more. Like if you say, "have you made a previous attempt at this question?" They can just say, "yes, but I'm not able to show it to you" and you have to say, "Oh, okay". (IT1)

IT6 had difficulty understanding students' questions, due to technological difficulties:

> Sometimes students aren't able to turn on their mics … or don't have one. So they're trying to type out their questions and when they're very technical, it can be quite difficult to communicate what exactly is meant.

5.1.2. Explaining more

These communication issues, especially the loss of non-verbal communication, sometimes resulted in tutors using a more didactic style of teaching online than they would adopt in person. AT2 was concerned they were talking at, rather than to, students:

> I am not quite sure how it's been received, and I hope I am not talking at them. When you are face-to-face you can immediately see if you've used a word they didn't understand. You know what maybe needs to go back and be repeated. I think students don't get those cues unless they are very comfortable putting something in chat. So I didn't personally find it hard to talk to them, I think some of them found we didn't have a normal interaction. I think the back and forth was missing.

Tutors also reported that they tended to coach students more closely and answer their questions more fully when online. While in person they feel comfortable leaving students 'hanging' in a workshop because they can return to them; online they find students move on from difficult questions when the tutor is not in the breakout room.

> So there might be a tendency to guide them a bit more closely, to ensure that they have got something out of it. … I am talking about if you're looking after four or five breakout groups yourself, getting back regularly enough to see is a bit more difficult. They can easily leave and they can easily change questions while you are gone … The number of times they said "Oh we left that one out" and I would say "That is the idea of being here, that you ask about the ones you can't do". (AT2)

AT4 also noted they 'talk a lot more' and IT1 stated they explain more too, though this was because of time limited 30 min appointments at the online MSC rather than monitoring multiple breakout rooms as in MESH workshops.

> Definitely it takes a bit longer now to figure out the root of their problem. And I think, in some ways, I'm more likely to help the student a bit more, whereas before I would have kind of left them alone to work out their problem and kind of come and gone from them. Whereas now when their appointment is done, it's done. (IT1)

The tutors as a whole had a preference for in-person interaction. They found it easier to provide explanations suitable to students' level with both the students' body language and their work in front of them.

5.1.3. Greater use of online resources

Tutors did appreciate the increased ease they felt in referencing mathematics resources during an online tutoring session.

> I am a little bit more comfortable online. The main reason being … especially with something like MESH, we can get questions about literally anything and when it's online … I can easily look up stuff and that really helps. (AT1)

IT3 also felt more confident being able to double check online resources during tutoring sessions:

> Funnily enough I am probably a little bit more confident giving help online, purely because I have the power to go and look something up if I need to … when you are doing it face-to-face you can still go and look something up and that's fine, but I think you can do it much quicker [online], you can do it while you teach and you can have a few things going on at the same time. … I can back myself up a bit more online.

The online resources that the tutors found helpful were also available to the students, and, as AT2 warns, this can be problematic for them. They noted that helping students to identify the best resources online was now part of being an MSS tutor and this will continue whether online or not.

> whilst they always search things online and did things online, because we are forcing them online they are looking more broadly for solutions and in some cases they then became aware that it's hard to select the right application, the right question, that right method that is being asked for any particular question; because there is so much out there, finding your way through it is difficult. So you're trying to help students monitor or discern the best options.

5.1.4. Students' use of chat

Some MSS tutors interviewed, who also lecture or tutor outside of MSS, reported how students were more confident to speak up in lectures and tutorials by using the chat facility than they might be in person. IT2 discussed how the way they provide support has changed since COVID-19, and reflected on how this new student confidence appears in the MSS context:

> Even with the MSC stuff the way that we bring them into a room just separately entirely from everyone else, they don't have anyone else around them. I guess that is a little different, maybe they would be more likely to ask what they would perceive as more silly questions and that sort of thing. Otherwise I don't really think there is that much [change].

IT2's perception that students being more confident asking questions online has not affected MSS too much is reasonable, as IT6 noted, students come to MSS 'actively seeking help' and thus are prepared to communicate.

