MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2025, 21(3), em2603
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/16062

University mathematics lecturers' experiences of teaching and learning during COVID-19 pandemic: A comparative study between Kuwait and United Kingdom

Sali Hammad [1*], Ruth Wood [2], Gordon Hunter [3], Christos Dimitriadis [4]

[1] Independent Researcher, KUWAIT
[2] Faculty of Health, Science, Social Care and Education, Kingston University, London, UK
[3] School of Computer Science and Mathematics, Kingston University, London, UK
[4] School of Education, Midwifery and Social Work, Kingston University, London, UK

Received 17 January 2025 ▪ Accepted 19 February 2025

Abstract

Educators around the world were forced into a sudden change from face-to-face teaching to online teaching because of the COVID-19 crisis. This study aims to investigate how mathematics university lecturers in Kuwait (KW) and the United Kingdom (UK) experienced and responded to this unprecedented and sudden change. It explores the challenges and opportunities related to an online mode of working. Using the technological, pedagogical and content knowledge framework, this study analyses responses from a questionnaire (31 KW and 438 the UK respondents) which focused the time period encompassing Spring 2021 to Summer 2021, while the data collection period lasted from Spring 2021 to Spring 2022. Responses revealed the centrality and importance of content knowledge impacting their technological and pedagogical knowledge. Respondents seemed to report experiences which were common to both countries such as insufficient time to adjust to the sudden change, the challenges of adapting teaching strategies, lack of good computer skills, limited student interaction and motivation. Understandably, the rapid change meant that institutions may have focused on supporting staff in using the widely available institutional technologies instead of providing specific subject resources and support which seemed to exacerbate the challenges faced. Findings from the study show that lecturer's technological knowledge developed over the pandemic period but contextually and pedagogically, their values and beliefs were most influential resulting in the majority of respondents indicating that they were not likely to pursue an online mode of working post pandemic.

Keywords: COVID-19, mathematics education, technology education

INTRODUCTION

The COVID-19 pandemic forced educators around the globe to transition rapidly to an online mode of teaching and learning. This was an unprecedented event and unfamiliar territory for most educators, requiring radical changes in educational practices at all levels. University campuses around the world had to close and lecturers of different disciplines had to migrate to online modes of teaching delivery and assessment resulting in a sudden impact on lecturers, learners and institutions alike (Atmojo & Nugroho, 2020; Bao, 2020; Cassibba et al., 2020; Feder, 2020; Kaup et al., 2020; Ní Fhloinn & Fitzmaurice, 2021a, 2021b; Sandars et al., 2020; Trenholm & Peschke, 2020; Verma et al., 2020; Vlachopoulos, 2020; Watermeyer et al., 2020).

Digital interfaces and online learning methods yielded both challenges and new opportunities. Faced with an unfamiliar environment, lecturers revised their practice to adapt the new circumstances (Cassibba et al., 2020; Ní Fhloinn & Fitzmaurice, 2021a, 2021b; Watermeyer et al., 2020) developing their professional skills, knowledge and understanding to do so (Sukma & Priatna, 2021). Whereas some lecturers attempted to

✉ sali.hammad@outlook.com **(*Correspondence)** ✉ r.h.wood@kingston.ac.uk ✉ g.hunter@kingston.ac.uk
✉ c.dimitriadis@kingston.ac.uk

Contribution to the literature

- This study contributes to an understanding of the global impact of Covid-19 by examining the teaching experiences of mathematics lecturers from Kuwait and the United Kingdom during the sudden transition to the online environment.
- Despite a growing sense of confidence taking over time about using technology in teaching mathematics, university lecturers from both countries largely remained unconvinced of the effectiveness of online learning.
- The educational systems and university mathematics lecturers in both countries were influenced differently by the governmental level involvements with the type of technologies and pedagogical approaches employed.

reproduce existing modes of practice (Cassibba et al., 2020; Ní Fhloinn & Fitzmaurice, 2021b), others viewed the change in mode as 'a steep learning curve' (Ní Fhloinn & Fitzmaurice, 2021b, p. 407) or as part of their 'natural development' (Radmehr & Goodchild, 2021), recognizing this as a pedagogical rather than a personal challenge (Cassibba et al., 2020).

Alongside the shift from an in-person, face-to-face pedagogic mode of working, mathematics, lecturers also faced specific challenges associated with the demands of the subject discipline. For example, the difficulty of presenting mathematical notation through the medium of the screen is problematic (Glass & Sue, 2008; Hyland & O'Shea, 2021; Irfan et al., 2020; Ní Fhloinn & Fitzmaurice, 2021a), where neither lecturer nor student had access to the necessary technology or experience to resolve the issue (Ní Fhloinn & Fitzmaurice, 2022). This, alongside the many complexities associated with the sudden shift to experiencing the world through the medium of the screen created shifts in the landscape of mathematics pedagogy.

This study aims to find out how university lecturers of mathematics responded to this unprecedented event, focusing on the educators' pedagogic knowledge and practice during the pandemic and their use of technologies. This includes strategies and techniques in their approaches to teaching including their use of assessments; their content knowledge in mathematics and its implication with the use of technology, in relation to pedagogy and how this, from the lecturer's perspective, appeared to impact upon students' engagement, interaction, attainment, and performance.

A comparative study between two different countries; Kuwait (KW) and the United Kingdom (UK) has been undertaken from January 2021. Of 1300 invitations, 469 university lecturers of mathematics completed the online questionnaire.

LITERATURE REVIEW

Transitioning to online learning is therefore neither simple nor immediate requiring careful consideration of 'online learners, lecturers, and content development' (Kebritchi et al., 2017, p. 21) with, among other factors, the students' readiness for working online and the lecturers' ability to manage time and employ relevant teaching strategies and approaches. The latter highlights the need to facilitate a culture where communication, interaction and positive relationships provide a safe learning environment for students to engage with one another and with the lecturer to facilitate learning.

Technological and institutional support in implementing an online approach is critical (Masrom, 2008) with relevant and timely training of professional development programs (Børte et al., 2023), alongside maintenance of equipment and support in troubleshooting to avoid the ensuing frustration from students and lecturers (Ní Fhloinn & Fitzmaurice, 2021b). These are some of the elements integral to successfully facilitating online learning. Essentially, the process requires substantial commitment of resources from the institution including the time of lecturers to translate both subject content and pedagogy to the screen.

Studies focusing upon the challenges of teaching mathematics online at the university level during COVID-19 have reported that lecturers largely employed learning management systems (LMS) available via their institution (Hyland & O'Shea, 2021; Sukma & Priatna, 2021), or ones that were publicly available (Irfan et al., 2020) depending upon what they were able to access (Ní Fhloinn & Fitzmaurice, 2021b). Lecturers making their initial forays into a LMS tended to create an online version of existing resources such as paper-based course material or use applications which reproduced, to a certain extent, a physical whiteboard (Borba et al., 2016; Ní Fhloinn & Fitzmaurice, 2021b). Replicating what is familiar in an unfamiliar environment is, perhaps, a natural development in learning design for lecturers who have been largely immersed in a face-to-face mode of delivery. However, the medium of the online environment poses both challenges and opportunities for lecturers and students alike.

In the sudden shift from face-to-face to online teaching in 2020, research reported that students felt that the interactive nature of the lectures they had experienced in face-to-face sessions had been adversely

affected (Hyland & O'Shea, 2021; Meehan & Howard, 2020). Group work was notably absent (Ní Fhloinn & Fitzmaurice, 2021a), with 97.2% of respondents in the study by Cassiba et al. (2020) indicating that they had experienced an absence of interaction for learning or as part of social exchange. Tutorials and access to services offering students support were also reduced (Hyland & O'Shea, 2021) with an expectation by lecturers that the student would take more responsibility for their learning (Radmehr & Goodchild, 2021).

Simultaneously, lecturers are faced with managing and responding to a reduced sense of interaction with their students and the challenges of limited resources to facilitate the swift step change into a fully online mode of working (Irfan et al., 2020). Many studies highlighted the difficulties lecturers faced in initiating and engaging students in discussion (Hyland & O'Shea, 2021; Ní Fhloinn & Fitzmaurice, 2021a; Radmehr & Goodchild, 2021), resulting in students feeling a sense of 'increased isolation and lack of motivation' (Hyland & O'Shea, 2021, p. 472). Alongside the implications for student well-being, reduced interaction prevents the lecturer from assessing the effectiveness of their teaching (Cassibba et al., 2020). This may be through reduced or absence of discussion in addition to a limited opportunity to convey emotional, multisensory, multimodal experiences where language, body language and non-verbal communication provide real-time feedback mechanisms (Ní Fhloinn & Fitzmaurice, 2021a; Rabardel & Samurçay, 2001) necessary for both lecturer and student working with abstract disciplines such as mathematics (Trenholm & Peshcke, 2020). Consequently, students who struggled in isolation from their peers and without the benefit of more immediate feedback informed via interactions with peers and lecturer often did so invisibly (Ní Fhloinn & Fitzmaurice, 2021a). As a hierarchical discipline, students need to understand how one level of learning informs the next and the relative invisibility of the students to the lecturer and to their peers can allow misconceptions and lack of understanding to propagate (Ní Fhloinn & Fitzmaurice, 2021a).

