Merging Mathematics Research and Development: Connecting Communities in an Emerging Network of Local and National Projects

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In this paper I share aspects of the work of my team, over the past twelve years as the incumbent South African Numeracy Chair at Rhodes University in Makhanda, South Africa. This is one of two National Research Foundation Chairs established to merge development with research in the search for sustainable solutions to persistent challenges in primary mathematics education particularly for 'disadvantaged' communities. The funding model stipulated establishing professional development (PD) with a minimum of ten schools, allowing flexibility, and, following rigorous evaluation, up to three five-year terms. This long-term flexible Research and Development (R&D) Chair model enabled a grounded, organically-emerging network of research-informed projects with multiple iterations enabling continual strengthening and gradual up-scaling. Here I share the PD and emergent projects from inception to date. This includes the Mental Starters Assessment Programme (MSAP) developed to address poor number sense and pervasive unit counting for calculating. MSAP emerged collaboratively from the first term experiences of the two Numeracy Chairs. Multiple iterations of design, implementation, and research, with key partners, enabled gradual upscaling in our second term with national piloting leading to roll-out with the Department of Basic Education (DBE) in our current third term. Thus, I hope to challenge dominant funding models that separate research from development in tightly-defined short-term cycles, and rather point to the possibilities within models that enable the development of an ever-improving and expanding network of R&D projects, informed by school and community partnerships.

It is a pleasure and an honour to give a keynote for the MERGA community that I have participated in, alongside my team of research collaborators and students, for the past few years. There are so many similarities between MERGA and our Southern African Association of Research in Mathematics, Science and Technology Education (SAARMSTE) which also holds an annual conference. Both communities provide essential participatory platforms for our ever-evolving, being and becoming, passionate, and engaged mathematics educators and researchers.

As noted in the abstract I draw on the body of work (and network) of my Chair team, and ongoing partnership with former fellow Numeracy Chair Hamsa Venkat, to elaborate on, and illuminate, the power of the *long-term, flexible,* '*development with research*' (R&D) funding model we have had the privilege of working with. [I note that this model of funding is quite different from, for example, Australian Research Council grants in length, flexibility and the][Foundation (NRF) Research Chairs in its inclusion of *development*]. A key broker in this model of Maths Chairs was Professor Mamokgethi Setati (now Phakeng) who brought together private funders (with particular interest in intervention work) and South Africa's Department of Science and Technology and National Research Foundation to establish six mathematics education research and development chairs. The appetite for this kind of funding emerges from the post-apartheid context with the urgency and ethical need to *respond* to challenges (that particularly impact the poor and historically racially oppressed), rather than to just report on problems. Major post-apartheid curriculum changes did little to address issues of inequality and poor performance in mathematics education. In 2010/2011 four R&D Chairs were appointed in secondary mathematics education (including Professor Jill Adler) and two in numeracy education (referring to mathematics in the early grades of schooling). The Chairs' brief was to work with the teachers of at least ten 'previously disadvantaged' schools to search for (research) sustainable scalable solutions to challenges encountered in mathematics education with an emphasis on reciprocal relationships between researchers and teachers where mutual benefits are negotiated (Setati, 2005). In design, the chairs ethically responded to the need to move away from reporting deficit research findings that simply feed into the problem (Graven, 2012), towards speaking about possibilities within the widely noted mathematics education 'crisis'.

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A key aspect of the power of long-term R&D programmes with flexible trajectories is that they allow repeated iterations of research and development programmes, improving and building capacity along the way, and thus strengthening the likelihood of success when scaling up (Venkat & Graven, 2022). In the talk I share a somewhat historical perspective on the emergence of a rich network of projects (beginning local and expanding nationally) to illuminate how long-term R&D funding, predicated on establishing local partnerships responsive to school needs (thus requiring flexible outcomes and deliverables), allows rich learning opportunities *for all* participants in the network (i.e. myself as Chair, researchers, teachers, learners, parents, teacher-educators, DBE partners) (Graven, 2019). I use this as a counterpoint to dominant funding models that work against such grounded longitudinal work. In last years' MERGA post-presentation discussion of our paper (Jorgensen & Graven, 2022), delegates expressed frustration with funding models that constrain opportunities for community partnerships to inform the direction and pace of research, particularly frustrating in the case of working with marginalised, indigenous and/or remote communities where research 'norms' are challenged. Thus, an aim of this paper is to highlight opportunities arising when funding enables flexible, responsive, community-informed, long-term research that is explicitly paired with development. While I acknowledge such funding opportunities are thin on the ground, and this model emerged from particular circumstances, I believe communities such as MERGA and SAARMSTE are well-placed to advocate for, and lobby private and public funders to support such endeavours.

