# Learning from the pandemic: Capitalising on opportunities and overcoming challenges for mathematics teaching and learning practices with and through technology

Nicola Bretscher, Eirini Geraniou, Alison Clark-Wilson and Cosette Crisan

*UCL Institute of Education, University College London*

This working group (WG) met for the third and final time in November to work on the six case studies that were presented during the March 2021 and June 2021 meetings. We recap an overview of the theoretical and methodological challenges faced by the mathematics education field when the prevailing boundaries of the classroom shifted and point to findings from recent research on how mathematics education adapted during the pandemic. We connect the WG case studies to these findings to draw conclusions with respect to how practitioners responded to teaching mathematics online and the evolution of their related practices. Drawing on contributions from WG members, we then suggest ways in which teachers' practices developed during the pandemic will impact evolving pedagogies in mathematics education.

**Keywords: online mathematics teaching and learning; home schooling; technology, online professional development; digital resource**

## Introduction

This working group (WG), which met for the third and final time in November 2021, was created to discuss the theoretical and methodological challenges faced by the mathematics education field when the prevailing boundaries of the classroom shifted as a result of the COVID-19 pandemic. Starting with the assumption that technology resources are being used, the WG aimed to explore the nature of these digital tools and their affordances, that is, what they offer to mathematical teaching and learning.

During the first two WG sessions in March and June 2021, six case studies of teachers' practices during teaching mathematics online were presented. In the final WG session, we connected the six case studies (CS1 - CS6) to findings from recent research on how mathematics education adapted during the pandemic structured by following the three pedagogical themes: introducing and developing understanding of new mathematical topics; managing interaction and communication in mathematics; assessing mathematics, both formatively and summatively. We then summarise WG participants' contributions, submitted via Padlet, to suggest how the experience of teaching in the pandemic might impact the evolution of pedagogies in mathematics education in the future.

## An overview of the theoretical and methodological challenges

The first WG session concluded with a presentation by Alison Clark–Wilson providing participants with an overview of the current theoretical and methodological ideas in the mathematics education field concerning technology use. In the final session, we returned to these ideas to point to some of the challenges presented when the prevailing boundaries of the classroom shifted during the pandemic. Three theoretical frames concerning mathematics teachers' knowledge, skills and practices in relation to technology use, predominant in research in the mathematics education field, are: 1. Technology and Pedagogical Content Knowledge (TPACK and its antecedent in relation to mathematics, M-TPACK), which focuses on the explicit knowledge of the teacher (Mishra & Koehler, 2006); 2. the Structuring Features of Classroom Practice (SFCP) focuses on teacher expertise and practice, much of which may be quite implicit (Ruthven, 2009), and 3. the Instrumental Orchestration (IO) framework has identified specific patterns of teacher activity around the instrumentation of student mathematical knowledge (Drijvers et al., 2010).

Each of these frameworks was developed in the context of 'normal' classrooms, that is, with a relatively standard set-up of teacher and pupils together in a room at school, an interactive whiteboard connected to the teacher's laptop or desktop computer and the boundaries of designated teaching and learning time (i.e. classroom lessons and homework). During the pandemic, physical and temporal boundaries were removed: teaching and learning might happen asynchronously and in a variety of locations. As such, lesson patterns, distinctions between classwork and homework, relationships and learning culture all necessarily changed. The software and hardware teachers used both evolved and varied more: negotiating new online platforms and improvising hardware set-up in a new location, often at home. All of these changes present challenges for the three pre-existing frameworks. For example, the IO framework was used to identify orchestration types such as 'link-screen-board' and 'discuss-the-screen' during whole-class work and 'walk and spot' during student individual work (Drijvers et al., 2010). During pandemic times, what previously constituted the 'screen' and 'board' have changed and may not even exist; the whole class may be present online but opportunities for discussion are constrained. During online teaching, a teacher can no longer 'walk' around a physical classroom, glancing over to 'spot' individual students' screens. Similarly, online teaching presents theoretical and methodological challenges in relation to the SFCP framework constructs. For example, the 'working environment' (Ruthven, 2009) refers to the physical surroundings in which lessons are conducted. Hence, conceptualising what this means in online teaching and/or gaining access to teachers' and pupils' 'working environments' is far from straightforward from either a theoretical or methodological point of view.