Issues associated with the need for, or lack of, specialized technologies to facilitate mathematical notation in real-time created barriers to teaching and learning (Glass & Sue, 2008; Irfan et al., 2020; Juan et al., 2011; Ni Fhloinn & Fitzmaurice, 2021a, 2021b; Sukma & Priantna, 2021). These are unique problems generated where the inability to present complex algorithms and theoretical concepts are involved (Dawadi, 2023). Lecturers often signaled the difficulty they found in teaching without the ability to handwrite worked examples for the students (Ifran et al., 2020; Ní Fhloinn & Fitzmaurice, 2021a). Cassibba et al. (2020) suggested that this mode of teaching was particularly relevant to 'blackboard lecturers' (p. 18) who place emphasis on the content rather than on interpersonal communication.

Juan et al. (2011) have previously argued that current, emerging and future developments in technologies might address this issue (p. 145), however, more recent research conducted at the time of the pandemic seems to suggest that it is unresolved within institutions (Irfan et al., 2020; Ni Fhloinn & Fitzmaurice, 2021a) and there remain individuals who would choose pen and paper or a physical whiteboard over electronic means of entering calculations (Bringula et al., 2021). This would also have been exacerbated during the pandemic where, up until this point, in-person, face-to-face learning had been the norm with institutions investing in technologies and resources for the classroom rather than the home environment.

Despite some of the advantages presented earlier, research conducted prior to and since the pandemic suggests that online learning generates a plethora of challenges for lecturers and students alike. Although technologies such as LMSs and video conferencing were available pre-pandemic with fully online mathematics teaching, according to some researchers, increasing globally (Trenholm & Peschke, 2020), the prospect of working in this manner was largely unfamiliar territory for most educators and learners who were faced with a sudden shift to online modes of delivery (Cassiba et al., 2020).

Contemporary research regarding lecturers' experiences of transitioning to an online mode of teaching at the unprecedented time of the pandemic, is relatively limited. Notable contributions are those of Ni Fhloinn and Fitzmaurice (2021a, 2021b, 2022), who reported on the experiences of 257 university mathematics lecturers across 29 countries; Cassibba et al. (2020) whose research examined the impact upon 27 mathematics lecturers in Irfan et al. (2020) who undertook research in Sumatra, Indonesia to understand the way in which 26 lecturers responded to the challenges of online delivery of mathematics in higher education.

Recognizing that the experiences of mathematics lecturers is contextualized, it is important to capture and examine data from across the globe to better understand the way in which lecturers experienced the impact of emergency remote teaching. Alongside the existing studies outlined above, this research offers unique insight into this phenomenon during the early stages of the pandemic (Spring 2021 to Spring 2022) as it occurred in KW and the UK.

Technological, Pedagogical, and Content Knowledge

The practice of teaching not only involves a teacher's values regarding the purpose and processes of pedagogy, but also includes assessment, planning and management of the activities and the taught environment alongside strategies, skills and relevant techniques (Koehler & Mishra, 2009). It is widely

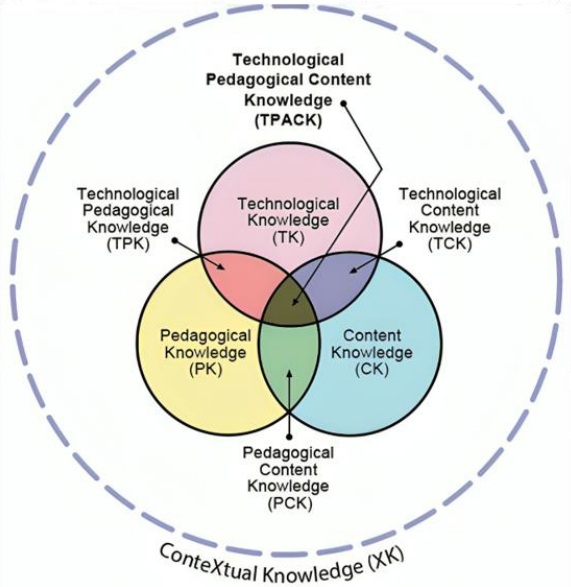

Figure 1. Revised version of the TPACK image (Mishra, 2019, p. 77)

recognized as complex requiring different forms of knowledge to be processed and applied according to the context (Koehler et al., 2013; Schon, 1991). This includes knowledge of the subject matter, in this instance mathematics, alongside pedagogic knowledge involving the way in which students learn, referred to as pedagogical and content knowledge (Shulman, 1986, 1987). The advent of microelectronics and digital technology brings further demands in terms of knowledge resulting in technological, pedagogical and content knowledge (TPACK) (Koehler & Mishra, 2009; Koehler et al., 2013). As argued by Koehler and Mishra (2009), technological knowledge (TK) is less stable than the other two as it is subject to rapid and dynamic development which defies definition beyond viewing it 'as evolving over a lifetime of generative, open-ended interaction with technology' (p. 64). More recently, the TPACK model of interconnected knowledge, often presented as three intersecting circles, has been subject to further development to include consideration of conteXtual knowledge (XK) (Mishra, 2019) depicted as a dotted circle surrounding the existing TPACK circles.

As a framework, TPACK provides a useful means of revealing and examining teachers' understandings of the way in which pedagogic, technological, contextual and mathematical (content) knowledges interact and intersect with one another to reveal the challenges and opportunities presented by the sudden shift to emergency remote teaching. Discussion and analysis of the data will allow the researchers to identify catalysts which might challenge existing practice, identify critical barriers to change and recognize the potential limitations of online modes of mathematics teaching in the context of higher education.

Figure 1 shows the revised version of the TPACK image (Mishra, 2019, p. 77).

Research Questions

1. How did mathematics university lecturers in the two countries change their pedagogical approaches during the COVID-19 crisis?
2. What, according to the university lecturers, were the challenges and opportunities arising from this sudden shift to an online mode of teaching?
3. What might be the implications for mathematics teaching in the higher education context?

SURVEY METHODOLOGY

A comparative case study methodology (Mangen, 2013) was adopted for this research. The study consists of quantitative and some open-questions of data collection, and analysis to examine how mathematics university lecturers responded to the challenges and opportunities of online teaching that emerged due to COVID-19. For example, what they changed, what methods and technological aids they used, how they perceived and evaluated the strategies and techniques they used for teaching, learning and assessment, how they were prepared for the new situation and what they felt they needed in terms of professional development and relevant resources. Through this comparative study, we wanted to identify shared and specific challenges that lecturers experienced across various institutions in the two countries and the practices or strategies they employed which they assessed as most effective in terms of online mathematics teaching.

Instruments and Methods Used in the Study

The quantitative component comprised the mathematics faculty/academic staff questionnaire of teaching strategies, techniques, and assessment experiences during the COVID-19 pandemic (given in the **Appendix A**).

The questionnaire was electronically designed using Google Forms. It aimed to collect the information described above from university teaching staff, who may be variously referred to as professors, lecturers, tutors, instructors and teachers within their relevant settings. Within this research, we use the term lecturer to refer to all of the aforementioned individuals. This would include those members of staff teaching both degree and foundation-level mathematics programs to specialist and non-specialist students in either the UK or KW.

The questionnaire consisted of 36 questions divided into five sections:

1. background,
2. technology instruments and assessments used before the pandemic period,
3. technology instruments and assessments used during the pandemic period,

Table 1. Mapping the questionnaire against the TPACK framework

Knowledge	Questions
Technological	8, 9, 10, 12, 13, 16, 19, 20, 21, 32, & 34
Pedagogical	8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, & 36
Content	10, 13, 32, & 34
Contextual	8, 9, 10, 12, 13, 16, 20, 21, 32, & 34

Table 2. Participants' profile

Participant status			Teaching experience			Age range			Mathematics course type taught		
AO	KW	UK	AO	KW	UK	AO	KW	UK	AO	KW	UK
Assistant, tutor, or lecturer	22.5%	31.05	< 5 years	3.0%	6.6%	34 or under	13.0%	10.5%	Foundation and undergraduate (pre-degree students)	54.8%	31.0%
Senior lecturer or assistant professor	42.0%	30.3%	5-10 years	35.0%	16.2%	35-39	29.0%	11.0%	Mathematics/statistics support sessions	66.5%	63.2%
Associate professor or principal lecturer	19.0%	22.8%	> 10 years	61.0%	77.6%	40-49	32.0%	48.2%	Specialist mathematics degree students	25.5%	75.8%
Professor	16.0%	16.2%				50-59	22.5%	27.2%	"Service" mathematics, e.g., for engineering, science, or business students	70.9%	43.2%
						60 or over	3.0%	3.7%			

Note. AO: Answer options

4. professional development during online teaching, and
5. online teaching experience.

