Mixed mode approaches to sustainable mathematics teacher educator development in areas with limited access to digital technologies

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We analyse outcomes from a 'Mathematical Thinking and IT' course adapted for East African mathematics teacher educators. The model supplements a ten-day face to face course with three months' distance learning as participants adapt and harness research-based materials and approaches. We asked, 'What are the affordances and constraints of this model, and of the available technology, for mathematics teacher educator development in this context?'. Qualitative evidence of mathematics teacher educators' longitudinal trajectories suggest that mathematics teacher educators with a threshold level of capacity for change, including critical levels of reflection, were able to make significant progress in their technological, mathematical and mathematics pedagogical expertise and to adapt, embed and further develop that in their practice, at least in the short- and medium-term; in contrast, those without such a threshold capacity appeared unable to re-envision practice. The initial course appeared sufficient to equip professionally confident mathematics teacher educators with technological capacity to access a range of materials for learning, and to support professional interchanges and development at a range of levels and granularities. However, subject-specific software and sources that support deeper mathematics learning, while appreciated by mathematics teacher educators, are not reliably and widely accessible in teacher or school student institutional contexts.

Keywords: distance learning; East Africa; mathematics teacher educator; primary mathematics; technology; WhatsApp;

Background

Bethell (2016) argues that for sub-Saharan Africa, mathematical attainment is very low in global terms, severely restricting access to economic and personal thriving in a global 21st-century. Consequently (p15, op cit) 'the most important group of interventions will be those concerned with equipping existing and future teachers of mathematics with the knowledge and competences necessary to help learners acquire deep understanding of mathematical concepts'. Participants in the ICMI global 'capacity network building project' (CANP) working in East Africa concluded that a priority within that for East Africa (EA) was the mathematical and pedagogical transformation of those responsible for teacher initial and continuing education. We report here on the consequent design-based research (Anderson & Shattuck, 2012) addressing that challenge for primary *mathematics teacher educators* (MTEs) in EA, starting from a model which is becoming well-established, and of proven efficacy, for *teachers* in South Africa. The first author initially adapted that model on theoretical grounds in 2019, drawing on Halai and Tennant (2016), and did so iteratively as the course progressed. It is intended that development will continue in the light of participant feedback, subject to appropriate funding. The second author participated herself as a secondary MTE: we were therefore alert in this study to threats to validity of analysis on account of our 'insider' roles.

The focus mixed-mode course was for East African (Ugandan, Rwandan, Tanzanian, Kenyan) upper primary (and lower secondary) mathematics teachers, together with MTEs. 'Mathematical Thinking and IT' (MT) comprised an intensive residential ten days face to face collaborative learning plus three months' supported distance learning via action research-related activity as participants enacted, evaluated and further developed for their local context, the materials and approaches used. Those were developed from sources harnessed successfully, and with open access, for the research-based AIMSSEC courses (e.g. Golding, 2018). These use a model focused on provision for large class, low-resource learning which, in parallel with development of teacher participants, equips participants to lead local teacher learning workshops. Additionally, enhancing competencies for using IT for teaching and learning mathematics plays a significant role. For the initial such course in EA, we recruited ten primary MTEs from across EA (five based in teacher training colleges and five school-based), who for the course worked alongside 19 primary teachers of mathematics.

The approaches used, evaluated for this context, and adapted, the structure adopted for previous South African *teacher* development courses for use with *MTEs*, as well as teachers, in East Africa. They addressed issues of EA curriculum content, context and framing, including analysis of effective low-tech delivery and approaches to addressing technical challenges. In line with EA espoused curriculum values, the course's approach modelled in its engagements with teachers (educators) active, meaning-making approaches to primary mathematics that together build sense-making, reasoning embedded in a deep conceptual grasp, link-making within and beyond mathematics, and mathematical problem-solving. Such aspirational mathematical functioning moves away from more traditional classroom practice based on rote learning and memorisation of standard examples, and is valued globally, though to date has not been achieved at scale (e.g. Eurydice, 2011), so the course is ambitious. Ideally, and for added confidence/knowledge/skills /embedding, participants would also engage in follow-up courses such as those described in Joubert and Kenny (2018).