## Emerging evidence against our three pedagogic themes

The six case studies that were discussed at the Spring 2021 BSRLM conference[1] and the Summer 2021 BSRLM conference[2], were summarised at the Autumn 2021 BSRLM conference, see Table 1.

---

[1] The first three case studies are detailed in Crisan, C., Bretscher, N., Clark-Wilson, A. and Geraniou, E. (2021) Proceedings of the British Society for Research into Learning Mathematics, 41 (1). Online at https://bsrlm.org.uk/wp-content/uploads/2021/05/BSRLM-CP-41-1-06.pdf

[2] The second three case studies are detailed in Clark-Wilson, A., Bretscher, N., Crisan, C., Geraniou, E., Gono, E., Neate, A., & Shore, C. (2021) Proceedings of the British Society for Research into Learning Mathematics, 41(2). Online at https://bsrlm.org.uk/wp-content/uploads/2021/08/BSRLM-CP-41-2-05.pdf

| | Introducing and developing understanding of new maths topics | Managing interaction and communication in maths | Assessing maths, both formatively and summatively | Emerging themes |
|---|---|---|---|---|
| Case study 1 | Synchronous practical demonstration of geometric proofs using a visualiser. | Synchronous modelling of students' responses using card shapes. | Enabled by the shared use of the visualiser. | How to 'model the maths' to encourage 'student engagement' and promote 'active learning'. |
| Case study 2 | Problems set in advance & synchronous session to share solutions. | Synchronous annotation of shared images, online graphing software & revealing of pre-prepared solutions. | | How to create opportunities for students to experience the integral nature of reading/ writing in maths. |
| Case study 3 | Modelling the use of dynamic maths software, contrasting by-hand methods | Interactive whiteboard, text chat, emoticons, presenter thumbnail | Formative assessment overt but limited e.g. using text chat, snapshot polls | Revealing constraints when modelling maths pedagogy. |
| Case study 4 | Static/dynamic images, closed/open-ended questions and freeform drawing. | Asynchronous, which forced the teacher's attention to detail when planning tasks. | Full visibility of students' activity, followed up via oral discussions with students. | The need to provide reassurance to students that their methods (and learning) is valid. |
| Case study 5 | Modelling of written maths on a physical whiteboard streamed via webcam. | Online "chat" of mostly words and numbers - little use of maths symbols/syntax. | Little or no opportunity. | Exposing the digital divide.<br><br>Increasing student isolation. |
| Case study 6 | Flipped approach - Video lectures followed by asynchronous online chat. | Adopted student choice of technology (Discord). | Feedback provided within the technology. | Establishing students' social presence was the priority. |

Table 1 A first draft synthesis of the first six case studies classified by pedagogic themes

The emerging evidence against our three proposed pedagogic themes: (1) Introducing and developing understanding of new maths topics; (2) Managing interaction and communication in maths; and (3) Assessing maths, both formatively and summatively, were discussed in light of findings from two recent research publications on how mathematics education adapted during the pandemic. In the first of these publications, Drijvers et al. (2021) investigated distance teaching practices in secondary mathematics education via online questionnaires in Flanders (the Dutch-speaking part of Belgium), Germany and the Netherlands. The second, Hodgen et al.'s (2021) report findings about remote teaching and learning of mathematics in Year 7 (11-12 years), based on survey and interview data with heads of mathematics in English schools.

### *Introducing and developing understanding of new mathematical topics*

In Case Study 1 (CS1), the introduction of new mathematical concepts took place by a synchronous practical demonstration using a visualiser, whereas in CS2 the authors decided to set problems in advance and discuss the pre-prepared solutions as shared and annotated artefacts during a synchronous session. CS3, modelled the use of dynamic mathematics software, while in CS4, there was the use of static and dynamic images, closed and open-ended questions as well as free-form drawing. In CS5, the teacher used a physical whiteboard to model written mathematics streamed via a webcam and in CS6, a flipped approach was discussed, that is video lectures which were followed by asynchronous online chat.