5.1.5. Students' preparedness and engagement

All UCD tutors discussed how the students they see online prepare differently for their support sessions than in person.

> I find that they tend to be more prepared when they're coming to the online MSC; just because they're more likely to have a question to show you, as in sharing their screen and showing you, than when they are in person and they don't have their laptop next to them and they're like "I need help with this problem sheet but I don't have it here" sort of thing. (IT2)

Contrary to IT2, IT5 found that not all students are prepared for their sessions online but did state that there are more prepared students online.

> It varies. There's always a number of students who seem out of their depth when they come to you with a problem, like they're not quite sure what they're asking you. They just know they don't know something. And other students who are very articulate about the nature of the problem. And others who like basically have the problem entirely solved … and as soon as you say one little thing they instantly get it and they barely need you at all … there are always those types of students in both online and offline. But, the number of students who seem more prepared seems larger than it did before.

IT3, on the other hand, was concerned about students not taking notes while learning online leading to them seeing students who are underprepared compared to how they might be in person.

> I've seen a lot of people who are struggling are also not taking notes. Sometimes for some students it could just be a bit much and a bit overwhelming and then they have this thing of "I'm just not going to look at any of it and I will just get help from people when I need it and they will explain everything to me" it can get a little bit difficult then because as a MSC person I am going "I need you to have a little bit in you to be able to help you. I can't just teach you everything from scratch". So in that case it's more difficult, because at least in person when you ask them "Have you got your notes with you?", they might have some scribbles on a page and it's something, it's better than nothing.

While UCD tutors discussed the varying levels of student preparation in the online setting, the focus of the WSU tutors was on the difficulty of getting students to engage in group work during online workshops and the extra resources required.

> The issue online was that it was difficult initially to get students to engage in a group. It took a long time to organize the groups to talk to each other, to learn how to share a whiteboard and we found quite a few students quite hesitant to work as a group. Quite a few of them decided they would work on their own and literally there was no conversation going on. So we needed a lot of staff to monitor that situation. In fact we decided that we probably needed twice as long and at least twice as many staff to run the same workshop as we would have done face-to-face. (AT2)

Assessing students' understanding via group work in MESH workshops was also more difficult online, requiring new pedagogical methods.

> With some of our workshops we now put a few questions up at the start, in the form of a poll, … which gives us at least a little bit of feedback as to their understanding of the topic; previously, we've not really bothered doing that because as we walked around the room, we get a fairly good sense where they're at anyway, so that has changed. (AT3)

Naturally the theme of pedagogical changes did not arise frequently within student interviews. Student comments that did refer to pedagogy confirmed they also noticed the

negative impact due to the lack of body language, difficulties in showing their work and an overall decrease in the 'interactive element of learning' as IS5 noted. The students also spoke about their increased use of online resources (other than MSS and those recommended by instructors) and some noted they feel more confident in speaking up online. The increased difficulty of engaging online due to lower attention span and learning using technology was also discussed by students. Clearly both issues have repercussions for tutors' pedagogy online.

5.2. Social interaction

The ways in which tutors and students interacted online yielded three subthemes (shown in the blue rectangular nodes in Figure 2). With respect to tutor-tutor interactions, the experiences of UCD and WSU tutors were different: while UCD tutors suffered a drop in collegial interaction online (and the loss of community and camaraderie that followed from this), the WSU tutors enjoyed greater collegial connection. Interactions between tutors and students were marked by a loss of rapport and connection and, in some cases, a more business-like mode of engagement. Some students accessed MSS as a way to replace the lost opportunities for peer-to-peer interaction due to the pandemic. A major concern for students was the lack of peer connection online and the effects of this on the quality of their learning. A significant observation was that much valuable mathematical learning can occur socially among peers and that this happens most effectively in in-person interactions.

5.2.1. Tutor-tutor interactions

For MESH tutors, the move online created a need to become familiar with Zoom. Thus, as AT3 discussed, they began meeting daily on Zoom and so their time spent together as a team increased.