The Context

The term 'crisis' is often paired with South African education, particularly mathematics education (e.g., Fleisch, 2008; Soudien & Harvey, 2021; Cosser, 2023). While our Grade 5 performance on TIMSS 2019 (Reddy et al., 2022) shows modest improvement since we began participating, we remain third from the bottom of 58 participating countries. In regional comparative studies we similarly perform worse than many of our poorer neighbours (Spaull & Kotze, 2015). We also have among the highest inequality in performance among wealthier and poorer learners. While we might challenge aspects of the validity of international comparative studies, our performance on our own annual national assessments (ANAs) last written in 2014 (as teachers refused to continue participating in them), was no better. Only 3% of Grade 9 learners got over 50% (DBE, 2014). 'Problems' have been noted to begin in the early grades of schooling with only 16% of Grade 3 learners performing at grade level and a learning gap of three grade levels 'between the poorest 60% of students and the wealthiest 20%' (Spaull & Kotze, 2015, 13). A widely noted cause of poor performance is the absence of number sense and the persistent use of the unit counting for calculations well beyond what is sensible or appropriate for the grade or number range (Schollar, 2008; Graven et al., 2013). Furthermore, learner access to mathematical meaning making is challenged when a fifth of Grade 1 children learn in English, increasing to almost 80% in Grade 4, this despite less than 10% speaking English as their first language, and despite a Language in Education policy that advocates home language instruction for at least the first four years of schooling (Robertson & Graven, 2019, 2021).

Teachers are often blamed for the crisis and yet the nature of the support they receive tends to involve short-term information dissemination sessions by district authorities aimed at curriculum coverage and compliance (Jita & Mokhele, 2012). Teachers have been sceptical about participating in such programmes due to a perceived lack of benefit, and particularly sceptical of those programmes involving research as this so often meant colluding in producing negative narratives about their work. Increasingly however attention is turning to initial teacher education given evidence that most teachers are not developing the knowledge required for primary mathematics teaching during their studies (Bowie et al., 2019).

In the South African Numeracy Chair Project (SANCP) we were determined to challenge deficit discourses by i) exploring opportunities for excellence in mathematics teaching and learning in marginalised, under-served communities and ii) communicating researched possibilities through multiple platforms. To do this, I developed ongoing partnerships with schools, teachers, district advisors, teacher educators and researchers, where jointly we could explore ways forward to challenges faced and create opportunities and share productive narratives of what is possible in South African mathematics teaching and learning.

Learning Through the Creation of Communities of Practice

The professional development (PD) programmes and the SANC research undertakings were developed with a Community of Practice (CoP) perspective of learning, drawing from the work of Wenger (1998) and Jaworski (2005). The latter's focus on critical inquiry communities is reflected in the names of three of the four PD programmes: early Numeracy-, Numeracy-, and Mathematics Inquiry Community of Leader Educators for Grade 1&2 (eNICLE), Grade 3&4 (NICLE), and Grade 4-7 (MICLE) programmes, respectively. We called the additional Grade R (pre-Grade 1) programme Early Number Fun (ENF), to highlight the emphasis on play-based learning pedagogies. It was the only single-grade PD CoP, a necessary arrangement, given that Grade R is a relatively new introduction to South African schooling with many teachers un- or under-qualified and few opportunities for PD tailored to the specialised nature of this important transition grade.