The above examples align with Drijvers et al.'s (2021) findings that during remote teaching, teachers were still able to introduce new mathematical topics alongside practising procedures and skills, however complex tasks involving mathematical reasoning and argumentation were limited (Drijvers et al., 2021). Hodgen et al. (2020) found that teachers' beliefs about consolidation work being easier to set and how best to avoid widening attainment gaps influenced their decisions about whether and how to introduce and develop understanding of new mathematical topics.

### *Managing interaction and communication in mathematics*

In CS1, the authors talked about managing the synchronous modelling of students' responses by using card shapes, while in CS2, there was a synchronous annotation of shared images, the teachers used online graphing software and revealed pre-prepared solutions in order to overcome the limitations in writing 'proper' symbolic mathematics in real time. In CS3, the authors mentioned the use of an online interactive whiteboard, the use of chat texting and emoticons as well as using a thumbnail to draw students' attention to certain points on the shared screen. In CS4, the authors argued about teaching asynchronously that forced the teacher to pay attention to detail when planning tasks. In CS5, the challenge with online 'chat' was argued, as it promotes the use of mostly words and numbers and there is very little use of maths symbols and syntax. In CS6, the authors mentioned that the students chose which technology to use to communicate outside of lectures.

In all six cases the strategies used to manage interaction and communication in mathematics lessons, reveal the various adaptations teachers had to make to achieve some mathematical learning. Drijvers et al. (2021) argue that the limited means for managing interaction and communication may hinder pedagogic approaches. They present as an example the complex tasks involving reasoning, which are not easily discussed with the means used for remote teaching and learning. Hodgen et al. (2020) added another limitation of remote education. They found out that engagement and interaction is most constrained for pupils who had lower prior attainment or other categorisations of disadvantage.

### *Assessing mathematics - both formatively and summatively*

In CS1, assessment was achieved with the use of a visualiser, which enabled the teacher to model the solutions and give verbal feedback during synchronous sessions. In CS2, assessment issues were not raised explicitly. In CS3, assessment strategies involved using the text chat functionality of the online platform and snapshots of polls that students take during the session. In CS4, assessment was achieved by setting students' activities which had to be submitted online and therefore every student's work was visible by the teacher. Then the teacher followed up by sharing their feedback via verbal discussions with students. In CS5, the authors argued that there was little or no opportunity for assessment, while in CS6, it was argued that feedback was provided within the technology that was used and teachers claimed that the lack of two-way communication hampered their abilities to assess the success of lessons and therefore grading and returning student work became necessary to assess students' progress in remote lessons. These findings align with recent studies that showed that formative assessment could be an issue due to limited opportunities to engage in mathematical talk, meta-cognitive activities or receive formative feedback (Hodgen et al., 2020), but also due to teachers' inexperience and low confidence in their skills for using digital technology for assessment purposes (Drijvers et al., 2021). Moreover, the most common forms of formative assessment include analysing submitted work and questions (verbal or in chat) during live online sessions (Drijvers et al., 2021). This finding resonates with those mentioned by the authors of CS3, CS4 and CS6.

## Predicting how mathematical pedagogies might evolve in the future

At the Autumn 2021 BSRLM conference, all participants were invited to discuss in groups of 3-4, the following question: "How do we envisage that teachers' practices developed during the pandemic will impact evolving pedagogies in mathematics education?", and submit their comments on a Padlet. We summarise participants' contributions next.