The questions were adapted from previous surveys developed by Almanthari et al. (2020), Hosny et al. (2021), and Watermeyer et al. (2020) to study the impact of COVID-19 disruption in educational settings in different phases. There were 33 close-ended questions (17 multiple choice, 16 Likert-type) and three open-ended questions asking to expand on a choice or add overall comments. All questions were mapped against the TPACK framework to allow the data collected to be analyzed according to this model (see **Table 1**).

From January 2021, about 1,300 invitations with a link to the electronic questionnaire were emailed to all universities in KW and the UK, offering mathematics courses to specialist and non-specialist mathematics teaching lecturers. The emails were addressed to the heads of the departments (or unit leads) and individual lecturers at different universities in both countries. We encouraged snowball sampling through those who would complete the questionnaire. The invitation included the participant information sheet. Hence, the participants knew the research's purpose and were informed of what was expected of them.

Before the study commenced, ethical approval was obtained from the researchers' universities in KW and the UK. Recruitment, collection of quantitative data and ethical data storage in each country were managed locally by the researchers from the participating universities in the UK and KW. Only anonymized data were shared between the researchers from both countries for comparison, interpretation, report writing and dissemination.

Data Analysis

469 mathematics university lecturers completed the questionnaire, 438 lecturers from the UK, and 31 from KW. The closed questions were analyzed using descriptive and inferential statistics. Descriptive statistics helped us identify patterns in the data. Inferential statistics helped us compare data from the UK to KW using the non-parametric test. Non-parametric tests are suitable for small samples and ordinal data that are not normally distributed (Gibbons & Chakraborti, 2011). Internal consistency for Likert-type questions was checked using Cronbach's alpha test, which showed an acceptable reliability rate of 0.682.

DATA ANALYSIS AND DISCUSSION

Participants' Profile

The profile of 438 participants is presented in **Table 2**. When this study took place, more than half of the participants in both countries possessed ten years of teaching experience or above, with a higher percentage in the UK (77%) compared with KW (61%). More than a third of all participants had a senior post position (senior/principal lecturers, assistant or associate professors).

The post-rankings were similarly distributed among the participants in both countries. More than half of all participants were between the ages of 35 and 49, with more groups below the age of 40 in the UK (6.6%) compared with KW (3%). Most differences appeared in

Table 3. Technology and platform used before and during COVID-19 lockdown

Answer options	Before (%)		During (%)	
	KW	UK	KW	UK
PowerPoint (or similar presentation tools)	77.4	87.2	97.4	91.5
Moodle, Blackboard, or Canvas	87.0	82.2	90.3	67.0
VLE to post assignments, grades, and course resources such as (word, pdf, audio, video, internet links, etc.)	56.0	62.0	100	100
VLE to access forums, student polls, and online exercises and quizzes	26.4	35.6	100	96.0
External websites (with textbook) for "static" or systems like Maple, Mathematica, or STACK	16.0	43.3	67.2	93.0
External websites for online exercises and quizzes	16.1	20.3	100	100
Own web-based (or computer-based, course handbooks) materials	32.5	51.0	93.0	98.4
Pearson materials and tools, Khan Academy, GeoGebra, or Desmos	39.0	18.0	48.4	22.1

Table 4. The online teaching delivery system during COVID-19 in both countries (How are online sessions for teaching new material delivered during the pandemic?)

Answer options	KW (%)	UK (%)
Entirely through pre-recorded sessions, no "live" streamed sessions	0.0	5.7
A mixture of pre-recorded and "live" sessions, but mostly pre-recorded	0.0	6.4
A mixture of pre-recorded and "live" sessions, in roughly	0.0	45.2
A mixture of pre-recorded and "live" sessions, but mostly "live" online sessions	0.0	8.2
Entirely "live" streamed sessions, no pre-recorded sessions	100	34.4

the types of mathematics courses they were teaching. In the UK, the majority was for specialist mathematics degrees (76%, compared to 26% in KW), while in KW, the majority was for degrees were for "service" mathematics (e.g., for engineering, science or business students) (71%, compared to 43% in the UK).

Technology Instruments and Practices Used Before and During the Pandemic for Teaching and Assessment (Technological and Pedagogical Knowledge)

Participants were asked to select the digital tools (e.g., Zoom, Canvas, PowerPoint, etc.), digital commercial schemes (e.g., Pearson, GeoGebra, Kahoot, etc.) and practices (e.g., blended learning, purely online, pre-recorded sessions, a mixture of pre-recorded and live online sessions, etc.) they used before and during the pandemic from a given list. Their responses are presented in **Table 3** and **Table 4**.

Most participants in both countries were using presentation tools such as PowerPoint before and during the pandemic with small increases for both countries evident during the period of COVD-19. This appears to be similar to university lecturers in other

countries as indicated by Ní Fhloinn and Fitzmaurice (2022) and perhaps reflects the dominance of such technologies as part of pedagogic practice. The response to LMS (such as Moodle, Blackboard, or Canvas) also revealed that many of the participants made use of these before and during the pandemic although the UK participants registered a reduced level of use during the pandemic (82.2% to 67%) in contrast to the slight increase revealed in KW (87% to 90.3%). It was interesting especially that the nature of students' and lecturers' backgrounds in using technology instruments in the classroom was less developed before the lockdown (Engelbrecht et al., 2020), and the nature of PowerPoint slides while teaching mathematics was generally low because of the difficulty of explaining mathematics on slides (Loch & Donovan, 2006).

For both countries, the way the LMS (or VLE as presented in the questionnaire) was reportedly used changed substantially with, for example, both countries indicating 100% response for posting assignments, grades, and course resources and providing links to external websites for online exercises and quizzes. In the first instance, the increase for both approximately doubled (KW 56% to 100%; the UK 62% to 100%) and in the second it was recorded as five times that prior to the pandemic (KW 16.1% to 100%; the UK 20.3% to 100%).

In all other responses, there was a clear increase in the use of LMS features (e.g., forum, student polls, and online exercises and quizzes), alongside external websites (e.g., for "static" content or systems, such as Maple, Mathematica, or STACK) and the use of participants' own web-based materials (or computer-based, course handbooks). There is some variation in the percentage of participants registering the use of such technologies with those in the UK recording high percentages of use both before and during the pandemic (apart from the LMS) to access forums, student polls, and online exercises and quizzes. By comparison, KW registered a slightly higher percentage response (100%) during the pandemic than the UK (96%). Nevertheless, the increase in the use of technologies is evident in both countries although the reduced use of LMS during the pandemic in the UK seems to contradict the apparent increase in the features within an LMS.

For KW, the institutional LMS alongside presentation software such as PowerPoint and other presentation

tools maintained their popularity before and during the pandemic with evidence that participants made greater use of the tools and functions available within the LMS during than they did before the pandemic. The greatest increase was evident where external resources and websites were concerned indicating the need to find solutions beyond those already available. The increased use of their own web or computer-based sources also suggests that participants sought to resolve challenges to the sudden shift in teaching by creating their own solutions perhaps because the existing technologies were not fulfilling the needs of either the lecturer or the students. This is possible if the pedagogic approach of the lecturer does not resonate with the design of the technologies available.

Although there are variations in the percentage use (before and during) between KW and the UK, the latter generally followed a similar pattern to that of KW. One point of departure is where Pearson materials and tools, Khan Academy, GeoGebra, or Desmos were concerned with KW registering a higher percentage of use in comparison to the UK (KW 39% compared to 18% in the UK before) with both indicating a marginal rise during the pandemic (KW 48.4% and the UK 22.1%). Such programs are directly related to the content knowledge of mathematics and pedagogic approaches associated with such content. The previously mentioned programs also provide symbolic, graphical, and interactive content that can improve the modes of representation and thinking for the students (Bruner, 1966; Galligan et al., 2010) and can also improve students' mathematical achievement (Hammad et al., 2020). However, such programs rely upon the technological, pedagogic and content knowledge of the lecturers facilitating their use. With programs such as PowerPoint or any other presentation tool, it may be argued that there is more opportunity to create content whereas more specialized software are more restrictive. Essentially, the design of software contains assumptions regarding the way in which individuals work and if these assumptions do not connect with those of the individual it is less likely that they will be employed.