Wenger's (1998) CoP learning theory, based on his earlier work with Lave (Lave & Wenger, 1991) in adult learning communities, argues that the location of learning is in processes of co-participation in CoPs involving changes in members' ways of being and becoming in relation to practice. Building on Wenger (1998, 214), all of SANC's PD CoPs were designed as living contexts, giving newcomers (and all members) access to competence and inviting "a personal experience of engagement by which to incorporate that competence into an identity of participation". In these CoPs our "history of mutual engagement around a joint enterprise" provides a context for "leading-edge learning, which requires a strong bond of communal competence along with a deep respect for the particularity of experience". As Wenger notes "When these conditions are in place, communities of practice are a privileged locus for the creation of knowledge." (p. 214)

With this perspective, enabling effective professional learning requires providing access to quality resources and ongoing interactions between experienced and newer members of communities, as well as to information, resources (physical, knowledge, and other), and opportunities for full participation (Lave & Wenger, 1991). All of SANC's PD programmes established partnerships with teachers in which a deep respect for the teachers' particularity of experience was the basis for engagement with a range of research- and practice-informed resources and emerging initiatives. All programmes were long-term (minimum 18 months) with regular engagement (once or twice per month) with more than 14 partner schools (over 120 teachers and DBE partners across programmes). A staggered approach to implementation of programmes occurred over the ten-years of the first two funding terms such that, by the end of 2020, teachers of all grades in our partner schools had had the opportunity to participate in a programme with many teachers participating in more than one programme. In the current third and final term of funding we meet with teachers across all programmes on a bi-annual basis. Our PD orientation documents emphasize partnerships where *all* are co-learners, bringing different experiences and expertise to the joint enterprise of searching for productive possibilities in mathematics teaching and learning.

SANC's PD activities, including those for use in classrooms and after-school clubs, drew on Kilpatrick et al.'s (2001) definition of mathematical proficiency as encompassing five interconnected strands: conceptual understanding; procedural fluency; strategic competence; adaptive reasoning, and productive disposition. These strands would be developed through facilitating active engagement with research- and practice-informed resources in social settings,

where language and various modes of communication were considered essential tools for understanding (Vygotsky & Cole, 1978). Although there were some variations in the key representations and activities emphasised in different grade level programmes, the driving idea across programmes was the development of number sense with emphasis on the following (considered high-leverage) priorities: sense making and reasoning; developing a structural understanding of number; using key manipulatives and representations; progressions from concrete; enabling home practices and second sites of learning; developing productive dispositions and growth mindsets; stimulating maths talk (language & multilingualism) as a key resource; and developing fluency and efficient strategies.

Our research CoP comprises post-doctoral, doctoral and masters' students as well as research and development collaborators in our Faculty of Education and beyond. We similarly engage regularly around the joint enterprise of researching sustainable ways forward to challenges in mathematics education, jointly attend writing retreats, and overlap with multiple research and professional CoPs through our participation at multiple conference and stakeholder forums. Researchers are actively involved in PD programmes and development projects. While there are constant newcomers and departures also from our research community, the funding allows for long-term relationships and a relatively stable 'core team' as many researchers move from master to doctoral to post-doctoral studies and in some cases to colleagues. This has allowed for a socially cohesive and dynamic research team with growing research expertise and impact.

Emergent Projects

Through SANC's partnerships with schools and teachers, the need for supplementary learner-focused and home-based programmes emerged. The challenge of most learners being one or more grades behind curriculum level expectations required increased opportunities to learn beyond the limited time in school, often further challenged by disruptive events (e.g., protests, lack of water supply, extreme weather conditions). Furthermore, school and after-care centre communities requested opportunities for SANC's engagement with learners and families outside of school hours. A range of learner- and community-focused programmes thus emerged (Table 1). In the presentation I will elaborate on these community-focused projects. Here, however, I focus on only the two learner-focused projects that have evolved to national scalability.

