
EDITORIAL

Life in the time of COVID: Thoughts on current trends and future directions in mathematics education

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This is a reflective, personal, and possibly somewhat self-indulgent piece, prompted by my thinking on current trends evidenced in recent editorial experiences with, and contributions, to several journals and book publications that report on contemporary mathematics practice and research internationally. As such, it is not intended as a definitive ‘state-of-play’ (in the sense of a meta-analysis or a systematic review of the literature), but as a means of considering some of the questions raised by these studies and using these to frame some potentially useful directions for future research, which I hope may be of interest and value to *Bolema* readers and researchers. A key observation underpinning my motivation for this piece mirrors the well-known historical example of the birth of Calculus, which grew somewhat independently, but contemporarily aligned, in the seventeenth century in England and France, with the work of mathematical giants, Newton and Leibniz. My editorial duties and contributing authorship to journals and books across a wide range of international platforms have led me to observe some common trends by researchers and teachers, who are similarly sometimes seemingly unaware of common approaches and influences in other countries and domains. These observations prompted the idea to highlight some of the common findings of these studies, and point out some questions these studies pose for future research.

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Studies and publications referenced here include, but are not limited to, my work as Associate Editor for two journals: the *Bolema Journal*, and the *International Journal of Mathematical Education in Science and Technology (IJMEST)*¹, the latter of which has produced three *Special Issues* in 2021 (Two showcasing selected papers from conference proceedings: (*Herenga Delta 2021, the 13th Southern Hemisphere Conference on the Teaching and Learning of Undergraduate Mathematics and Statistics* (12 articles, see EVANS; OATES, 2021); *INDRUM 2020 (International Network for Didactic Research in University Mathematics*, eight articles; HAUSBERGER; BOSCH, 2021), and a third *Special Classroom Notes* Issue examining issues arising from the COVID-19 pandemic, *Takeaways from teaching through a global pandemic – practical examples of lasting value in tertiary mathematics education*, 21 articles; SEATON; LOCH; LUGOSI 2021). Other contemporary works include my role as Guest Editor (see OATES; SEAH, 2021) for a *Special Issue* of the *Australian Journal of Education*, with seven articles examining *Learning progression/trajectories in mathematics and science education*; as a contributing author to a chapter (GALLIGAN *et al.*, 2020) which reviewed recent research in tertiary mathematics in the latest four-yearly MERGA² review of Australasian-focused research (BOBIS *et al.*, 2020, *Research in Mathematics Education in Australasia (RiMEA) 2016–2019*); and two chapters with a technology focus, the first a chapter in *The Handbook of Cognitive Science*,³ which explores the role of the internet in the process of developing students into independent learners, through the different forms of blended learning and how humans and media interact in the learning process (ENGELBRECHT; OATES, 2021); and a second chapter which examines, and provides explicit examples of an authentic assessment to promote active online learning and a critical reflection for pre-service teachers in a mathematics pedagogy course (OATES; DENNY, 2021).

Not surprisingly, given their publication over 2020 to 2021, a consistent theme in many of these works, and indeed a motivating driver behind some (e.g., SEATON; LOCH; LUGOSI, 2021), is the pervasive effect of the COVID-19 pandemic on mathematics education. Even before the role of technology was forced into stark relief by the need for most schools and universities to suddenly go online, many studies had been debating the role technology played in shaping, and the potential for it to change, the ways in which we teach and learn mathematics

¹ Available at: <https://www.tandfonline.com/action/journalInformation?show=aimsScope&journalCode=tmes20>. Access in: 30 oct. 2021.

² Mathematics Education Research Group of Australasia. Available at: <https://www.merga.net.au/>. Access in: 30 oct. 2021.

³ Available at: <https://meteor.springer.com/project/dashboard.jsf;jsessionid=JD8w3bmv4IjhMfVsbzapuRMWxh7rU4QDpc1IQVHG.spr-prod-app-16?id=1030&tab>About>. Access in: 30 oct. 2021.