> Previously our team would have a face-to-face meeting maybe two/three times a year and a Zoom meeting maybe another three times a year. When COVID happened we started having daily Zoom meetings, partly to socialize, partly to practice the technology.

Pre-COVID-19, MESH operated with one tutor in each of the libraries whereas during COVID-19 there were two tutors in one Zoom room simultaneously. This was quite a change as AT4 reflected:

> When you do it face-to-face, you're really quite radically on your own, to the extent that you don't see your colleagues from month to month. And so, I suppose it's paradoxical that in an online format, you're more in contact with your colleagues than before.

All MESH tutors appreciated this increase in interaction with AT1 highlighting one benefit in team teaching where one tutor could assist with a query another tutor might not be familiar with, stating 'the tutors complemented each other'.

In contrast to the WSU tutors who found they could support each other more online, the UCD tutors who, pre-COVID, worked with two to five tutors in the same room, found they were more disconnected online. This was attributed to tutors taking students into breakout rooms individually and the fact there were usually only two tutors online per shift.

> Most of the time I'm just working with one other tutor now, whereas before I would've been on with far more. It means that when I'm with just one other tutor I know them a bit better, but overall, when we were in person, we would have had far more time to talk to each other

> and say, "Oh, are you good with Python? Do you want to swap?" whereas now it's harder to have contact with two people at one time in two separate chat bars and in person. So I talked to them less overall, which is sad. (IT1)

Tutors at UCD were used to and appreciated collaborating but found it difficult to do this online due to the added digital barriers as IT2 discussed:

> If you've a quick question for another tutor it's a lot more difficult, whereas before you would be interrupting but it wouldn't feel as much like an interruption because you're not leaving your room, breaking into their room, and then asking them a question. So I would be more hesitant, if I have a problem, to ask other tutors now. I think there is also less interaction when, it's not as busy in the MSC, because it's a lot easier to just mute your mic and go off and do other work … Whereas when you're actually in the MSC you'd just sit around chatting if that ever happened.

The social element of working as a MSC tutor has been negatively impacted with many tutors in agreement with IT2. IT6 was saddened by the loss of community and IT3 noted that while the work is still being done there is less camaraderie between tutors.

> Communication is definitely still there when it needs to be to get work done and problems solved. … But in terms of general upbeat feeling about work and general happiness surrounded by friends and stuff, definitely there is not as much.

The Irish students also noted reduced interaction online between UCD tutors, in comparison to in-centre.

> They're [tutors] obviously in the same room. Like last year if they couldn't get something they'd call one of the others. Whereas now, I was online and one of them didn't know what to do, and he had to go email another one to ask and we're sitting waiting, and it was very different. (IS5)

5.2.2. Tutors' and students' interactions different

Tutors also reported loss of rapport with students. IT6 found themselves 'cracking more jokes and just trying to get the morale up' because interacting with students could be 'weird'. AT4 noted students were:

> more business-like over Zoom. … I have a lot of regulars face-to-face, you get to know them and start talking about life … And then you might even continue just talking to people until the next student comes in. But you found that because there were more students [waiting] and because, I suppose in the back of the mind you've got the person who's the host thinking what's that person doing in that breakout room, and so you tend to be more focussed and business-like about your interactions.

IT1 reflected that while interacting with one student online is manageable, two or more students simultaneously was difficult:

> It works well when you see one person. When you see two, it almost loses its effect then, but when you have a group of people online and you're trying to help each of them, because, tutoring is slightly different to lecturing or teaching, you want everyone to be interacting. It gets too messy and it doesn't work as well. Whereas in person that was fine.

Students, however, were not using MSS in groups as much online according to their tutors.

> There are far fewer groups of students. … I guess some of them will show up as half a social thing and half as a students' thing. They show up with two/three friends and get help but

> they're not really doing that any more. The only way you end up working in a group is that if there are several people from the same module there who don't necessarily know each other. They just happen to be there for the same module. (IT2)

IT4 believed that lack of interaction among students was a major problem with online learning, and led to 'bewildered and lost' students.