The technology available to East African primary teachers is often limited in terms of devices with sustained online access: distance support therefore needs to focus on asynchronous use of downloadable apps and WhatsApp rather than using online synchronous fora or needing frequent web access. Teachers typically have access to a mobile phone, which might or might not be a Smartphone. They might also, but frequently do not, have one or more desktop computers in school, with probably intermittent web access - and electricity. Some Kenyan classrooms, in contrast, have received international funding for a tablet for each child – though sometimes without the teacher expertise to take advantage of that, or web access. Our main research question was ***'How and why should AIMSSEC approaches and materials be adapted for East African MTEs, school system and technology contexts, and what impact can they then have?'.*** In this paper, we ask in particular, ***'What are the affordances and constraints of the available technology for supporting primary MTE development in this East African-adapted model?'***

Learning mode: We know that, relative to face to face modelling approaches, synchronous webinars for mathematics teachers can offer equivalent opportunities to learn mathematical content but only inferior access to learning new pedagogical approaches (Golding and Bretscher, 2018), and we assume this extends to MTEs. Pedagogical approaches therefore need to be very clearly communicated during the face to face phase of the course, so as to compensate for the limitations of distance learning for pedagogical change. Design already incorporates fundamental established facets of effective professional development for teachers, including that it is longitudinal and active in approach; concrete and classroom-focused; focused on both subject and subject pedagogical development; interspersing new learning with classroom enactment, exploration and reflection; informed by external expertise; collaboratively supported; and with scope for mentored contextualisation (Walters and Briggs, 2012). Prior to first teaching in 2019, the course had already been adapted to accommodate a 'best fit' of EA curricula and to take into account known facets of prevailing approaches to teacher initial and continuing education. However, 'official' accounts of both curriculum and teacher education proved limited in depth, detail and alignment with reported practices 'on the ground', so that actively seeking out participants' accounts of their contextual constraints and opportunities proved critical to development.

MTE learning is complex (Jaworski and Woods, 2008), and takes place on a number of levels. Classroom teachers in planning have to engage with the primary learners' perspective, as well as a range of subject-related and generic foci (e.g. Ball Thames and Phelps, 2008); for MTEs there is a meta-level of inducting teachers into such thinking. Most primary teacher education in EA currently focuses not on primary mathematics and its pedagogy, but on higher-level mathematics per se (Halai and Tennant, 2016); further, primary MTEs based in colleges are not in general required themselves to have experience of teaching in primary classrooms, so that an expectation on this course that they engage with primary classroom level considerations from the point of view of primary teachers and primary learners, was very demanding. For *school-based* MTEs, engaging largely with post-qualification teacher development, the issues are still complex because of the layers involved. The development of the EA course included MTEs at only a late stage, so in the residential phase they worked collaboratively with practising classroom teachers.

Course assessment included formative assessment throughout the initial phase, including self-assessment via completion of a daily reflective journal supported by tutors; an end of residential course examination targeting both mathematical and mathematics pedagogical knowledge appropriate to the primary phase; and the completion of three practice-based reflective assignments at the end of each of the next three months, for which distance support was available. The first of these focused on detailed planning/evaluation for learning of a lesson incorporating differentiated but inclusive, active, meaning-making approaches; the second *on* the running of a collaborative professional development workshop introducing teachers to such approaches, and teaching of a parallel primary learner lesson; the third for MTEs offered a choice to participants of deepening learning around the first assignment by focusing on a different curriculum area, or extending the second assignment activity into a more ambitious planning (and possibly facilitation) of teacher workshop(s). For the first two assignments, MTEs were asked to adapt core teacher assignments for their own professional context, while focusing on the key implications for classroom teachers. For some, the assignments offered opportunity to adopt a quasi-action research mode as they adapted materials and approaches for their own teaching context, and shared their reflections on those with their tutors. Detailed formative feedback was given on each assignment.

The study

This paper focuses on the learning of the ten primary MTEs (typically educating teachers of 5-14+ year olds in EA) as that is the group whom the EA CANP have identified as having the greater potential for enhanced impact. Participation in upper primary education in EA is now near-universal, but comparatively recently so (Halai and Tennant, 2016). Data were drawn from MTE journals, in-course working sessions and end-of-course examination, as well as assignments, email and WhatsApp communications with/from the ten primary MTEs. They were sent an internet-based questionnaire, backed up by a Word version, after their first assignment and after return to them of tutor feedback on the third. Responses to these were added to data, and supplemented by audio-recorded, transcribed face to face interviews with one school-based MTE (pseudonym Kirabo), immediately after Assignment 2, and again at an interval after assignment 3. Two MTEs did not complete the assignments (or the second questionnaire): both had struggled to respond to the reflective expectations, partly because of language challenges and the depth of mathematical thinking envisaged, but both cited pressure of work for withdrawal.

