

Sustaining and scaling up research-informed professional development for mathematics teachers

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Received: 19 September 2017 Accepted: 19 December 2017

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Education research journals regularly report on small-scale studies that have been successful in changing mathematics teachers' classroom practices. But it is rare to find professional development programs for teachers of mathematics that have been scaled up and sustained over time. This article reports on a research-informed, large-scale professional development project initiated by a state education system in Australia that now involves a large number of schools and teachers. The project developed a cluster model for bringing together primary and secondary school teachers to build their curriculum knowledge, confidence, and enthusiasm for teaching mathematics. The study aimed to identify factors that contribute to the sustainability and scaling up of this initiative. Drawing mainly on interviews with 61 participants – teachers, school curriculum leaders, principals, and regional education leaders – the study identified factors related to professional development content, collective action, and leadership at the school and regional levels. The findings contribute to the literature on mathematics education reform and identify implications for supporting teachers and schools in this enterprise.

Education research is often criticised for its lack of impact on classroom practice, and the divergence between research and practice seems to be especially pronounced in mathematics education. Boaler (2008), for example, contends that “mathematics is the subject with the largest gap between what we know works from research and what happens in most classrooms” (p. 91). Despite this disparity, education research journals regularly report on small-scale studies that have led to changes in classroom practice of individual or small groups of mathematics teachers. Such findings are specific to the context in which the study was conducted but there is recent international interest in scaling up sustainable interventions in mathematics teacher professional development (e.g., see Higgins & Bonne, 2011; Roesken-Winter, Hoyles, & Blömeke, 2015). In a recent review of Australasian research in this area, Beswick, Anderson, and Hurst (2016) called for greater attention to be given to “issues of scale, sustainability, and the impacts of PL [professional learning] at organisational and systemic levels” (p. 347).

This article reports on the findings of an investigation into a professional development project, instigated by an Australian state education system at a regional level, which has been sustained over time and has expanded to involve more than 70 schools and over 200 teachers. The initiative developed a cluster model for bringing together primary and secondary school teachers and principals to analyse student performance data, create diagnostic tasks that reveal students' current mathematical understanding, and demonstrate teaching practices that promote mathematical problem solving and reasoning as well as fluency and understanding. Planning for these professional development sessions is informed by relevant research in mathematics education, for example, via professional reading undertaken by regional education officers or discussions with university-based researchers. The regional education officers act as curriculum

experts who deliver the sessions, with occasional invited input from mathematics education researchers. There is a growing number of schools volunteering to join the initiative and commit professional development funding, suggesting that schools see this approach as effective. Self-reported improvements in teacher confidence, knowledge, and classroom practice; teacher perceptions of greater student enjoyment of mathematics; and improvement in student performance on national numeracy tests provide evidence to support this perception. The aim of this article is to identify factors that contribute to the sustainability and scaling up of this initiative, with a view to contributing to the literature on educational change.

Background and context

The professional development initiative is situated within one of the administrative regions of an Australian state education department. The region has 219 state schools, serving more than 115,000 students. The impetus for the initiative came from the introduction in 2011 of the first nationally consistent Australian Curriculum (ACARA, n.d.a). One of the ways in which the state responded to the new curriculum was to prepare a comprehensive resource package comprising year level plans, unit plans and supporting materials, and lesson plans and resources across the different learning area curricula. The package was launched with a high expectation by state department officials that teachers in government schools should use these materials; in addition, the package was later made available to the state's non-government school sector and to some other Australian education jurisdictions. Although the package was intended to support implementation of the Australian Curriculum, this is a top-down approach that risks alienating teachers if they have not been involved in its development. Such an approach may also communicate mistrust of teachers' capacities to plan tasks, lessons, and assessment to meet diverse student needs (Barton, Garvis, & Ryan, 2014).

The assessment context for the professional development initiative is also significant. Since 2008 the literacy and numeracy skills of all Australian children in Years 3, 5, 7, and 9 have been tested annually in the National Assessment Program – Literacy and Numeracy (NAPLAN). The national and state/territory governments are keenly interested in NAPLAN results as an indicator of the quality of teaching and learning in Australian schools. Recently, concerns have been expressed at the lack of long term improvement in numeracy achievement since the NAPLAN tests were introduced, provoking debate on strategies for a national response (Masters, 2016). At the same time, however, researchers have consistently drawn attention to the negative impacts of high stakes NAPLAN testing, such as the devaluing of teacher professional judgment in appraising student learning, pressure on schools and principals to find "quick fixes" for lifting test scores, and the emergence of questionable practices for achieving this improvement. (Klenowski & Wyatt-Smith, 2012; Thompson & Cook, 2014). Thus the background to the initiative was framed by national and state-based assessment and curriculum contexts that had potential to devalue teachers' professional knowledge and skills.

The initiative discussed in this article involved regional education officers working with six clusters of primary and secondary schools to improve the quality of mathematics teaching and learning. The broad goals of this work are to improve:

- students' performance on NAPLAN numeracy tests;
- students' dispositions towards mathematics (engagement, enjoyment, perception of relevance); and
- teachers' knowledge, confidence, and enthusiasm for teaching mathematics.