Students spoke extensively about the loss of connection with their peers and tutors/lecturers caused by moving online. AS3, talking about this new disembodied relationship with their instructors, said:

> You don't have that personal connection as such. There is a little bit of human taken away from it. So, it's not as … well still friendly, but … you haven't got that next level of communication. You haven't got the body language. I wouldn't go as far as saying I am disconnected, but it's just not as connected.

5.2.3. Decreased student-student interaction

Most comments on social interactions were students who spoke about the lack of peer interaction online.

> We don't actually talk much to other students so whether in a lecture or whatever, there's not much interaction … unless workshops, we try to do our best, but you can see there's a reservation in people. (AS1)

AS5 discussed how they use MESH more because they found themselves unable to connect with their peers online. AS6 too appreciated MESH, as that was the only opportunity they had to interact with fellow students:

> The main thing is mostly you don't interact with students. Okay, other than the MESH workshops … they're the only ones where they let you interact with other students, so it helps you to learn which it does. But generally speaking, in all my university classes there's no interaction whatsoever. And they [instructors] even turn off the chat bar function.

However, student experience of interactive online sessions varied with AS7 finding their peers were less committed to interacting online:

> Contributors don't turn on the camera and they even hesitate to type in chat. When you're in a physical environment that's a more collaborative environment. There's no black screen to hide behind. You've already mentally committed yourself to being there. So if you're in the classroom and you're already there, you're committed to at least learning. … When you're in person, you can't ignore a question for 5, 10 minutes, get back to that later. That happens in the online collaborative environment, there's no commitment, or there's less commitment because you have to be committed to at least be there in the first place, but … commitment is significantly less.

In contrast, AS4 enjoyed online socialization:

> I think that when I'm online I can banter a little bit and just make jokes about other things, whereas in person most of my social interaction is telling people how to do the work. People ask questions of me and I'm a fairly smart guy and so I'm like "I'll help you".

AS3 found online MESH workshops to be similar to on-campus workshops apart from an increased concern about interrupting their peers:

> I did have one group session that was face-to-face with MESH and it was fairly similar because you take your problem, you do it, and then if you came to a problem you would say "Hey I've

> got an issue, have a look at my working" and show it to the person next to you, whereas I think on Zoom you can do a similar thing, but I think you're more concerned about interrupting your peers.

IS4, on the other hand, described working with their peers online as difficult and very different from in person where they could easily discuss mathematical problems and found their peers explained potential points of confusion.

However online they found:

> there is no option for a proper discussion and even through a screen it's still completely different because you're trying to get help and there could be connectivity issues and then they're sharing a screen and trying to write on the screen and then you're kind of writing on the screen too and it's just not good. (IS4)

Other students similarly reported that their peers aid their comprehension of mathematics in person.

> I just feel like it's already harder to comprehend stuff when you're looking at a screen and not being interactive in person. When you are surrounded in class by everyone it's more easy to focus and understand what is being taught and engage. (IS6)

IS5 found that their mathematical learning was more peer-dependent than they realized:

> One of the biggest things is none of us realized how learning maths is quite social in that when we're sitting in the lectures and tutorials, without realizing, we spoke to each other so much and, just even silly questions, came up in the tutorials. Whereas when you're on your own now, … it's staring at the screen and you're like, I've no idea what's going on here.

IS5 expanded on this point of the importance of peer support saying:

> a lot of my support before COVID came from my friends, without me knowing, in that we'd be sitting together at lunch and someone would be like, "Oh, do you know how to do that?" And you're just constantly listening to people, talking about stuff. So it went in without you realizing, whereas now it's like, you don't have that as much, … if I don't actively go look online for someone to help me with my issues with questions, there's no other way to do it.

AS1 echoed IS5's sentiments on how peer-to-peer teaching used to occur more before COVID-19 noting that it has changed how they use MSS as a result, with a shift to seeking help individually:

> Online we don't really work in groups as often as we used to do in the library where one person would just go in and seek help and then they teach all the other people in the group. And that's how we would learn, by teaching one another. What happens is that actually supports what you learn, that you're able to teach somebody else. And in this instance, we just have to go individually, because, it's hard to work in a group via Zoom.