Research tools were developed iteratively in a grounded approach (Charmaz, 2006) through January to June 2019, and forthcoming assignment requirements developed in the light of emerging data, responding in particular to the depth of MTE confidence and reflection shown. Survey and interview questions focused on participants' experiences as they embarked on applying course ideas in their home settings; and their experiences, support and learning through the three assignments, including their evidence for impact on workshop participants and on primary mathematics learners. All data collection events included a probe as to application of IT learning for the context, and the technological affordances and constraints of the locally available technology, for professional purposes.

Throughout, we use MTEs' *capacity* in a field to mean their available resources of related knowledge, skills and affect (Golding, 2017). Grounded analysis resulted in emerging themes of technology resources (software and hardware) and related MTE capacity; MTEs' own mathematics capacity; MTEs' own mathematics pedagogy capacity; MTEs' capacity for mathematics teacher pedagogy; impact on other teachers and on primary learners. Throughout, names used are pseudonyms. Teacher effective in-service learning is characterized by Horn (2010) as drawing successively on replays, rehearsals, and re-envisioning practice, and here we extend those notions to MTE learning. The nature of the related study as design-based research inevitably means that emergent themes do not necessarily align completely with others in the field, and also that further design considerations are interwoven with findings from data in what follows.

Findings

Technology resources and capacity: Eight of the ten primary MTEs had their own smart 'phones, and were fluent in using basic social media. Three possessed their own laptop (in two cases, very slow), and six had at least 'moderately easy' access to a desktop computer in their workplace, though during the course almost all commented about lack of reliability of internet access and/or power. Most (at least seven) could email confidently, but only four claimed prior confidence in sending attachments. Few regularly used the Internet to access resources, in part because browsing without structure is expensive on data use. All eight had used WhatsApp for social purposes, but initially, none for professional interchange. None claimed familiarity with mathematics-specific software, and only two regularly used a computer for professional purposes.

During the residential course, participants had daily sessions using computers, and during those, engaged hands-on with Geogebra (free subject-specific software for geometric exploration, graphing or handing data), with the free AIMSSEC App that offers detailed self-help plans for mathematics teacher collaborative workshops for all phases),with sending emails and attachments, with writing documents for professional purposes, with searching particular internet sites for teaching support and inspiration, and with the use of WhatsApp for professional purposes. At the end of the course, each was given a USB containing all course materials used, including all those at that time included on the AIMSSEC App. At present, internet access for these MTEs is such that in subsequent data collection only three referred to internet searches or downloads, whereas all reported use of the USB content. None of the school-based MTEs has access to a projector in the classroom, and three of the college-based educators do – though not always with an available computer to link into it.

Technology sessions therefore majored on teachers building familiarity and confidence with their own use of the relevant software, and with use for professional purposes of exploration, planning, teaching and assessment, and administration. Their range of experiences covered all of Hoyle's (2018) categories of digital tool use, but Mishra and Koehler's (2006) 'technological pedagogical content knowledge' is not yet relevant to MTEs in these contexts. However, MTEs were able to 'replay' their current practice and 'rehearse' new ways of approaching professional tasks with digital support, in Horn's (2010) terms, though they were sometimes challenged to 're-envision' ways of working because of practical access to, and reliability of, the necessary technology. In interviews, Kirabo regularly pointed to her wish to share the joys of geometric exploration using Geogebra with her teachers, but the nearest set of computers was in a school some distance away, and on the occasion she had booked that for a workshop, there was no power. However, she also pointed to enhanced professional use of the school's one computer, for organisational but also pedagogical purposes, including exploring the Internet for resources for other curriculum areas, such as science.

All were required to engage with at least one AIMSSEC workshop for an assignment, and all did so successfully, usually via their USB rather than downloading the most recent content via the App. Data download costs are a significant issue for teachers in EA, and unfortunately, WhatsApp has recently been targeted for additional taxation, presumably because it is seen as a tool for social media, so an optional extra, rather than a conduit for professional interchange. However, in the distance phase, and as in So (2016), most MTEs made much more use of the WhatsApp group set up, rather than email, and indeed, were far more responsive to tutor communications via WhatsApp. All sent assignments by email, and received feedback that way.