Table 1

Emergent Learner-focussed and Community-focused Projects

Learner-focused Projects	Community-focused Projects
• After School Maths Clubs [National scaling of clubs with NGO & DBE district partners since 2015] • Mental Starters Assessment Programme (MSAP) [National scaling with DBE provinces since 2021]	• Family Maths days • Family Maths Storytime programme • Math/Science camp with after-care centre learners and facilitators • Community resource drive: Local newspaper maths activity supplements; online and Facebook resources expanded during Covid-19

The After School Maths Clubs were designed to be informal supportive learning spaces in which groups of learners and facilitators/teachers would explore maths, solve problems and play maths games free from the constraints of large class teaching with the pressure of curriculum conformity. Emphasis is placed on talking maths, asking questions, being free to be messy, playing fluency and strategy games, and being an active (rather than passive) learner (Graven, 2015). Following the first pilot in 2011, multiple clubs were set up at local partner schools and after-care centres (catering for

vulnerable learners). The clubs were run by researchers in the Chair team (along with teachers and facilitators), and provided us the opportunity to work directly with learners and to trial several research-informed resources and activities prior to engaging with them in PD CoPs. They also provided an empirical field for several post-graduate research projects. Some researchers ran their own clubs or supported others to run clubs. For example, three SANC researchers who were also teacher advisors in the DBE, researched the expansion of clubs as part of their district work with teachers, each working with ten teachers to set up and run clubs (see Stott et al., 2017). Following multiple presentations by our club researchers across various platforms (e.g., Baart, 2019), we began receiving requests from various mathematics education NGOs working across multiple provinces for support in setting up clubs. To date, hundreds of Maths Clubs have been set up across grades and provinces and we (our Chair and various NGOs, particularly OLICO) have formed a Maths Clubs Collective of partners collaborating to provide quality club resources and support to those willing to run clubs (see mathsclubs.co.za). The scalability of the Maths Clubs thus emerged organically from SANC's local work, expanding nationally in partnership with DBE teacher educators and NGOs.

The Mental Starters Assessment Programme (MSAP) emerged from the grounded experience of working with teachers and learners in SANC's first five-year term. It was jointly conceptualised in 2016 by our two Numeracy Chairs, with key partners, as a possible national intervention aimed at addressing the pervasive persistence of unit counting for calculating and an absence of number sense. The opportune 'classroom space' identified for implementation of targeted teaching for number sense and progression away from unit counting was the 10-minute 'mental maths warm-up' start of lessons. Research had indicated that this space was being ineffectively used in many classrooms (Venkat & Naidoo, 2012). The curriculum space identified was mental strategies. The policy space, as pointed out by our partner Dr Marc Chetty (DBE's Acting Director: National Assessment), was a call focusing on diagnostic assessments. In terms of teacher professional development, we saw MSAP as an ideal space for promoting the use of key representations that support developing a structural understanding of number. These included the empty number line and part-part-whole diagrams, representations that were not visible in many classrooms. The relatively low-stakes lesson starters and diagnostic assessments had the advantage that they could be run concurrently with other DBE initiatives making it less likely they would be derailed by possible future policy initiatives. While beyond the scope to elaborate upon here, the MSAP teacher guides and print masters (available on the DBE platform www.education.gov.za/MSAP2022.aspx) provide Grade 3 teachers with six units each focused on a calculation strategy (bridging through ten, jump strategy, doubling and halving, reordering, rounding and adjusting, and linking addition and subtraction), with a brief pre-test (with rapid recall, strategic calculating and strategic thinking items), 8 scripted (and QR code demonstrated) lesson starters, followed by a post-test. The pre- and post-testing focuses on learner gains rather than raw marks. (See, e.g., the QR code, below, for the support video for Jump Strategies Lesson Starter 2). Following multiple iterations of trialling, gradually scaling up from Chair-run local feasibility trials to DBE-run provincial trials, the project is now being rolled out nationally by the DBE. (See Graven & Venkat, 2021; Askew et al., 2022, for discussion on the evolution of MSAP and research results).