During the pandemic and at the time this research was undertaken, participants were asked to select the ways in which they chose to deliver online sessions for new teaching material (see **Table 3**). The responses revealed the proportion of live/pre-recorded content participants used. For KW, all participants selected entirely live with no pre-recorded content whereas the UK participants largely selected a mixture of live and pre-recorded (45.2%) followed closely by entirely live sessions (34.4%) with the remaining 20.3% divided amongst the other categories. In KW, it was a requirement by the ministry of higher education, to ensure consistency across educational sectors (schools, colleges, private and public universities) that sessions were delivered live and not pre-recorded. In contrast, most university lecturers in KW recorded lectures during class time in order to assure that students had a back-up lecture in case of missing non-attendance through, for example, illness. In the UK, the mode of delivery was largely guided by the HE institution with lecturers able to explore alternative and individual ways of working to support student learning. This would explain the variation found in the UK in comparison to that within KW. Most lecturers in both countries had to switch to sudden online teaching, increase the use of the basic technology tools (90% and sometimes 100% for the use of PowerPoint and a LMS, LMS to post assignments, grades, and course resources, online quizzes and assignments, and online computer programs and applications) and applications used before the pandemic, and open towards learning the use of new generation of technology software and applications. (Borba et al., 2016; Engelbrecht et al., 2020; Radmehr & Goodchild, 2021) indicated that increasing the use of the technology instruments during the pandemic to support mathematics teaching in the classroom assisted in improving communication and teaching mathematics to the students.

This was becoming a common use and direction that mathematics university lecturers took during the pandemic (Ní Fhloinn & Fitzmaurice, 2021b). The UK responses reflected slightly higher responses in using online textbooks, static, Maple, or Stack 93% (compared to KW 57%), while KW participants reflected more responses in using a variety of web applications such as Pearson, Khan Academy, GeoGebra, and Desmos (KW 48% compared to the UK 22%). Some university lecturers (11%) in the UK used pre-recorded teaching sessions exclusively, as shown in **Table 3** although such an approach, according to Le (2022), could negatively impact students' achievement, and thereby "deepen the academic inequality between students with higher and lower abilities" (p. 3). Le (2022) also recommended combining live, online, and prerecorded lectures in order to improve students' achievement.

Changes to Teaching and Challenges Encountered During Teaching Online Courses

The results presented in **Table 5** reveals 90.3% of respondents from KW created different kinds of assignments which was much higher compared to the UK (17.4%). The UK lecturers indicated that a higher percentage created instructional videos (87.9%) compared to KW (38.7%). KW mathematics lecturers employed a higher percentage of interactive activities (29%) and presentations (32.3%) in comparison to the UK (8.7% and 7.3%, respectively). This could reflect the emphasis on life, synchronous modes of teaching and learning experienced in KW as opposed to the variation of live/recorded approaches adopted in the UK where interactive activities were designed to be completed with

Table 5. Changes in teaching implemented during COVID-19 (Changes implemented during teaching courses online)

Answer options	KW	KW (%)	UK	UK (%)
Created different types of assignments	28	90.3	76	17.4
Created new instructional videos	12	38.7	385	87.9
Created new interactive activities	9	29.0	38	8.7
Used interactive class presentations	10	32.3	32	7.3
Gave more time to class discussions	19	61.2	253	57.8
Created a new course format	23	74.0	382	87.2
Changed the distribution of credit between assignments	10	32.2	324	74.0

Table 6. The greatest challenges mathematics faculty members had to go through during the pandemic

Greatest challenges	KW	KW (%)	UK	UK (%)
Not enough time to adjust to the sudden impact of the COVID-19 situation	19	61.3	309	70.5
Adapting to new teaching strategies	22	71.0	298	67.0
Teaching outside my comfort zone	23	74.2	387	88.4
Lack of good computer skills	13	41.9	278	63.5
Lack of educational technology skills	13	41.9	309	70.5
Recording sessions successfully	0	0.0	198	45.2
Writing mathematical equations and formulae in "live" online sessions	31	100	265	60.5
Low motivation of students	29	93.5	400	91.3
Low concentration and attention on the part of students	24	77.4	398	91.0
Low student willingness to interact	28	90.3	365	83.0
Technical problems/bad internet connection	15	48.4	328	75.0
Students cheating	23	74.0	305	70.0
Grade inflation	23	74.0	345	78.0

the students whereas recorded videos allow for independent, asynchronous modes of working.

Alongside these changes in pedagogical practice, lecturers seemed to face similar challenges to one another as they shifted from the familiar face-to-face, in person approach to the online setting (see **Table 6**). The most significant challenge common to both countries was student engagement, followed by student assessment. The former is noted in **Table 6** as low motivation (93.5% and 91.3% in KW and the UK, respectively) often described as the limited interaction between lecturer and student with students seemingly unwilling to respond to or ask questions (90.3% KW; 83% the UK). Low concentration and attention also registered a high return (77.4% KW; 91% the UK), alongside concerns surrounding student cheating (74% KW; 70% the UK) and grade inflation (74% KW; 78% the UK).

Translating pedagogy designed for an in-person, live event to the medium of the screen where lecturers and students were separated by space and sometimes time was problematic. Familiar ways of working did not comfortably adapt, and pedagogic knowledge was challenged. This is not to say that existing knowledge was inappropriate or unsound, rather, lecturers' values and beliefs regarding the practice of teaching and assessing mathematics were disturbed when the context of learning changed. The level of discomfort felt by the lecturers (72.4% KW; 88.4% the UK) is, perhaps, indicative of the additional demands placed upon them in navigating and managing such change with "adapting to new teaching strategies" (71% KW and 67% the UK).

It is interesting to note that the well-documented issues surrounding the difficulties of writing mathematical equations and formulae during live sessions was clearly registered by the teachers in KW (100%) but less so by those in the UK (60.5%). This is, perhaps, related to the dominance of live sessions in KW where the problems associated with writing and demonstrating mathematical calculations and formulae through the medium of technology are already well-documented (Irfan et al., 2020; Le, 2022).

Coupled with the suddenness of the change from in-person to online, lecturers felt ill-prepared having insufficient time (61.3% KW and 70.5% the UK), nor the necessary TK (lack of good computer skills, 41.9% KW and 63.5% the UK; lack of educational technology skills, 41.9% and 70.5%), to translate and adapt teaching materials and approaches into an online pedagogical mode of working (adapting to new teaching strategies, 71% KW and 67% the UK). In all instances, the responses of the UK lecturers indicate a higher sense of unease than those of lecturers in KW. This may be due to the wider range of approaches documented in **Table 4**, however, the changes in teaching (**Table 5**) suggest that lecturers from both the UK and KW explored a range of changes to their teaching, albeit to different extents as indicated by the percentage response.

The percentage of the UK participants experiencing technical and internet connection difficulties (75%) might, however, explain the lower percentage of entirely live online sessions reported by the UK lecturers than KW participants (see **Table 4**). Lecturers in KW were directed to deliver their sessions live and this may have

Table 7. Experiences of teaching online through the first three semesters

Answer options	My online Spring 2020 semester/term was			My Autumn 2020 online semester/term is/was			My Spring 2021 online semester/term is/was		
	UK (%)	KW (%)	p-value	UK (%)	KW (%)	p-value	UK (%)	KW (%)	p-value
Very bad	0.2	6.0	< 0.001	0.5	0.0	< 0.001	0.5	3.2	< 0.001
Bad	67.1	60.2		1.8	0.0		2.5	0.0	
Good	28.1	11.9		78.6	31.2		9.7	2.7	
Very good	2.6	21.9		15.6	68.8		83.8	71.5	
Excellent	2.1	0.0		1.1	0.0		2.3	3.2	
Not applicable	0.0	0.0		2.3	0.0		1.2	19.4	

Table 8. New teaching ideas explored during the online experience of teaching mathematics (New teaching ideas have explored during the online experience of teaching mathematics?)

Answer options	KW	KW (%)	UK	UK (%)
Implementing video-casts in the lectures/seminars	7	22.5	83	19.0
Using a particular application {software "application", or "mathematical application"}	26	84.0	363	83.0
Using Padlet for brainstorming	1	3.2	6	1.4

determined the nature of the challenges they experienced whereas, problematic connectivity for the UK lecturers generated the need to adapt accordingly through a mixture of online and pre-recorded content. Pedagogic knowledge associated with assessment was also challenged with concerns over academic integrity. For example, one UK lecturer indicated in an open question response that

> "we have had difficulties with exams, with students cheating both through collusion and through using websites that provide solutions. It is also difficult to set an exam of the correct difficulty without any bookwork questions"

and another stating that

> "there has been an explosion in plagiarism, especially via the website Chegg. This will make it necessary to completely re-model assessment systems in future. writing live math on tablets is really hard."

Such problems challenged existing practice, requiring lecturers to consider alternatives. This does not suggest that exams are inappropriate methods of assessment, rather that the move to online acted as a catalyst in challenging existing practice and the exploration of alternatives.