Students also found that their peers aided their engagement with AS4 stating 'being in a group of my peers, like, not one-on-one, makes it a lot easier [to receive support]'. IS1, speaking for their fellow students said:

> Others mentioned the loss of the classroom environment went against their concentration. Whereas if you are in a classroom environment you would be a bit more up and alert.

These reports of difficulty engaging due to a lack of peer interaction coupled with student accounts of poorer attention spans and mathematical comprehension difficulties clearly affected students' learning online.

5.3. Usage of online MSS

As mentioned in the background section, online MSS was significantly under utilized in comparison to its in-person format. The smaller number of students who did use online MSS was nonetheless very appreciative of it and praised the features that distinguished it from subject-based tutorials or lectures. For example, they noted the individualized, interactive and equitable nature of the support they received, and the fact that MSS tutors gave them more time to share and work through their problems.

5.3.1. One-on-one MSS appreciated

Clearly the MSS provided by WSU and UCD aided students in what still proves to be a difficult learning environment. Some tutors reflected on this:

> I get a lot more students who are willing to just have a conversation. They are not popping in wanting to get their answers and then leaving. They are more popping in, getting their answers, and then saying "How does this work for modules? How do I do this with certain exams? Who should I talk to about this? What do you think about x, y and z?" I think more so students like the idea that they can actually have a conversation with someone and maybe they feel a little bit daunted about asking a tutor or lecturer as they see them in a position that is way above them. … not that the lecturers and tutors aren't friendly but it gives you a chance to be friendlier in the MSC. It's a little less formal. So overall they just have the chance to be a little bit more open about things that they are concerned about. And I think getting more one-to-one chat with someone who has probably gone through something similar in terms of their degree, tends to calm them down quite a bit. (IT3)

The students seemed to really appreciate the one-on-one interaction MSS provided. As IS1 commented:

> I really felt in a privileged position there because it's like your own personal maths assistant and you can flesh out your problem in a completely frank way. I think sometimes in the classroom, somebody might be embarrassed … For me, that's the main difference, because sometimes you want more of the tutor's time and so the online support has been amazing.

IS2 and IS3, both identifying interactive learning as important, enjoyed how the MSC provided some interaction with IS3 saying the MSC is where they 'get the more hands on thing, even if it's not like in person'. IS5 explained that the MSC is:

> the best way to ask the questions cause you have your mic on, you can describe what the problem is … they have the whiteboards, so you can share documents, you can speak to them. It's more like you're equals, you're talking to them, it's a lot easier to communicate because it's just asking your question rather than trying to type the numbers and stuff.

UCD students found that there often was not enough time in large online tutorials to have all their questions answered and so they used the MSC. IS4 explained that they try to book in with their subject's tutor in the MSC and this has 'made me feel closer to the tutors because I have actually had more one-on-one time with them than in the tutorials'.

The WSU students were similarly appreciative of MESH with AS3 noting that it:

> reinforced the idea that there are people there to help you, that they don't expect you to go through university just by yourself and lock yourself away and don't talk to anyone, if you've got a problem just keep working at it until you drive yourself insane. I think that they're doing it for us to reinforce that idea that, yes, we're actually here to help you.

AS2 also mentioned how MESH helped them and how enthusiastic the tutors were:

> It really helps to know that I've got a support network of just people who are there and are on standby to help me out. Yeah, especially getting the emails to me. I can just write them something and they helped me out; because they're really keen, when they jump online.

Online learning has brought much student appreciation for the service MSS provides despite the changes to pedagogy and social interaction.

6. Discussion

The results indicate that the rapid move to online MSS has led to a range of pedagogical changes. These include a decrease of non-verbal communication leading to difficulty diagnosing students' issues; technological difficulties hindering communication; and struggles to determine students' knowledge of the topic(s) under discussion. This has negatively impacted the tutor-student discourse and forced tutors to utilize a didactic, rather than dialectic, style of teaching. The suggestion in Lowe et al. (2016) of a reduction in student and tutor dialogue in online compared to in-person settings is explained in Bork and Rucks-Ahidiana (2013) by the relative absence of 'socialisation processes' that allow deeper, 'multi-modal' connection between the parties (Smith et al., 2008). The absence of in-person interaction allied with tutors' difficulty in accessing visual cues is just one of the communication issues highlighted in this paper that will require further research in the pursuit of effective online MSS.