Mathematics capacity: Four of the five training college-based MTEs had degrees in mathematics, as part of which they had studied education, though three had not themselves taught in a primary school, and two not in any school. The other MTE based in a teacher training college, and the five experienced teachers who also had a teacher continuing education role, had all been through EA primary teacher training provision and were locally considered experts in mathematics education, as required for enrolment on the course as an MTE. Examination results from the ten were mean 86%, SD 9%, as compared with a mean of 68% (SD 25%) for the whole primary group of 29. Mathematically, then, they were relatively confident, although in-course probing showed limited depth to many mathematical concepts. All ten claimed in survey 1 and/or in journals to have significantly developed their understanding of primary mathematics through the course, and their confidence to probe the associated meaning-making and link-making, both within and beyond mathematics, though assignments also exposed continuing limitations to that. There is a tension between the study of post-primary (and often post-secondary) mathematics that is often the focus of primary teacher preparation, and the deep knowledge of primary mathematics that the literature suggests is what is needed for effective teaching (e.g. Adler and Davis, 2006).

Mathematics pedagogy capacity: For all primary MTEs, the course featured substantially novel approaches to pedagogy, focusing as it did on active learning for meaning-making. The size of the whole primary group, at 29, was not comparable with the sizes most MTEs encountered in their own school or college (often 100 or more); nevertheless, after initial skepticism about availability of resources and adaptation to large classes, participants were observed to rapid adopt proactive discussion of adaptations so as to transfer the learning opportunities they were themselves experiencing. This continued into assignment work, with e.g. Kirabo generalizing 'people maths' approaches to form a 'human abacus' with her learners. MTEs all expressed personal enjoyment, and mathematical elucidation, via the active approaches taken, and through the ten days developed confidence to spontaneously share ideas for further localized development. Here, the 'modelling' approach taken meant participants directly experienced mathematics in ways intended to be used in classrooms, so that the move from 'replaying' home learning situations, to 'rehearsing' alternatives aligned with new experiences, was well-supported, and the more experienced MTEs were often also to 're-envision' context-specific adaptations of those, in Horn's (2010) terms. They also reported enhanced confidence to probe, to explore, to take risks in their classrooms as they began to prepare lessons in more depth and deliberation, drawing too on their own in-class experiences:

> 'I have spent some time preparing for this lesson and so I was more confident that if the pupils ask, I can answer. But I did not know that you can play games to help teach about place value, and my pupils and I are having very much fun and so they want to learn and they ask when can we play some more games and can we make up one that will make me get stuck. I think it is a good approach' (Tony, Assignment 1).

Capacity for mathematics teacher pedagogy: From early on, reflective journals and in-session talk showed college-based MTEs, three of whom had little experience in their role, and less experience as primary teachers, were challenged to re-envisage for their teacher education role approaches they personally claimed to experience as, for example, 'inspirational and concept-changing' (Elizabeth, journal, day 5). They chose to complete assignments via a comparatively challenging, verging on subversive, role that engaged trainee teachers in non-standard material, using approaches non-standard in EA classrooms, though were offered alternatives that would instead have meant working with local teachers and local primary classrooms. Given their backgrounds, there was not a straightforward option for them, but assignment reflections show only the most confident three such were able to re-envisage their teaching practice to accommodate practices that deeply reflected course approaches, and the other two failed to complete the assignments.

Four of the five school-based MTEs, in contrast, appeared to thrive on the assignments, developing clearly differentiated approaches to working with teachers instead of children, but transferring approaches to planning for learning, and to active, meaning-making collaborative tasks, and developing those between assignments 2 and 3. Kirabo, for example, worked with an in-school colleague who had also been on the course, to prepare a series of four after-school teacher workshops that saw full attendance by seventeen local teachers, targeting areas of the curriculum that participants had deemed most problematic.

> 'They have been inspired, they kept choosing to come back and now they want more. They say they are now enjoying their maths teaching so much.' (Kirabo, interview 2).

The fifth school-based MTE had comparatively weak mathematics knowledge, and assignments, as well as survey responses, showed he struggled to be confident to 'let go' of familiar didactic approaches especially with other teachers, though also with his own class: his accounts suggest he had neither the deep mathematical knowledge nor the confidence to fully adopt the approaches promoted on the course and via the AIMSSEC App. MTEs, then, between them showed how demanding on the teacher such approaches can be, with some struggling to rehearse, let alone re-envision, course-aligned practice. However, in the residential phase, it was clear that college-based MTEs benefited in their reflection on, and application of, both mathematical and pedagogical approaches from working in collaboration with practising teachers; equally, teachers who were comparatively weak mathematically brought to the group not only specific pedagogical experiences from their own classrooms, and associated reflections related to re-envisaging those, but also opportunity for all present to see the direct impact on mathematics learners of active meaning-making approaches.