Mathematics Lecturers' Rating Their Teaching Experience During the Pandemic (Technological, Pedagogical, and Content Knowledge)

Mathematics lecturers were asked to rate their teaching from very bad to excellent in different semesters during the pandemic (see **Table 7**). Both KW and the UK assessed their early experience in the Spring of 2020 to be largely 'bad' (KW 60.2% and the UK 67.1%). However, by the Autumn of 2020, experiences were evaluated as largely 'very good' (KW 68.8%) or 'good' (the UK 78.6%) with Spring 2021 documenting both KW and the UK lecturers' experiences as being 'very good' (KW 71.5% and the UK 83.8%). Comments offered by respondents indicated that, over time, there was a sense of increasing familiarization and perhaps confidence in the use of technologies. For example, a UK-lecturer answering an open question

> "Spring 2020 was not an easy semester to teach but using more technology tools to communicate with the students, trying to motivate them towards learning, and learning their tricks on how to use technology, made online teaching at later semesters becoming easier" (the UK-lecturer).

It seems that the necessity to teach online, brought about by the pandemic, may have been the driving force required to explore and learn how to use a wider palette of technologies to overcome the challenges. Learning how to use technologies does require time and a sense of purpose. Should a lecturer have strong views regarding how a subject should be taught, it is likely that they will choose not to explore alternative approaches and associated resources. During the pandemic, there may not have been more time available but the need to find solutions during a period of remote emergency teaching acted as a clear driving force for changes in pedagogy and TK.

Most lecturers from both countries agreed that they explored new ideas (as indicated when answering an open question) by using particular software and mathematics applications such as Polling; breakout rooms in Zoom for group work; Wooclap for revising lessons; PowerPoint with mathematical symbols; Wacom pen; Bitesize videos to supplement online lectures; synchronous online teaching (even for large classes); visualizer; limited pre-recording; timed open book exams; good exchange in department and discipline about teaching methods; MATLAB Grader for frequent low stakes assessment; oral exams; using

Table 9. Development through using online means of teaching

Answer options	I have discovered new assessment methods which work well for distance learning or in pandemic and other crisis situations.			My online teaching experience has improved my computer skills.			I can access appropriate technologies to support my online learning, teaching and assessment.		
	UK (%)	KW (%)	p-value	UK (%)	KW (%)	p-value	UK (%)	KW (%)	p-value
Strongly disagree	24.1	3.1	< 0.001	0.5	3.1	< 0.001	0.2	3.1	0.004
Disagree	64.9	43.8		2.1	18.8		1.6	9.4	
Neutral	5.3	9.4		8.7	12.5		5.7	6.2	
Agree	4.1	40.6		86.2	59.4		89.0	71.9	
Strongly agree	1.6	3.1		2.5	6.2		3.4	9.4	

Table 10. Institutional support

Answer options	My institution has been supportive in facilitating the move to online learning, teaching and assessment.			The online training offered at my institution was vital towards moving to online learning.		
	UK (%)	KW (%)	p-value	UK (%)	KW (%)	p-value
Strongly disagree	0.2	0.0	< 0.001	1.4	0.0	< 0.001
Disagree	0.2	6.2		4.6	0.0	
Neutral	3.4	3.1		52.5	3.1	
Agree	90.8	62.5		39.0	81.2	
Strongly agree	5.3	28.1		2.5	5.6	

participation to enforce student interaction; and using Pearson to create multiple versions of tests (see **Table 8**). A KW lecturer stated that

> "it's very interesting to realize how much have we learnt after adopting online teaching. This enables using so many different software and applications to teach during COVID-19" (KW-lecturer).

Professional Development During Online Teaching (Contextual Knowledge)

Mathematics lecturers were asked to indicate on a five-point Likert-scale whether the changes in practice during the pandemic enabled them to

(a) discover new assessment methods,

(b) improve their computer skills, and

(c) learn to access appropriate technologies to support their online learning, teaching and assessment.

Their responses (see **Table 9**) show that for both countries lecturers agreed that their computer skills (KW 59.4% and the UK 86.2%) and access to relevant technologies (KW 89% and the UK 71.9%) had improved.

When they were asked whether they could access appropriate technologies to support their online learning, teaching, and assessment, most lecturers in both countries (92% in the UK compared to 89% in KW), agreed that they could access the appropriate technologies to support their online learning, teaching and assessment. Overall, 89% of the UK lecturers disagreed with the statement that they had new methods of assessment for distance learning (24.1% strongly disagreed) whereas lecturers in KW were almost evenly split between agreeing (43.7% with 3.1% strongly agreeing) and disagreeing (46.9% with 3.1% strongly disagreeing). This suggests that the experiences of lecturers in the UK were less positive. A UK-lecturer explained that

> "through online teaching, I have not learnt new assessment teaching methods especially related to teaching mathematics,"

whereas lecturers in KW may have had more positive but nonetheless varied experiences. A KW lecturer indicated that

> "through a personal search, I had to investigate for more recent technological tools and software such as 'Polling', Wooclap for revising lessons, and Bitesize videos to supplement online lectures that allowed me to have a little more flexibility into online teaching."

Previously, the concerns of the lecturers surrounding academic misconduct was raised (**Table 6**) and the degree to which this was resolved in terms of the methods of assessment employed may have determined the degree to which lecturers agreed or disagreed with this statement.

Institutional support (see **Table 10**) was viewed positively in both countries with responses in KW being more positive in comparison to those of the UK lecturers. This was also reflected in responses rating the online training available where lecturers in KW were largely positive, the majority of those within the UK remained neutral with 39% registering agreement. The explanations offered by respondents recognized the range of opportunities available, for example,

Table 11. Will lecturers continue to use digital tools when back to face-to-face teaching? (Will lecturers continue to use digital tools when back to face-to-face teaching?)

Answer options	KW	KW (%)	UK	UK (%)
Yes, regularly	8	25.8	112	25.60
Yes, sometimes	18	58.0	259	67.40
Occasionally	4	12.9	26	5.90
Very rarely	1	3.2	2	0.46
Never	0	0.0.	1	0.23
My teaching is not normally face to face	0	00	2	0.46

> "we received a variety of training sessions by the IT department during the pandemic. This includes sessions on how to use Moodle, MS Teams, to communicate with the students during live sessions or on Chat rooms, and to record sessions and post them on Moodle but not specialized programs relating to teaching mathematics or sciences" (KW-lecturers).

This experience seems to be similar to that of the UK lecturers who stated that

> "we (at the math department) needed some more training on how to use certain mathematics applications, how to insert some mathematical terms and models while teaching online (more subject specific trainings)" (the UK-lecturer).

This highlights the importance of addressing content knowledge in concert with TK associated with mathematics; although general training may have been the priority to address the immediate challenges brought about by the rapid move towards online delivery, the content matter is integral to the successful teaching of the subject. The former is undoubtedly important and the logistics of managing institutional change would understandably take precedence, however, at the subject level, such training would not necessarily facilitate or support staff in transitioning successfully from existing ways of working requiring, perhaps, specialist support including access to relevant technology.

Future Recommendations for Online Teaching in Mathematics (Contextual Knowledge)

Considering the future after the Pandemic, most mathematics university lecturers in both countries agree that they will continue to regularly use digital tools when returning to face-to-face teaching (25.8% in KW compared to 25.6% in the UK) (**Table 11**). The more cautious respondents signaled that they would sometimes use digital tools (58% KW and 67.4% the UK). Universities seem to be putting plans in place to capitalize on the knowledge developed during COVID-19, anticipating continued use of the technologies which might serve to enhance and support pedagogic practice. For example, commentary from respondents which expanded upon their responses to the question as to whether they would continue to use technologies when returning to a face-to-face mode of delivery indicated that

> "university upper administrations at several universities in KW have requested to video-record all live face-to-face sessions and post them on Moodle (LMS). They explain that they aim to offer the students another version of the lessons taught available at home for their reviews" (KW-lecturer).

Similarly, a UK- lecturer explained that

> "recording of classes is strongly encouraged after going back to face-to-face teaching, but not compulsory. I tend to record my classes whenever possible. This is useful for students who have been absent *(e.g.)* for illness, and for students who did not attend classes in order to review them again" (the UK-lecturer).

According to the responses of the lecturers in this study, the future of online teaching in mathematics is not certain by any means. However, it will, as Blankenberger and Williams (2020), argue, be important for university management to support their faculty members with the necessary TK in case it is needed in the future for any crisis such as the recent pandemic or for providing distance learning courses in mathematics regardless of emergency situations.