One of the major strengths of MSS is that it affords opportunities for tutors to assist students with their queries and encourage independent learning by using students' thinking and getting students to 'hold the pen'. The evidence from this study indicates that, due to the transition to online tutoring, a more tutor-led approach was adopted which may affect students' long-term learning as a less independent mindset is fostered. The perception of tutors' that it is mostly better-prepared students seeking help online could compound this problem. An implication of the tutor-led approach discussed in Lowe et al. (2016) is that, in reducing opportunities for free dialogue, it increases the 'structure' of online lessons. A finding of the review in Martin et al. (2020) (and references therein) is not only that learning strategies such as time management, metacognition, goal setting and effort regulation correlate positively with academic success, but that there is also a 'positive relationship between a learner's self-regulation and interaction … communication and collaboration' (p. 9). A mitigating factor is that many students have the ability to turn on cameras and provide tutors with some pedagogically beneficial non-verbal communication cues. However, this requires careful negotiation by tutors as not all students may be in a position to have cameras on.

MSS tutors benefited from increased ease of access to online resources while tutoring online but were concerned about how students were using such materials. Tutors' pedagogical choices are affected by students' knowledge and they feel there is a need and responsibility to guide students in appropriate resource selection.

It is clear that online MSS requires a different set of pedagogical and technological skills. Common techniques such as giving students thinking time are harder to implement. Thus research into appropriate tools and techniques for online MSS is needed to inform staff development. Training in the management of one-on-one and especially student group interactions could prove to be beneficial for MSS tutors, with a couple of caveats:

any institutional support should be discipline-specific and do more than merely reassemble traditional approaches (Trenholm, 2013). As emphasized in Hodds (2020) and Johns and Mills (2021), all participants should have access to technologies required for their online learning and teaching, including a device suitable for writing mathematics (for example, a tablet).

The tutor and student responses comparing the nature and importance of social interaction in online and in-person MSS have revealed some strong themes. The most prominent theme was a perception of the relative disconnectedness of the online teaching and learning experience. Tutors reported struggling to engage with disembodied students, whose online presence was often reduced to stilted Zoom chat, or faceless audio. Students complained about the loss of casual in-person interactions that would happen in classroom settings or incidental social situations outside of class. This is not surprising given the findings of the Australian Student Experience Survey, which received responses from 280,301 students in 2020. Compared to 2019, there was a large drop in learner engagement (16 percentage points), and in working with other students as part of university study (14 percentage points) (The Social Research Centre, 2021). Again this interaction loss is concerning, especially given the role of social interaction in enabling deep learning (Johnson & Johnson, 1987; Kreijns et al., 2003), and a strong sense of community and connection (Händel et al., 2020).

Alongside this generally negative set of attitudes were some rays of light. Students appreciated moments of informal interaction with their peers online, and were grateful for any opportunity to communicate with friends. WSU tutors appreciated the enhanced collegiality that came from more frequent interactions with their fellow tutors in Zoom, and the wider opportunity for co-teaching online – particularly as it was possible to accommodate tutors' subject specializations.

In contrast to WSU tutors, UCD tutors' observations about collegial interaction online highlight what has been lost: incidental conversation that would happen during 'down time' in in-person MSS sessions; camaraderie and a sense of community. It must be noted that WSU and UCD staff worked differently before the move to online MSS. Because of the multi-campus nature of WSU, tutors worked in isolation when on campus, whereas multiple UCD tutors worked in the same room as their colleagues simultaneously. Online, both tutor groups had similar levels of contact with their colleagues; this meant an increase in contact for WSU tutors and a decrease for their UCD counterparts.