(e.g., ATTARD *et al.*, 2020; BORBA *et al.*, 2016; BORBA; CHIARI; ALMEIDA, 2018; ENGELBRECHT; LLINARES; BORBA, 2020). In hindsight, such studies may be seen as foreshadowing, or setting the stage for the sudden demands the pandemic thrust upon us, reflecting the observation by Borba, Chiari and Almeida (2018) that technological developments were transforming societies and educational processes well before COVID had emerged. In 2019, there was a call for papers for a special issue of *ZDM*, with a central theme to investigate the evolvment and transformation of the classroom with the growing integration of the internet into the learning process. However, in their editorial piece for the 16 articles that subsequently appeared in Volume 52(5) *Online mathematics education and e-learning*⁴, Engelbrecht *et al.* (2020) note how the COVID-19 pandemic risks trampling over many of the aspirational transformations described in these studies. They ponder if 2020 will be remembered as the year in which education changed, observing that while the crisis provided an opportunity for change, the radical transformation to online teaching and learning caused by the COVID-19 pandemic “is not the [evolving] way we would have liked to conduct this transition” (p. 3) to more effective forms of blended learning.

Such questions are also highlighted by others over this period, with respect to both teaching and learning, and research. Successive editorials in 2020 issues of the *Bolema* journal (v. 34, n. 67; v. 34, n. 68) question the effects of the pandemic, with Miarka and Maltempi (2020) for example questioning, in the early stages of the pandemic, if learning would ever return to the previous ‘normal’? With respect to the impact on research and *Bolema* publications, they ponder how, like teaching, research might adapt to the virtual world forced on us by the pandemic, and further, what are the methodological challenges of such processes? Later in the year, as the fuller impact and long-suffering nature of the pandemic became more apparent, Font and Sala (2020) built on the questions posed by Miarka and Maltempi (2020), suggesting five aspects in which they see mathematics education is being, or might be affected by the pandemic. The first is a predictable increase in research into the actions taken by teachers in general (and those of mathematics in particular) in response to the pandemic. Such research is exemplified in the 21 articles featured in the 2021 *IJMEST Classroom Notes Special Issue* (SEATON; LOCH; LUGOSI, 2021), which provide a collective snapshot of contemporary practices and responses to COVID in undergraduate mathematics teaching. The focus of these articles is consistent with the eight themes identified as directions for future research by Bakker, Cai and Zenger (2021), namely: *approaches to teaching; goals of mathematics education;*

⁴ Available at: <https://link-springer-com.ezproxy.utas.edu.au/journal/11858/volumes-and-issues/52-5>. Access in: 30 oct. 2021.

relation of mathematics education with other practices; professional development of teachers; technology; equity, diversity, inclusion; affect; and assessment. The critical nature of one of these themes, assessment issues in tertiary mathematics, is evidenced by the more than half of the articles in the *Classroom Notes Special Issue* (12 out of 21 articles) with an assessment focus. These articles consider both formative assessment (e.g., how might students monitor their progress in a self-directed online environment?) and summative assessment (e.g., with respect to maintaining integrity in online examinations). Wider assessment issues and the pandemic also underpinned the September 2020 call for papers in a commissioned book (Volume 6) in the *Global Education in the 21st Century Series* (BARKATSAS; MCLAUGHLIN, 2021), with the objectives to:

- Explore authentic assessment research, approaches, and practices at all levels of education.
- Explore program evaluation and teacher evaluation research, approaches, and practices at all levels of education.
- Disseminate mixed method studies, qualitative studies, quantitative studies, discipline-based narratives, and case studies of sustainable authentic assessment and evaluation approaches and practices (including Covid-19 studies) at all levels of education.