In light of the national curriculum and high-stakes assessment context that framed the initiative, an additional goal is to (re)build teachers' expertise in interpreting and implementing the Australian Curriculum and in using assessment evidence to improve student learning. Since 2012, the approach taken to this intervention has evolved from a regionally funded model of individual coaching of teachers and mandated school participation into a voluntary, school-funded cluster model with collective participation of groups of teachers. Starting in 2015, the number of participating schools has grown from 5 to more than 70 and the annual funding that schools provide for teacher release has increased from less than \$50,000 to more than \$400,000. All of this funding has been voluntarily redirected from the schools' existing professional development budgets, replacing spending on commercially produced curriculum resources or external consultants. Thus implementation of the initiative is cost-neutral for schools and the state education department. In addition, many schools volunteer to continue their participation each year beyond the six months for which they initially enlisted (see Proffitt-White, 2017, for a more extensive description of the processes developed within the cluster model). Clearly, then, there is evidence that the initiative has been sustained and scaled up over time.

The research literature suggests that efforts to scale up educational innovations are usually approached from either a top-down or a bottom-up perspective (Begg, Davis, & Bramald, 2003). Top-down approaches that propose a linear transfer from research to policy to practice are mostly considered to be ineffective because they do not empower the people implementing the change to make decisions or take ownership of the change process. Bottom-up approaches may seem preferable because they involve teachers in identifying problems that matter to them and working together on developing solutions. However, such approaches can also be ineffective if they only lead teachers to replicate existing weaknesses. The cluster model that is the focus of this article seems to combine top-down approaches led by officers of the state education department and bottom-up approaches motivated by teachers' own needs, while additionally "seeding" the professional development environment with externally validated research knowledge. Although there is considerable support for these approaches in the education research literature, we believe that it is rare to find this kind of effective implementation in practice. To understand factors contributing to the effectiveness of this initiative we draw on literature on teacher professional learning and scaling up sustainable interventions.

Teacher professional development at scale

A great deal is now known about designing effective professional development for teachers. Mewborn's (2003) review of research on professional development for teachers of mathematics concluded that change is a long term, evolutionary process that can be supported by giving teachers opportunities to engage with mathematical concepts and their own students' thinking as they struggle to understand these concepts. Mewborn, together with Wilson and Berne (1999), also argued that professional learning is enhanced when it occurs in school-based contexts so that teachers can try out and validate ideas in their own classrooms, and collectively discuss issues and problems with supportive colleagues. Teachers' need for collaboration, experimentation, and reflection is unlikely to be met by short-term workshops that demonstrate innovative materials without support for trialling the materials in their own classrooms.

Garet, Porter, Desimone, Birman, and Yoon (2001) surveyed more than 1000 mathematics and science teachers in the US to examine characteristics of professional development they had experienced and the self-reported effects on the teachers' learning. Based on their analysis of the research literature, these investigators distinguished between structural and core features of

professional development activities. Structural features included the type of activity (short-term workshops or courses offered away from the school context vs activities such as coaching and mentoring embedded in the teacher's regular work day), duration of the activity (contact hours and time span), and the extent of collective participation by groups of teachers from the same school, department or year level. Core features were defined as the extent to which there was a focus on content knowledge and how children learn this content, opportunities to engage in active learning (observing and being observed in one's classroom; planning classroom implementation; reviewing student work; giving oral or written presentations), and the coherence of the professional development activities (connections with other activities; alignment with national, state and local curriculum frameworks and assessment; opportunities for communication with colleagues engaged in the same reform efforts). These measures contributed to a causal model suggesting that all three core features – content focus, active learning, and coherence – had a positive influence on teacher knowledge, skills and classroom practice. Amongst the structural features, sustained and intensive professional development was more likely to have a reported impact on teacher learning than shorter duration activities. Garet et al. (2001) identified cost as a major challenge in providing the kind of professional development with the characteristics they discovered to be associated with teacher learning. However, Loucks-Horsley, Love, Stiles, Mundry, and Hewson (2003) additionally pointed to a number of critical issues in extending effective programs to teachers in other schools, including scaling up beyond early adopters and building capacity for sustainability.

Roesken-Winter et al. (2015) argued that scaling up involves more than just a quantitative increase in the number of participating teachers or schools: it also is associated with qualitative changes in responsibilities, norms, and practices that bring scaling up into a dynamic and co-dependent relationship with sustainability. Coburn (2003) captures well the nuances and tensions in understanding "scale." She develops a definition with four interrelated dimensions: depth, sustainability, spread, and shift in reform ownership. Depth refers to "what" changes, and implies that reform at scale must cause teachers to fundamentally rethink their beliefs instead of simply prompting superficial uptake of materials or classroom activities. Scale can only be achieved if change is sustainable over time in the face of shifting priorities and competing demands – yet it is rare for research designs to allow for discovery of whether change achieved in the short term has lasted over time. Spread entails adaptation as much as replication of an innovation, but this idea hints at the tension between fidelity and flexibility in achieving large-scale reform. On the one hand, fidelity to underlying norms and principles would seem to be essential in spreading a reform initiative; on the other hand, certain types of spread might involve adapting and re-embedding these norms and principles in new contexts, leading to different enactments of the reform that nevertheless retain its integrity (see also Tirosh, Tsamir, & Levenson, 2015). A shift in ownership of the reform from external to internal authority gives responsibility to schools and teachers for enacting the initiative, thus contributing to its sustainability.