Student-tutor contact also both increased and decreased, depending on the circumstances. Some tutors noted a lack of rapport with students and being more 'business-like'. In contrast, other tutors reported students wanting to stay on and chat about other aspects of university life. This may be due to students' lack of peer interaction, the fact that they didn't present as much to online MSS in groups and the individual nature of online learning.

For their part, students working in groups in online MSS reported a subdued atmosphere, affected by their peers' reluctance to contribute to public discussion or even allow themselves to be engaged. This was frustrating for some respondents, who felt that a seemingly sparsely populated learning environment diminished collaboration. The effect of this in limiting opportunity for socially-mediated learning (Johnson & Johnson, 1987) might have equity implications in favouring students better adjusted to self-regulated learning, for example (Protopsaltis & Baumi, 2019). They also described the benefits of being physically proximate to other students, and tutors, in in-person settings. Such benefits included

stronger mental commitment, improved focus and – in the absence of technology-created distractions – deeper concentration and a sense of continuity through the lesson.

A related, striking, observation on this theme was the extent to which mathematical learning is social. Students admitted to being unaware, until COVID-19, of what was gained from their peers on campus in terms of the implicit or 'accidental' learning that happens in this environment. This resonates with Meehan and Howard (2020), where students noted that they 'missed the easy interactions with peers and lecturers that they enjoyed pre-COVID' and the 'the negative impact this absence had on their learning' (p. 24). For mathematics educators forced to practice online, this presents a challenge. There is potentially much 'hidden' or 'osmotic' learning that happens in in-person contexts, where complex and subtle social dynamics can aid students' alertness, concentration, commitment and readiness to learn. Such contexts also foster an open attitude to learning, where fellow students are recognized, present and available to offer peer support or simply human companionship. Opportunities should be created for students to interact informally online to replace some of the informal face-to-face contact, and recognize the value of social interaction in students' intellectual development (Sorensen & Donovan, 2017).

While obviously missing their peers and lecturers, students clearly appreciated the opportunity to talk directly to MSS tutors one-on-one. MSS is different to timetabled forms of learning due to its focus on personalized interaction, which is doubly valued by students in the online setting. Appreciation for tutors' enthusiasm and positivity was evident from students' reports. WSU students praised MESH workshops as one of the only places where they were permitted and encouraged to talk to each other. In general MSS has always been a highly appreciated student service but the limitations of online learning have brought this into sharper focus for the students.

7. Conclusion

In the COVID-19 era, much has been learned about what is possible in the realm of teaching, supporting and learning mathematics online. This study has shown that, despite the different circumstances of the two institutions, the impact of the pandemic-enforced move online on MSS tutors and students was largely similar. The themes of pedagogical changes, social interaction and student appreciation of MSS have all highlighted the shared desire among staff and students for connection and communication.

The one-on-one interaction that is a key feature of MSS was very much appreciated by students who came to realize the value of lost in-person peer-to-peer learning. Tutors struggled pedagogically due to the loss of non-verbal communication with students and the inability to see students' prior work or understand their questions due to technological issues. Moving forward, tutors' online pedagogical training and organization of peer-learning opportunities for students should be key priorities for MSS best practice. The benefits of on-campus interactions for tutors and students are clearly evident and cannot be overlooked in any institutional expansion of online MSS. This study has shown that in general these benefits were not replicated in the online setting enforced by the pandemic. Thus, as most higher education institutions intend to continue with some form of hybrid MSS post-pandemic (Hodds, 2020) further research is required to explore how this might be achieved.

Potential research questions stemming from this study include: is it possible to characterize optimal online MSS pedagogy?; if so, do MSS tutors have the necessary skills and access to relevant training to reach this level?; how can the peer-to-peer social interaction that is important to students and their learning, be addressed in online MSS? It will be important to monitor the aspects of MSS relating to pedagogy, social interaction and student appreciation as MSS develops post-pandemic.

In conclusion, this paper documents the experiences of MSS students and tutors during the early days after the rapid transition to online tutoring and learning. While the findings may not be surprising to MSS practitioners it is nonetheless important to highlight these issues to aid the future development of MSS.