Assessment was the primary focus of the 17 articles featured in this publication, but connections to other themes are also clear, with several chapters exploring technology-supported approaches to foster active learning, collaboration, and visualization (e.g., ERSOZLU; LEDGER; HOBBS, 2021; OATES; DENNY, 2021; SEAH; HORNE, 2021), while others examined cultural and equity issues, and affective factors (e.g., SANTOS; FORTUNATO; MENA, 2021; WILKS-SMITH, 2021). Exemplifying the aspects highlighted by Font and Sala (2020), and the themes of Bakker, Cai and Zenger (2021), questions raised in these studies include how common classroom-based collaborative pedagogies and formative assessment techniques may be adapted for online use (OATES; DENNY, 2021), and the need for greater investigation on the impact of teacher practice on student learning, especially in the Brazilian context, where the authors suggest it is a missing component. “There is a need of substantial analysis on teachers’ practice by observing pedagogical strategies used, teachers’ dispositions and beliefs, test scores, or students’ surveys” (SANTOS; FORTUNATO; MENA, 2021, p. 326).

In respect of changes in teaching and delivery, Font and Sala (2020) observe that while many seemingly successful actions have been taken in response to the pandemic, from a research perspective we have little evidence of the effects of such moves. For example, how

might the use of virtual environments affect the learning of school mathematics from the point of view of learning and learning outcomes? Such questions are also emphasized by Engelbrecht and Oates (2021), whose article focuses on the ways in which computer-mediated networks support social interaction, cooperation, and collaboration, for learning and knowledge building. They observe how the physical classroom as we have known is changing and describe how the sudden switch to fully online learning has amplified perspectives such as self-determined and self-directed learning for students (heutagogy, see for example, BLASCHKE, 2019), including self-regulation (BAKKER; CAI; ZENGER, 2021), and questions on how to develop and evaluate the effectiveness of blended or hybrid learning environments (ENGELBRECHT; OATES, 2021). Traditionally, online learning environments have been largely asynchronous (i.e., where learning is conducted in the students' own time), but COVID-19 has thrust the spotlight more closely on how we might develop synchronous online learning, with capacity for instructor-student and peer-to-peer interaction? Engelbrecht and Oates (2021) conclude by framing several issues that require further research in this respect, many of which resonate closely with the second aspect highlighted by Font and Sala (2020), namely, what is the effect of technology on the teaching and learning of mathematics when technology, in addition to being a resource (as has been frequently the case to date), becomes the main means of education? Key questions here centered around epistemic factors, and the mathematical and cognitive value of online tools and approaches, including:

- What technology should students use to support their own mathematical learning as well as collaboratively the learning for other students? How might they make effective choices with the multitude of options available in informal contexts?
- How can social media tools be combined with the best practices in teaching and contribute effectively to student engagement, and the development of deeper mathematical understanding? (ENGELBRECHT; OATES, 2021, p. 31)

Three other aspects of mathematics education identified by Font and Sala (2020) are not discussed in detail here, but their importance and commonality are evidenced in other studies so are worth repeating, even if briefly. The third aspect they identify is the emergence of new teaching and learning problems introduced by the pandemic, or existing problems that the pandemic has amplified, issues which feature strongly in the most significant theme found by Bakker, Cai and Zenger (2021, see next discussion). Their fourth aspect, echoed by Bakker, Cai and Zenger (2021) is with respect to questions about our mathematics research discipline, and the impact on higher education research and publication rates (FONT; SALA, 2020). Their final aspect considers the impact of the pandemic on conferences and other mathematics education

congresses. In this latter respect, Evans and Oates (2021, p. 1) observe that the pandemic “has been a period when optimism was often elusive and when challenges sometimes seemed insuperable and overwhelming. The resilience of the Delta research and teaching community⁵ is being tested”. While Font and Sala (2020) recognize these challenges, they also optimistically note the emergence of an increased number of virtual conferences, with benefits (notwithstanding time-zone challenges) of increased international participation, and greater access for participants from developing nations, a point of equity highlighted by Bakker, Cai and Zenger (2021).