Network of Interconnected CoPs and Projects Engaging Locally and Beyond

The long-term flexible funding model for the Chairs thus enabled an innovative network of mathematical research and development projects that provided members (i.e., learners, teachers,

teacher educators, families, researchers) opportunities to engage in ongoing activities with members from different communities, providing multi-directional learning opportunities for all members. Figure 1 shows the way in which various projects (indicated in the triangles) connected members from the different communities. Opportunities for members to participate in multiple projects and communities enabled them to broaden their engagement with mathematics education and/or research activities and to develop leadership trajectories along the way (Graven, 2019). Many teachers, teacher educators, and researchers thus expanded their engagement to become centrally participating members in multiple CoPs they had not previously 'belonged' to. Teachers, for example, became researchers participating in conference CoPs, and became involved in supporting districts in teacher 'training', and providing input into national initiatives. Researchers were inducted into multiple national and international conference communities, and some became teachers/facilitators (in clubs) and teacher educators (in PD CoPs) (Graven, 2019). Figure 1 shows how flexibility of funding enabled the Chair to go far beyond its mandated PD triangle. In terms of the research mandate, our Numeracy Chairs grew South Africa's field of primary mathematics research. To date our SANC, Rhodes team of researchers have contributed over 170 peer-reviewed papers published in conference proceedings, book chapters and local and international journals. Comparing the decades 2003-2012 and 2013-2022, Morrison et al.'s (in press) review of South African research in mathematics in the early grades (Grade R,1,2, & 3) found that *journal* articles increased more than fivefold (with an increase from 1 to 20 in top international journals). Analysis of this growth points to substantive contributions from the two Numeracy Chair research teams.

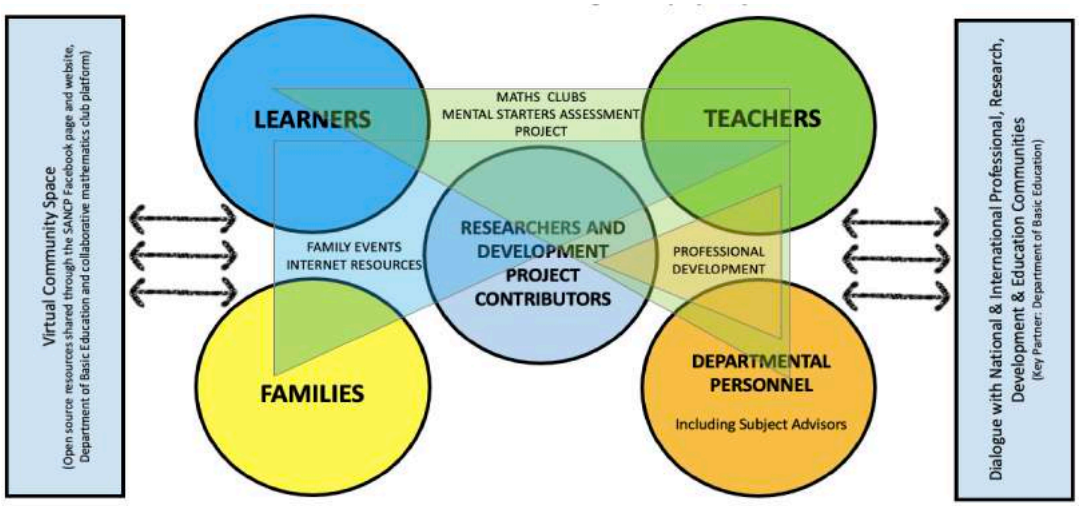

Figure 1. Communities interconnected through project spaces (adapted from Graven et al., 2022).

Concluding Remarks: Returning to the Funding Model

It has been an enormous privilege to have the opportunity to support both research and development in primary Mathematics as the South African Numeracy Chair at Rhodes University since 2011. In this paper I have pointed to the way in which three key aspects of the Chair funding model: long-term engagement, research *with development*, and flexible 'deliverables', enabled ethical, grounded work that supported the emergence of a powerful network of communities. Multiple learning opportunities emerged from this network far exceeding the sum of those available within each individual project or community. The network provided a momentum for learning that grew with time and allowed key stakeholders in mathematics teaching and learning to work together in ways that supported dialogue and mutual collaborative learning. The longitudinal timeline allowed multiple stakeholders to shape the work and allowed the ever-improving and expanding iterations of programmes to support capacity-building across different communities thereby increasing the opportunity for successful scalability and sustainability.

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