Notes

1. Introduced in 2012, the Bonus Points initiative meant mathematics was afforded unique status as a subject for school leavers with an extra 25 points (from a maximum of 100) being awarded for a passing grade (at least 40%).
2. In this paper 'subject' refers to what is sometimes called 'unit' in Australia and 'module' in Ireland where both terms refer to a standard unit of an instructional section within a university programme, that is a 'self-contained' component of instruction.

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Appendix. Indicative interview questions

A.1 Student questions

(1) Could you tell me a little about your experience of online learning/teaching mathematics since last March?
   (a) What were the challenges?
   (b) What were the benefits?
   (c) What are the main differences for you between online and face-to-face learning/teaching?
(2) Is there anything about the subject of maths specifically that makes it more or less difficult to learn/teach online as compared to other subjects?
(3) Turning now to your experience of receiving/providing support online in your maths and stats study, how would you describe the experience?
   (a) How frequently have you used/provided support services?
   (b) What type of services have you used/provided?
   (c) Has the way you access/provide support changed since COVID-19?
   (d) If so, why?
   (e) Have you received support in any subjects other than maths or stats?
   (f) If so, how does the support you have received in maths and stats compare to the support you have received in these other subjects?
   (g) Do you usually access support individually or in a group?
   (h) Has the support made you feel more connected to your fellow students, teachers or the university more generally?
   (i) Where else have you gone for help (if not a dedicated learning support service)?
(4) Tell us about your interactions with support staff online:
   (a) Is it easy or difficult to communicate with them?
   (b) Do they make you feel comfortable and ready to learn?
   (c) Are they usually successful in helping you with your problems or questions?
(5) If you have received both online and face-to-face support in maths and stats, could you tell me about the differences between the two?
   (a) When you seek help from a teacher because you don't understand a maths concept or solution method, for example, is it easier or more difficult to discuss your issues with them online or face-to-face?
   (b) Do you interact with other students differently online vs face-to-face?
   (c) Are you more comfortable receiving support online vs face-to-face?
   (d) Are you more confident in seeking help online vs face-to-face?
(6) Has receiving support online changed your attitude to the subject in any way?
   (a) Has that change, if any, been positive or negative?
(7) If your future subject choices were flexible, would you wish to study more or less university maths in the future?
(8) Are there any elements of online support that you prefer and would not want to lose upon resumption of 'normal' arrangements (post COVID-19)?
(9) What about the opposite: are there any elements you do not prefer?

A.2 Tutor questions

(1) Could you tell me a little about your experience of online teaching mathematics since last March?
   (a) What were the challenges?
   (b) What were the benefits?
   (c) What are the main differences for you between online and face-to-face teaching?
(2) Is there anything about the subject of maths specifically that makes it more or less difficult to teach online as compared to other subjects?
(3) Turning now to your experience of providing maths and statistics support online, how would you describe the experience?
   (a) How frequently were or are you providing support services?
   (b) What type of services have you provided?
   (c) Has the way you provide support changed since COVID-19?
   (d) If so, why?
   (e) How would you describe your interactions with your fellow teachers online?
(4) Tell us about your interaction with support users (students) online:
   (a) Is it easy or difficult to communicate with them?
   (b) Are you usually successful in helping them with their problems or questions?
(5) If you have provided both online and face-to-face support in maths and stats, could you tell me about the differences between the two?
   (a) When you are speaking to a student, is it easier or more difficult to discuss their issues with them online or face-to-face?
   (b) Do you interact with other teachers differently online vs face-to-face?
   (c) Are you more comfortable giving support online vs face-to-face?
   (d) Are you more confident in giving help online vs face-to-face?
(6) Has giving support online changed your attitude to the subject in any way?
   (a) Has that change, if any, been positive or negative?
(7) Has this affected how you think about your future in teaching maths and stats?
(8) Are there any elements of online support that you prefer and would not want to lose upon resumption of 'normal' arrangements (post COVID-19)?
(9) What about the opposite: are there any elements you do not prefer?