The participants' critical and reflective comments raised further issues about the future landscape of mathematics education due to the pandemic. Participants thought that we might lose our skill to write and gesture when teaching remotely due to the constraints of the digital technologies used. They recognised the difficulty of using mathematical syntax in online learning platforms and argued that 'mathematics written words' became far more casual when using the chat. They wondered about whether schools would retain access to paid-for mathematics platforms as backup in case of future lockdowns as teachers and students have existing familiarity with them. Participants mentioned teachers' "blindness" to learners' outcomes during online synchronous teaching and wondered whether we are moving towards a state whereby the learner has more autonomy – choosing when and how to be assessed, posing their own questions and completing them. Similarly, to the latter point, they mentioned an advantage of using the 'chat' feature during remote 'live' lessons as it opens up new ways for students to have a voice. At the same time though, they argued about the emergence of the teacher 'co-pilots', where a second person monitors students' messages. A group of participants claimed that teachers became increasingly aware of past assumptions. They stated that:

> For example, certain aspects of interaction, such as students forming 'collaborative study groups' at university level or of 'presence', became salient as things-we-cannot-assume. In at least some cases, this created new opportunities to reflect on equity and access to multi-dimensional ways.

Another group mentioned that in particular about Initial Teacher Education, there was an agreement that videos/recordings of 'information' sessions will continue to be used as well as online tasks pre- or post- sessions. It was interesting that participants recognised that some teachers 'got over the hump to try' as the pandemic-panic led them to try out pedagogies that they were aware of but had not previously experimented with (e.g. flipped classroom approaches). Regarding mathematics specific digital technologies, there were contrasting predictions. Participants suggested that teachers might not carry on using such digital technologies when they returned to face-to-face teaching, whereas other teachers might choose to use them more as they became aware of what such digital technologies can do.

Finally, this working group seemed to have inspired the participants to think about a number of important questions, such as: How will teachers embrace their new learning with respect to digital technological tools that was triggered during moments of crisis?, Will we all learn more about using additional technological tools (e.g. integral whiteboards, styli for writing mathematics) now we appreciate the limitations of the chat (for example)?; How will we be able to monitor and capitalise on the often lively discussions within synchronous (and asynchronous) chat?; Will any new etiquettes (i.e. cameras and microphones on for all participants) become new social norms for the synchronous online mathematics lectures/lessons/tutorials?".

## Conclusion

We conclude that our questioning of how we envisage that teachers' practices developed during the pandemic will impact evolving pedagogies in mathematics education should linger for longer in our minds. Our six case study contributors and workshop participants highlighted multiple challenges for the remote teaching of mathematics with, and through, technology. Hence both teachers' pedagogies and our associated theoretical frameworks and methodologies will continue to evolve to enable us to understand, and aim to overcome, the identified challenges. However, as mathematics educators and researchers living in a digital era, we cannot (and should not) ignore the fact that many more teachers and learners had opportunities to engage with technology during the pandemic, which provides a unique moment for the field.

## Acknowledgments

We would like to thank the contributors of the six case studies presented and our participants for their engagement, their reflections and the fruitful discussions.

## References

Drijvers, P., Doorman, M., Boon, P., Reed, H., & Gravemeijer, K. (2010). The teacher and the tool: Instrumental orchestrations in the technology-rich mathematics classroom. *Educational Studies in Mathematics, 75*(2), 213–234.

Drijvers, P., Thurm, D., Vandervieren, E., Klinger, M., Moons, F., van der Ree, H., Mol, A., Barzel, B., & Doorman, M. (2021). Distance mathematics teaching in Flanders, Germany, and the Netherlands during COVID-19 lockdown. *Educational Studies in Mathematics, 108*, 35–64. https://doi.org/10.1007/s10649-021-10094-5

Hodgen, J., Taylor, B., Jacques, L., Tereshchenko, A., Kwok, R., & Cockerill, M. (2020). Remote mathematics teaching during COVID-19: Intentions, practices and equity. UCL Institute of Education.

Mishra, P. and Koehler, M. (2006). Technological Pedagogical Content Knowledge: a framework for teacher knowledge. *Teachers College Record*. 108(6).

Ruthven, K. (2009). Towards a naturalistic conceptualisation of technology integration in classroom practice: The example of school mathematics. *Education and Didactique, 3*(1), 131-152.