Perhaps, in the immediate future, there may be a move towards blended learning where technological and pedagogical knowledge gained during recent events might infuse practice to varying degrees (Howard et al., 2018; Trenholm et al., 2012) with, as suggested by Howard et al. (2018) and Trenholm et al. (2012) recordings of lectures made available to students via the LMS in case they wish to review the taught materials outside the face-to-face, real time classroom setting. However, the responses regarding the effectiveness of online teaching of mathematics is less encouraging. Overall, respondents disagreed with positive statements regarding ease of use, and the quality of teaching (see **Table 12**). Lecturers from both KW and the UK agreed that an online mode of working was not superior or equal to face-to-face, real-time experiences. This seems to agree with research undertaken prior to or during the pandemic (for example; Boz & Adnan, 2017;

Table 12. Effectiveness of online mode for teaching and learning mathematics

Answer options	Teaching mathematics through online teaching is as good and as easy as face-to-face courses.			Students can learn mathematics using an online teaching system just as much and as easily as in traditional face-to-face courses.			High-quality online teaching and learning can be achieved in my online mathematics classes.		
	UK (%)	KW (%)	p-value	UK (%)	KW (%)	p-value	UK (%)	KW (%)	p-value
Strongly disagree	85.6	9.4	< 0.001	84.9	12.5	< 0.001	44.6	3.1	< 0.001
Disagree	8.9	84.4		7.6	81.2		38.9	50.0	
Neutral	3.2	6.2		3.4	0.0		5.3	18.8	
Agree	1.8	0.0		3.4	6.2		9.4	28.1	
Strongly agree	0.5	0.0		0.7	0.0		1.8	0.0	

Greiffenhagen, 2014; Kurt, 2019; Lin et al., 2016; Ní Fhloinn & Fitzmaurice, 2021a; Quinn et al., 2015; Yoon et al., 2014). Lastly, Radmehr and Goodchild (2022) and Li et al. (2022) explain that online teaching and learning in mathematics is still developing, which has led to challenges when working in this environment. The experiences brought about during the pandemic may have contributed a great deal to a technological and pedagogical knowledge surrounding online approaches to teaching mathematics in higher education, however, the dominant mode of working is currently in person and in real time.

Limitations of the Study

KW and the UK academic systems follow different academic schedules. Lecturers at both countries were going at different stages of their academic year when the survey was distributed, which made it more difficult to complete collecting the data as initially planned (Spring 2021 to Summer 2021). Also, lecturers' different experiences during the pandemic and their motivation could have impacted on their willingness to participate in the study and complete the questionnaire in the period as originally planned.

CONCLUSION

This article contributes to determining how mathematics university lecturers from KW and the UK responded and experienced the challenges associated with the rapid transition to online modes of delivery during the COVID-19 crisis. Using the TPACK framework, the interconnectedness between the various forms of knowledge were apparent. The participants' mathematical content knowledge appeared to be central, influencing both technological and pedagogical forms of knowledge. Contextually and pedagogically, individual values and beliefs surrounding how mathematics should be taught, seemed to emphasize the importance of in-person, face-to-face, teaching. At governmental level, lecturers in KW were directed to deliver taught sessions in a 'live' rather than pre-recorded format. Such directives seem to have influenced the type of technologies and pedagogical approaches employed.

Despite a growing sense of confidence in TK over time, lecturers from both countries largely remained unconvinced of the effectiveness of online learning. For the lecturers in the UK, the reliability of connectivity and associated technology was problematic, adversely affecting experiences from the onset. Arguably, this may also have given rise to innovation where lecturers sought solutions for problems resulting in varied pedagogical approaches and exploration of alternative technologies.

Lecturers from both countries seemed to face similar challenges to one another as they shifted from the familiar face-to-face approach to that of online teaching where they experienced reduced opportunity to interact with their students and faced challenges in resolving issues associated with assessment. Understandably, the necessity to respond rapidly meant that institutions may have focused upon supporting staff in using the widely available institutional technologies rather than discipline-specific, specialized resources. This may also have contributed towards the drive to find solutions from elsewhere, thereby acting as a catalyst for the development of technological and pedagogical knowledge.

Ultimately, technologies that resonated with lecturers' values and beliefs surrounding how best to teach mathematics were more likely to be adopted. Lecturers' TK may have been enhanced and developed during the period of emergency remote teaching resulting but once the need to deliver online is removed, lecturers seem likely to return to pre-pandemic mathematical pedagogy.

Author contributions: SH: design of the study, data collection and analysis, drafting of the manuscript, cleaning, storing, and organizing data, data curation, investigation, revising and reviewing drafts; **RW:** review of literature, revising and reviewing drafts; **GH:** data collection and curation, resources; **CD:** revising and reviewing drafts, project administration. All authors have agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Ethical statement: The authors stated that the study was approved by the University Research Ethics Committee at Gulf University for Science and Technology on 26 November 2020 and by the Kingston University Research Ethics Committee on 15 March 2021. Written informed consents were obtained from the participants.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

REFERENCES

Almanthari, A., Maulina, S., & Bruce, S. (2020). Secondary school mathematics lecturers' views on e-learning implementation barriers during the COVID-19 pandemic: The case of Indonesia. *Eurasia Journal of Mathematics, Science and Technology Education, 16*(7), Article em1860. https://doi.org/10.29333/ejmste/8240

Atmojo, A. E. P., & Nugroho, A. (2020). EFL classes must go online! Teaching activities and challenges during COVID-19 pandemic in Indonesia. *Register Journal, 13*(1), 49-76. https://doi.org/10.18326/rgt.v13i1.49-76

Bao, W. (2020) COVID-19 and online teaching in higher education: A case study of Peking University. *Human Behavior and Emerging Technologies, 2*, 113-115. https://doi.org/10.1002/hbe2.191

Blankenberger, B. & Williams, A. M. (2020) COVID-19 and the impact on higher education: The essential role of integrity and accountability. *Administrative Theory & Praxis, 42*, 404-423. https://doi.org/10.1080/10841806.2020.1771907

Borba, M. C., Askar, P., Engelbrecht, J., Gadanidis, G., Llinares, S., & Aguilar, M. S. (2016). Blended learning, e-learning and mobile learning in mathematics education. *ZDM Mathematics Education, 48*, 589-610. https://doi.org/10.1007/s11858-016-0798-4

Børte, K., Nesje, K., & Lillejord, S. (2023). Barriers to student active learning in higher education. *Teaching in Higher Education, 28*(3), 597-615. https://doi.org/10.1080/13562517.2020.1839746

Boz, B., & Adnan, M. (2017). How do freshman engineering students reflect an online calculus course? *International Journal of Education in Mathematics, Science and Technology, 5*(4), 262-278.

Bringula, R., Reguyal, J. J., Tan, D. D., & Ulfa, S. (2021). Mathematics self-concept and challenges of learners in an online learning environment during COVID-19 pandemic. *Smart Learning Environments, 8*(1), Article 22. https://doi.org/10.1186/s40561-021-00168-5

Bruner, J.B. (1966). *Toward a theory of instruction*. Harvard University Press

Cassibba, R., Ferrarello, D., Mammana, M. F., Musso, P., Pennisi, M., & Taranto, E. (2020). Teaching mathematics at distance: A challenge for universities. *Education Sciences, 11*(1), Article 1. https://doi.org/10.3390/educsci11010001

Dawadi, S. D. (2023). Teaching mathematics through online at the university level: An ethnographic inquiry. *The Educator Journal, 11*(1), 98-113. https://doi.org/10.3126/tej.v11i1.54458

Engelbrecht, J., Borba, M. C., Llinares, S., & Kaiser, G. (2020). Will 2020 be remembered as the year in which education was changed? *ZDM Mathematics Education, 52*, 821-824. https://doi.org/10.1007/s11858-020-01185-3

Feder, T. (2020). Universities overcome bumps in transition to online teaching. *Physics Today, 73*(6), 22-24. https://doi.org/10.1063/PT.3.4492

Galligan, L. A. (2011). *Developing a model of embedding academic numeracy in university programs: A case study from nursing* [Doctoral dissertation, Queensland University of Technology].

Gibbons, J. D., & Chakraborti, S. (2011). *Nonparametric statistical inference* (5th ed.). CRC Press. https://doi.org/10.1201/9781439896129

Glass, J., & Sue, V. (2008). Student preferences, satisfaction, and perceived learning in an online mathematics class. *MERLOT Journal of Online Learning and Teaching, 4*(3), 325-338.