Impact on other teachers and on primary learners: However, eight of the ten MTEs were able to evidence significant positive impact on either primary learners or trainee teachers, and seven of them on other local practicing teachers also:

> 'It has changed the attitude of my teachers to maths: they are interested and chase me to borrow resources we have made, and they talk enthusiastically about it…. And the children have caught that: they are trying out different methods and getting very excited about maths, now its hands-on practical and enquiry-based. Children are becoming very inquisitive, and spending time in the library investigating ideas.' (Kirabo, interview 2).

Kirabo also talked explicitly about learner attainment:

> 'I've been marking the related assignments and I'm seeing them improving so much. They're getting excited and they are achieving excellent results. And they know they are getting better, so they feel great.' (Kirabo, interview 1).

For those based in teacher training colleges, working with local teachers was a significant achievement, given their usual limited professional interaction with serving teachers, but also reported to be helpful to their trainees:

> 'I organised the workshop for local teachers, and they really responded well to it, and they kept adding new ideas for their classroom. So when I adapted the approach in the AIMSSEC workshop for my trainees, they know it's not on the syllabus and they were resistant at first, but then they were so enthusiastic about how much it will help them when they are next in school.' (Agnes, Assignment 3)

Discussion and conclusion

It is not possible to reliably generalise from a small sample such as that analysed here, but there are some indicators for consideration. Equally, although there is clear evidence of MTE development from the residential part of the course, and through progression in assignment responses, much of the evidence of their own, and certainly others', learning, originates in MTE accounts. These are inevitably subjective, and open to bias or the desire to please, although in many cases they are also specific, for example when David says in Assignment 2,

> 'I did not know there were many ways of thinking about a fraction, and I did not know I can make links between these things (fractions, decimals and percentages)'.

Further, the two authors are, in different ways, 'insiders' to the reported study. As such, we have endeavoured to be explicit about the nature of data supporting our analysis, and will have subjected the account to participant validation.

The serendipitous co-location of primary teachers, school-based MTEs and college-based MTEs provided a compelling need for modelling of inclusive pedagogies that affirmed and challenged all, including through peer learning. It also provided authentic classroom-embedded and teacher education-focused discussion that would simply not have arisen without such a mix: future provision will therefore set out to replicate that richness. Similarly, it is clear that Kirabo benefited greatly from being able to work with a colleague to prepare, challenge and discuss embedding in their school and in wider workshops. A model which, for example, pairs MTEs with a local experienced teacher so that they can take their professional development forward together clearly has potential.

We claim, then, that MTEs with a threshold level of capacity for change, including critical levels of reflection, were able to make significant progress in their technological, mathematical and mathematics pedagogical expertise and to adapt, embed and further develop that in their practice, at least in the short- and medium-term; reports suggest they were also able to positively influence the mathematical and pedagogical capacity of other teachers, and to impact primary pupil learning – of mathematics and of positive affect. In contrast, those without such a threshold capacity appeared unable to effectively re-envision practice. Quite what that threshold comprises, we do not yet know.

In terms of technology, the initial course discussed appeared sufficient to equip professionally confident MTEs with technological tools to access a range of materials for learning, and to support professional interchanges and development at a range of levels and granularities, via smart 'phones, occasional access to a computer or laptop, a variety of Apps, social media groups, and organisational/executive software, though easy access to appropriate software and hardware remains a challenge for some. However, subject-specific software that supports deeper mathematics learning, while appreciated by MTEs, is not widely accessible in many EA teacher or school student institutional contexts, so that embryonic related skills and confidence can easily dissipate.

However, in general, the approaches successful for primary teachers in South Africa appear to transfer, with only moderate adaptation, to MTEs, both college-based and school-based, in East Africa although further consideration needs to be given to the most appropriate assignment expectations for those who are college-based, since there is currently such a chasm between their expected college role, and the primary classroom teacher's experience. Of course, it might be that the time is ripe to re-consider the EA approaches to initial primary teacher education, so as to better align them with the professional demands of teaching for 21st-century needs. Overall, then, the study offers analysis of an emerging course structure that appears to have potential as a sustainable approach to teacher, as well as teacher educator, development for those needs, in the EA context.

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