In a similar fashion to the way in which COVID-19 intersected with the publication of the *ZDM* special issue, influences from the COVID-19 pandemic can be seen in the approach and focus of several other studies initiated prior to the pandemic outbreak. In the precursor to the study by Bakker, Cai and Zenger (2021) cited earlier for example, the researchers note how reporting of results from their initial survey conducted in 2019 (planned for presentation at 2020 NTCM and ICME), was shaken up by the crisis. In 2019, they asked the question “On what themes should research in mathematics education focus in the coming decade?” (BAKKER; CAI; ZENGER, 2021, p. 2) They received 229 responses from 44 countries, and their initial analysis identified the 8 themes listed earlier, as a focus for future research: They were, however, prevented from presenting their results, and the researchers thus pondered how respondents might think differently about the themes formulated for the future due to the pandemic? They decided to resurvey their participants, asking the question “Has the pandemic changed your view on the themes of mathematics education research for the coming decade? If so, how?” (BAKKER; CAI; ZENGER, 2021, p. 2). They observe that the general gist of responses in 2020 was that the pandemic had:

... functioned as a magnifying glass, ... on themes that were already considered important ... systemic societal and educational problems were said to have become better visible to a wider community, and urge us to think about the potential of a new normal (BAKKER; CAI; ZENGER, 2021, p. 5).

With respect to teaching and learning, the responses in 2020 supported the findings and questions raised by other studies cited previously (e.g., FONT; SALA, 2020; ENGELBRECHT; OATES, 2021), with for example more emphasis on interaction, collaboration, higher-order and critical thinking (BAKKER; CAI; ZENGER, 2021). With respect to research, Bakker, Cai and Zenger (2021) describe how several respondents felt that the pandemic has highlighted the extent to which mathematics education research has been less than accessible or insufficiently

⁵ The Biennial Delta Southern Hemisphere Conference on the Teaching and Learning of Undergraduate Mathematics and Statistics. Available at: <https://www.herengadelta.org/>. Access in: 30 oct. 2021.

responsive to the needs of practitioners and students in the past, and more so now in respect of immediate concerns. They ask if we perhaps “need a particular type of communication research within mathematics education to learn how to convey particular key ideas or solid findings?” (BAKKER; CAI; ZENGER, 2021, p. 13).

Not all studies over this period explicitly referenced the pandemic, but even within many of these, similar issues are evident. The RiMEA review (BOBIS *et al.*, 2020) encompasses 14 chapters presenting critical analyses of research in mathematics education in Australasia over the years 1026 to 2019 (i.e., the period leading up to the pandemic), and serves to highlight significant enduring trends and forecast possible directions for future research. While the chapters are not explicitly organized around themes, their collective focus resonates with those themes described previously (e.g., BAKKER; CAI; ZENGER, 2021; FONT; SALA, 2020). In their discussion entitled *Focusing our understanding of Initial teacher Education*, Way *et al.* (2020) echoes the observation of dos Santos, Fortunato and Mena (2021) with respect to teachers’ practice, noting very few studies that have been specifically designed to deeply explore the experiences of pre-service teachers from their own perspectives, as distinct from the practices of teacher educators. They see a need for “more longitudinal studies with rich data drawn directly from pre-service teachers...across a range of institutions” (WAY *et al.*, 2020, p. 108). Several of the chapters likewise mirror calls for increased development and evaluation of pedagogies as described earlier (BAKER *et al.*, 2021; ENGELBRECHT; OATES, 2021; FONT; SALA, 2020). Attard *et al.* (2020) for example make several recommendations for future research directions in respect of teaching and learning with digital technologies, including:

- Investigation of how digital technologies are being used to develop mathematical content knowledge in pre-service early childhood and primary teachers.
- Develop deeper understanding of how technology can be used to position students to have more voice and control in mathematics classrooms and promote rich, two-way interaction (ATTARD *et al.*, 2020, p. 341).