Greiffenhagen, C. (2014). The materiality of mathematics: Presenting mathematics at the blackboard. *The British journal of sociology, 65*(3), 502-528. https://doi.org/10.1111/1468-4446.12037

Hammad, S., Graham, T., Dimitriadis, C., & Taylor, A. (2020). Effects of a successful mathematics classroom framework on students' mathematics self-efficacy, motivation, and achievement: A case study with freshmen students at a university foundation programme in Kuwait. *International Journal of Mathematical Education in Science and Technology, 53*(6), 1502-1527. https://doi.org/10.1080/0020739X.2020.1831091

Hosny, M., Zanchi, C., & Louiz, D. (2021). La continuité pédagogique au Koweït et au Maroc: Etat des lieux et mesures prises [Educational continuity in Kuwait and Morocco: Status report and measures taken]. *Recherches et Pratiques, 2*(1). https://doi.org/10.57086/dfles.221

Howard, E., Meehan, M., & Parnell, A. (2018). Live lectures or online videos: Students' resource choices in a first-year university mathematics module. *International Journal of Mathematical Education in Science and Technology, 49*(4), 530-553. https://doi.org/10.1080/0020739X.2017.1387943

Hyland, D., & O'Shea, A. (2021). The student perspective on teaching and assessment during initial COVID-19 related closures at Irish universities: Implications for the future. *Teaching Mathematics and its Applications: An International Journal of the IMA, 40*(4), 455-477. https://doi.org/10.1093/teamat/hrab017

Irfan, M., Kusumaningrum, B., Yulia, Y., & Widodo, S. A. (2020). Challenges during the pandemic: Use of

e-learning in mathematics learning in higher education. *Infinity Journal, 9*(2), 147-158. https://doi.org/10.22460/infinity.v9i2.p147-158

Juan, A. A., Steegmann, C., Huertas, A., Jesus Martinez, M., & Simosa, J. (2011). Teaching mathematics online in the European area of higher education: A lecturer's point of view. *International Journal of Mathematical Education in Science and Technology, 42*(2), 141-153. https://doi.org/10.1080/0020739X.2010.526254

Kaup, S., Jain, R., Shivalli, S., Pandey, S., & Kaup, S. (2020). Sustaining academics during COVID-19 pandemic: The role of online teaching-learning. *Indian Journal of Ophthalmology, 68*(6), Article 1220. https://doi.org/10.4103/ijo.IJO_1241_20

Kebritchi, M., Lipschuetz, A., & Santiague, L. (2017). Issues and challenges for teaching successful online courses in higher education: A literature review. *Journal of Educational Technology Systems, 46*(1), 4-29. https://doi.org/10.1177/0047239516661713

Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content knowledge (TPACK)? *Journal of Education, 193*(3), 13-19. https://doi.org/10.1177/002205741319300303

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education, 9*(1), 60-70.

Kurt, S. (2019). Moving toward a universally accessible web: Web accessibility and education. *Assistive Technology, 31*(4), 199-208. https://doi.org/10.1080/10400435.2017.1414086

Le, K. (2022). Pre-recorded lectures, live online lectures, and student academic achievement. *Sustainability, 14*(5), Article 2910. https://doi.org/10.3390/su14052910

Li, L., Tong, Y., Wei, L., & Yang, S. (2022). Digital technology-enabled dynamic capabilities and their impacts on firm performance: Evidence from the COVID-19 pandemic. *Information & Management, 59*(8), Article 103689. https://doi.org/10.1016/j.im.2022.103689

Lin, Y. W., Tseng, C. L., & Chiang, P. J. (2016). The effect of blended learning in mathematics course. *Eurasia Journal of Mathematics, Science and Technology Education, 13*(3), 741-770. https://doi.org/10.12973/eurasia.2017.00641a

Loch, B., & Donovan, D. (2006). Progressive teaching of mathematics with tablet technology. *Australasian Journal of Educational Technology, 9*(2), 1-6.

Mangen, S. (2013). Cross-national qualitative research methods: Innovations in the new millennium. In P. Kennett (Ed.), *A handbook of comparative social policy* (pp. 243-263). Edward Elgar Publishing. https://doi.org/10.4337/9781782546535.00023

Masrom, M. (2008). Critical success in e-learning: An examination of technological and institutional support factors. *International Journal of Cyber Society and Education, 1*(2), 131-142.

Meehan, M., & Howard, E. (2020). *Report on undergraduate mathematics students' perceptions of the affordances and constraints of the online environment for learning*. https://www.ucd.ie/msc/t4media/msc_students_perceptions_online_learning.pdf

Mishra, P. (2019). Considering contextual knowledge: The TPACK diagram gets an upgrade. *Journal of Digital Learning in Teacher Education, 35*(2), 76-78. https://doi.org/10.1080/21532974.2019.1588611

Ní Fhloinn, E., & Fitzmaurice, O. (2021a). Challenges and opportunities: Experiences of mathematics lecturers engaged in emergency remote teaching during the COVID-19 pandemic. *Mathematics, 9*(18), Article 2303. https://doi.org/10.3390/math9182303

Ní Fhloinn, E., & Fitzmaurice, O. (2021b). How and why? Technology and practices used by university mathematics lecturers for emergency remote teaching during the COVID-19 pandemic. *Teaching Mathematics and its Applications: An International Journal of the IMA, 40*(4), 392-416. https://doi.org/10.1093/teamat/hrab018

Ní Fhloinn, E., & Fitzmaurice, O. (2022). Mathematics lecturers' views on the student experience of emergency remote teaching due to COVID-19 *Education Sciences, 12*(11), Article 787. https://doi.org/10.3390/educsci12110787

Quinn, D., Albrecht, A., Webby, B., & White, K. (2015). Learning from experience: The realities of developing mathematics courses for an online engineering programme. *International Journal of Mathematical Education in Science and Technology, 46*(7), 991-1003. https://doi.org/10.1080/0020739X.2015.1076895

Rabardel, P., & Samurcay, R. (2001). From artifact to instrumented-mediated learning. In *Proceedings of the New Challenges to Research on Learning International Symposium*. Center for Activity Theory and Developmental Work Research.

Radmehr, F., & Goodchild, S. (2021). Online mathematics teaching and learning during the COVID-19 pandemic: The perspective of lecturers and students. *Nordic Journal of STEM Education, 5*(1). https://doi.org/10.5324/njsteme.v5i1.3914

Sandars, J., Correia, R., Dankbaar, M., de Jong, P., Goh, P. S., Hege, I., & Pusic, M. (2020). Twelve tips for rapidly migrating to online learning during the COVID-19 pandemic. *MedEdPublish*. https://doi.org/10.15694/mep.2020.000082.1

Schon, D. A. (1991). *The reflective practitioner*. Ashgate Publishing.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14. https://doi.org/10.3102/0013189X015002004

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-23. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Sukma, Y., & Priatna, N. (2021). The effectiveness of blended learning on students' critical thinking skills in mathematics education: A literature review. *Journal of Physics: Conference Series, 1806*, Article 012071. https://doi.org/10.1088/1742-6596/1806/1/012071

Trenholm, S., & Peschke, J. (2020). Teaching undergraduate mathematics fully online: A review from the perspective of communities of practice. *International Journal of Educational Technology in Higher Education, 17*(1), Article 37. https://doi.org/10.1186/s41239-020-00215-0

Trenholm, S., Alcock, L., & Robinson, C. L. (2012). Mathematics lecturing in the digital age. *International Journal of Mathematical Education in Science and Technology, 43*(6), 703-716. https://doi.org/10.1080/0020739X.2011.646325

Verma, A., Verma, S., Garg, P., & Godara, R. (2020). Online teaching during COVID-19: Perception of medical undergraduate students. *Indian Journal of Surgery, 82*(3), 299-300. https://doi.org/10.1007/s12262-020-02487-2

Vlachopoulos, D. (2020). COVID-19: Threat or opportunity for online education? *Higher Learning Research Communications, 10*(1), Article 2. https://doi.org/10.18870/hlrc.v10i1.1179

Watermeyer, R., Crick, T., Knight, C., & Goodall, J. (2020). COVID-19 and digital disruption in UK universities: Afflictions and affordances of emergency online migration. *Higher Education, 81*, 623-641. https://doi.org/10.1007/s10734-020-00561-y

Yoon, J., & Lee, J. (2014). Community project: Integrating math and science by using technology. In *Proceedings of the Society for Information Technology & Teacher Education International Conference* (pp. 3002-3010). Association for the Advancement of Computing in Education.

APPENDIX A: MATHEMATICS FACULTY/ACADEMIC STAFF QUESTIONNAIRE REGARDING TEACHING EXPERIENCES, STRATEGIES, TECHNIQUES, AND ASSESSMENT DURING THE COVID-19 PANDEMIC

Please respond to each statement using the scale provided in each question.

General Information

1. I am a mathematics university teacher at a university in
   a. Kuwait
   b. United Kingdom
2. For UK based participants only
   a. I work at a "pre-1992" university
   b. I work at a "post-1992" university
   c. I work at both "pre-1992" and "post-1992" universities
   d. I am unsure at which of those types of university I work
3. Identify your teaching position at your school or department of mathematics
   a. Assistant/tutor/instructor
   b. Lecturer
   c. Senior lecturer/assistant professor
   d. Associate professor/reader/principal lecturer
   e. Professor
4. How much teaching experience do you have?
   a. Less than 5 years
   b. Between 5 and 10 years
   c. More than 10 years
5. Which age range do you come under?
   a. Under 25
   b. 25-29
   c. 30-34
   d. 35-39
   e. 40-44
   f. 45-49
   g. 50-54
   h. 55-59
   i. 60 or over
6. What type of students (or type of groups) do you teach? (select all which apply)
   a. Foundation and undergraduate (pre-degree students)
   b. Mathematics/statistics support sessions
   c. Specialist mathematics degree students
   d. "Service" mathematics, e.g., for engineering, science, or business students
7. Which academic years have you used online teaching & learning (select all which apply)
   a. Before 2019-2020
   b. 2019-2020
   c. 2020-2021
   d. Other (please specify): _____.