In their chapter reviewing studies on tertiary mathematics and statistics, Galligan *et al.* (2020, p. 285) conclude by posing six questions for further research in tertiary mathematics and statistics education, including studies which examine “the co-evolution of pen-enabled technology, the flipped classroom, and blended learning to create learning cultures to assist students to gain a deep understanding of mathematics”. As noted earlier, the COVID-19 crisis may have disrupted this co-evolution with its sudden demands for online learning, but the questions of how to effectively develop cultures of effective blended-learning remains

paramount. In another of their concluding questions, Galligan *et al.* (2020) add support for studies to investigate the effects of the pandemic on our mathematics education research and community (e.g., FONT; SALA, 2020; MIARKA; MALTEMPI, 2020), to seek “better understandings of some of the higher-level contexts of mathematics and the application of mathematics and statistics in work-integrated learning contexts and HDR research” (GALLIGAN *et al.*, p. 285). In their discussion of *Innovative and Powerful Pedagogical practices in Mathematics Education*, Hunter *et al.* (2020) may well be considered as presaging some of the issues accentuated by the pandemic, when they argue that we “need effective pedagogy for *all* learners and ... ambitious, future-focused teaching in mathematics education” (HUNTER *et al.*, 2020, p. 293). They call for studies which challenge the status-quo of current practices (as COVID-19 has demanded), and importantly, how we might know if the developing practices are transferable from one context to another? We need to distinguish “the difference between knowledge that something can work and knowledge of how to actually make it work reliably over diverse contexts and populations” (BRYK, 2015, p. 469, *apud* HUNTER *et al.*, 2020, p. 313). Hunter *et al.* (2020) suggest we may need to adopt different research paradigms to examine such questions, and how this can be done is itself seen as a fruitful line of future research.

Finally in this discussion, I consider here the emerging body of research and interest in using learning progressions and trajectories (LP/Ts), with associated questions of how these may be used to better inform student learning (e.g., CONFREY; SHAH; BELCHER, 2021; SEAH; HORNE, 2021). In support of the call for papers showcasing LP/T’s in the *AJE Special Issue* (see the editorial by OATES; SEAH, 2021), and mirroring the earlier call by Bakker, Cai and Zenger (2021) for greater practical accessibility of research, the *Special Issue* guest editors cite the observation by Confrey *et al.*, (2019, p. 76, *apud* OATES; SEAH, 2021, p. 1), that despite considerable research into teaching and learning, “much of the accumulated knowledge is neither readily accessible nor actionable, by most classroom teachers” in the primary and secondary years. The *AJE Special Issue* features seven articles which showcase a range of theoretical perspectives and methods of investigation, reflecting the recognized potential of using LP/Ts research in generating a closer link between research and practice. A common thread through these articles is the value of LP/Ts in highlighting the need for linking of curricula content, both within, and between subjects. However, the guest editors observe that, at the present time, there is insufficient evidence in respect of the impact learning progressions may have on planned curricula developments, and emphasize the need for further research into LP/Ts’ applications in the classroom context. They frame two key questions worth further

investigation:

- how does LP/Ts research assist teachers in planning activities and implementing differentiated instructions to support the diversity of needs within the classroom?
- considering the increasing emphasis on STEM education, what is the potential for LP/Ts research as a framework for interdisciplinary collaboration between mathematics and science discipline, to explicitly nurture its growth from the early childhood years onwards (OATES; SEAH, 2021, p. 3).

In addition, we might note that these studies have so far focused predominantly on teaching, with the impact of LP/Ts on student learning in the long term still largely unexplored.

In summary, this discussion has highlighted many issues of contemporary interest for mathematics education, for example issues associated with constraints of online learning caused by the pandemic, and it has identified several areas of interest and significance in future research. For me, a key factor in many of the studies discussed here is both the way in which the pandemic has questioned our current practice, and to what extent it will shape and influence our future practice? As we emerge from the immediate and somewhat frantic responses thrust on us by the crisis, future research should ask to what extent have our classrooms and research practices changed? Have we really entered a ‘new normal’ as it is often described, and, if so, in what ways is it better, or perhaps less effective than before? And if we have indeed entered a new normal, how are we equipping and supporting our teachers, students, and researchers to adapt to, and thrive in this new environment? To what extent do our Initial Teacher Education courses reflect the new and emerging practices we have described, for example are we now better equipping our teachers to teach online with effective, technology-based pedagogies? How have our research approaches and methodologies developed to investigate these questions appropriately? I look forward to seeing studies emerging, and more specifically, as an Associate Editor, submitted to *Bolema*, that look to address such questions.

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