Technology Instruments and Assessments Used Before the Pandemic Period

8. What online communication tools and supporting software which could be used for mathematics teaching were you aware of and/or used to support your teaching before the current circumstances with COVID-19? (please select all that apply)
   a. Zoom
   b. BBB (Big Blue Button)
   c. Microsoft Teams
   d. Google Class
   e. Skype
   f. Moodle
   g. Blackboard
   h. Canvas
   i. Other (please specify): _____.
9. How would you rate your own level of computer (IT) proficiency
   a. Very basic
   b. Somewhat limited
   c. Fair
   d. Good
   e. Excellent
10. Which technological tools did you use to teach or support your mathematics classes before the current circumstances with COVID-19? VLE means "virtual learning environment", such as Moodle, Blackboard, or Canvas (please select all that apply)
    a. PowerPoint (or similar presentation tools)
    b. Moodle
    c. Blackboard
    d. Canvas
    e. VLE to make assignments available to students
    f. VLE to post students' grades
    g. VLE to upload course resources such as (Word, PDF, audio, video, internet links, etc.)
    h. VLE to access forum
    i. VLE to do student polls
    j. VLE for student online exercises and quizzes
    k. External websites (e.g., with textbook) for "static" instructional resources
    l. External websites for online exercises and quizzes
    m. Computer algebra (or similar) systems, such as Maple, Mathematica, or STACK
    n. Your own web-based (or computer-based) materials
    o. Your own purely text-based materials (e.g., course handbooks)
    p. Pearson materials and tools
    q. Khan Academy
    r. GeoGebra
    s. Desmos
    t. Kahoot
    u. Other (please specify): _____.

Technology Instruments and Assessments Used During the Pandemic Period

11. What approach was your institution using for teaching in Autumn/Fall 2020
    a. Purely online teaching

b. "Blended learning"–a mixture of online and face to face, but mostly online
c. "Blended learning"–a mixture of online and face to face, in roughly equal amounts
d. "Blended learning"–a mixture of online and face to face, but mostly face to face
e. Entirely face to face classes

12. How are online sessions **for teaching new material** delivered at your institution?
    a. Entirely through pre-recorded sessions, no "live" streamed sessions
    b. A mixture of pre-recorded and "live" sessions, but mostly pre-recorded
    c. A mixture of pre-recorded and "live" sessions, in roughly equal amounts
    d. A mixture of pre-recorded and "live" sessions, but mostly "live" online sessions
    e. Entirely "live" streamed sessions, no pre-recorded sessions
13. Which instruments and tools are you using to teach and assess mathematics during the COVID-19 pandemic? (please select all that apply)
    a. PowerPoint (or similar presentation tools)
    b. Moodle
    c. Blackboard
    d. Canvas
    e. VLE to make assignments available to students
    f. VLE to post students' grades
    g. VLE to upload course resources (in formats such as Word, PDF, audio files, videos, internet links, etc.)
    h. VLE to provide access to student forums
    i. VLE to carry out student polls
    j. VLE for student online exercises and quizzes
    k. External websites (e.g., with a textbook) for "static" instructional resources
    l. External websites for online exercises and quizzes
    m. Computer algebra (or similar) systems, such as Maple, Mathematica, or STACK
    n. Your own web-based (or computer-based) materials
    o. Your own purely text-based materials (e.g., course handbooks)
    p. Pearson materials and tools
    q. Khan Academy
    r. GeoGebra
    s. Desmos
    t. Kahoot
    u. Educational games
    v. Breakout rooms for assessment
    w. Collaborative group projects
    x. Breakout rooms for class activities
    y. Auto-corrected exercises and quizzes
    z. Other (please specify): _____.
14. What changes did you implement during teaching courses online? (please select all that apply)

Statement	Yes	To some extent	No
Created different types of assignments			
Created new instructional videos			
Created new interactive activities			
Used interactive class presentations			
Gave more time to class discussions			
Created a new course format			
Changed the distribution of credit between assignments			
Created different types of assignments			

15. What were the greatest challenges you faced when teaching online in Spring 2020? (Please select all that apply)
    a. Not enough time to adjust to the sudden impact of the COVID-19 situation
    b. Adapting to new teaching strategies
    c. Teaching outside my comfort zone
    d. Lack of good computer skills
    e. Lack of educational technology skills
    f. Recording sessions successfully
    g. Writing mathematical equations and formulae in "live" online sessions
    h. Low motivation of students
    i. Low concentration and attention on part of students
    j. Low student willingness to interact
    k. Technical problems/bad internet connection
    l. Students cheating
    m. Grade inflation
    n. Other (please specify): _____.
16. What new teaching ideas have you explored during your online experience of teaching mathematics? (Please select all that apply)
    a. Implementing video-casts in the lectures/seminars
    b. Using a particular application {software "application", or "mathematical application"}
    c. Using *Padlet* for brainstorming
    d. Other (please specify): _____.
17. Have you faced the same difficulties during the current academic year (2020-2021) as in 2019-2020?
    a. Yes, definitely
    b. To some extent
    c. No
    d. Not applicable
18. Do you agree or disagree with the following statement: "I have discovered new assessment methods which work well for distance learning or in pandemic and other crisis situations."
    a. I strongly agree
    b. I agree
    c. I am neutral
    d. I disagree
    e. I strongly disagree

Professional Development During Online Teaching

19. "My online teaching experience has improved my computer skills."
    a. I strongly agree
    b. I agree
    c. I am neutral to this statement
    d. I disagree
    e. I strongly disagree
20. "I can access appropriate technologies to support my online learning, teaching and assessment."
    a. I strongly agree
    b. I agree
    c. I am neutral
    d. I disagree
    e. I strongly disagree

21. "I still need more training for teaching online."
    a. I strongly agree
    b. I agree
    c. I am neutral
    d. I disagree
    e. I strongly disagree
22. Will you continue to use digital tools when you are back to mainly face to face teaching?
    a. Yes, regularly
    b. Yes, sometimes
    c. Occasionally
    d. Very rarely
    e. Never
    f. My teaching is not normally face to face
23. If "yes", which digital features or tools would you like to keep using once you are back to mainly face to face teaching? Type your answer(s) in the space below: _____.
24. "My institution has been supportive in facilitating the move to online learning, teaching and assessment."
    a. I strongly agree
    b. I agree
    c. I am neutral
    d. I disagree
    e. I strongly disagree
25. "The online training offered at my institution was vital towards moving to online learning."
    a. I strongly agree
    b. I agree
    c. I am neutral
    d. I disagree
    e. I strongly disagree

Online Teaching Experience

26. "Teaching mathematics through online teaching is as good and as easy as face-to-face courses."
    a. I strongly agree
    b. I agree
    c. I am neutral
    d. I disagree
    e. I strongly disagree
27. "Students can learn mathematics using online teaching system just as much and as easily as in traditional face-to-face courses."
    a. I strongly agree
    b. I agree
    c. I am neutral
    d. I disagree
    e. I strongly disagree
28. "High quality online teaching and learning can be achieved in my online mathematics classes."
    a. I strongly agree
    b. I agree
    c. I am neutral
    d. I disagree

e. I strongly disagree

29. My online Spring 2020 semester/term was
    a. Excellent
    b. Very good
    c. Good
    d. Bad
    e. Very bad
30. My Autumn/Fall 2020 online semester/term is/was
    a. Excellent
    b. Very good
    c. Good
    d. Bad
    e. Very bad
    f. Not applicable
31. My Spring 2021 online semester/term is/was
    a. Excellent
    b. Very good
    c. Good
    d. Bad
    e. Very bad
    f. Not applicable
32. How satisfied are you in with your ability to facilitate mathematics online learning, teaching and assessment?
    a. Strongly satisfied
    b. Satisfied
    c. Neutral
    d. Dissatisfied
    e. Strongly dissatisfied
33. "I have been satisfied with my choices of assessments during …" (please select all that apply)
    a. Spring 2020
    b. Summer 2020
    c. Autumn/Fall 2020
    d. Spring 2021
34. "I now feel well-prepared to deliver all mathematics appropriate to my duties through online teaching, learning, and assessment."
    a. I strongly agree
    b. I agree
    c. I am neutral
    d. I disagree
    e. I strongly disagree
35. Write any comments about what mathematics teaching strategies, techniques, and assessment methods you think have worked best during this online experience: _____.
36. Write any comments about what mathematics teaching strategies, techniques, and assessment methods you think have worked **worst** (or not worked) during this recent online experience: _____.