Tirosh et al. (2015) identified a number of possible factors affecting the sustainability and scalability of four system-initiated mathematics teacher professional development programs. Factors within the programs affecting sustainability and scaling up included the original motivation and the extent to which this aimed to meet the needs of the system or the needs of the teachers, the program content, and the degree of collective participation. Factors beyond the program were also influential, such as the support that teachers gained in their school environment and ways in which positive outcomes, especially improvements in student learning, were made visible, shared with others, and celebrated. This review and the discussion of scale offered by Coburn (2003) highlight the need to attend to structures, organisations and systems as well as the conduct of professional development sessions in which teachers participate.

For some time Cobb and his colleagues have been investigating what it takes to improve the quality of mathematics instruction at scale (e.g., Cobb & Jackson, 2011; Cobb, McClain, Lamberg, & Dean, 2003; Jackson et al. 2015). Cobb and Jackson (2011) developed an empirically grounded theory of action, based on their research in the US education context, that has five key components. The first is a coherent instructional system that supports teachers' development of ambitious teaching practices. The elements of such a system correspond to what Garet et al. (2001) might refer to as "core features" of professional development. In Cobb and Jackson's model these comprise: clear goals for student learning; a vision for instructional practices that lead to students attaining these goals; materials to help teachers develop these practices; sustained, district-based professional development that focuses on these practices and is organised around these materials; school-based professional learning communities; assessment aligned with learning goals that informs instruction and identifies students who are struggling; and additional supports for struggling students. Consistent with previous research on professional development and scaling up, Cobb and Jackson nominate teacher networks as the second component of their theory of action. Their third component, mathematics coaching, can be implemented in a variety of ways but focuses on providing teachers with access to more accomplished colleagues who can work closely with them on problems that are close to practice. The fourth and fifth components are school and district instructional leadership respectively, which resonates with the ideas expressed by Coburn (2003) and Tirosh et al. (2015) concerning gaining support from others in the school environment, making change visible, spreading reform initiatives, and shifting ownership from the system to teachers and schools.

We adopt Cobb and Jackson's (2011) framework to identify factors that contributed to the sustainability and scaling up of the regional professional development initiative discussed in this article. We organise our analysis around three features of the initiative: (1) the extent to which the content of the program represented a *coherent instructional system* supporting teacher development of ambitious teaching practices; (2) support for *collective action*; and (3) instructional *leadership*. We view collective action as incorporating *coaching* and *teacher networks*, and instructional leadership as taking place at *school* and *regional* level.

Research design and methods

The first author has been meeting informally with the regional education officer who led development and implementation of the cluster model (the third author of this article) once or twice each year since 2012 to act as a sounding board for development of the initiative as it unfolded over time. However, the research study we report in this article was conducted in 2017. It employed purposeful sampling to identify three existing clusters of schools participating in the regional professional development initiative. The school clusters were chosen to exemplify different stages of engagement with the cluster model and different professional development foci within each cluster in order to investigate key similarities and differences between them. Identification of schools was undertaken in consultation with the regional education officer. Data in this article are drawn from participants in two of the clusters, Cluster A comprising a high school and its six feeder primary schools in a regional city and Cluster B comprising six primary schools in the rural hinterland of a densely populated coastal centre. Cluster A was the first cluster to be established, building on a prior history of collaboration between schools in the area, while Cluster B is one of the newer clusters. As Australasian research suggests that primary school teachers often enter the profession with negative attitudes towards mathematics and weak mathematical content knowledge (Anthony, Cooke, & Muir, 2016), these two examples provide an

opportunity to examine the workings of clusters that supported primary teachers in strengthening their professional knowledge and confidence in teaching mathematics.

Participants in the study were teachers and curriculum leaders who attended the cluster professional development workshops, principals of participating schools, and regional leaders responsible for the professional development initiative. Two whole-day workshops were scheduled in the first half of the school year for each school cluster to undertake professional development activities. The first two authors attended these workshops to observe the content and structure of activities and collect sample materials prepared by teachers. The third author, who was the professional development facilitator for this initiative, provided additional data in the form of presentations made to schools and to regional and state education department leaders to explain its goals, methods, and outcomes.

Interviews with teachers, school curriculum leaders, and principals were mostly conducted during the second workshop for each cluster. Teachers were interviewed in school groups; school curriculum leaders were interviewed with teachers or individually; and principals from the same school cluster were interviewed together. A small number of principals were unavailable during the workshops and instead interviewed via telephone. Ten interviews were conducted with members of Cluster A, comprising 18 teachers, 5 school curriculum leaders (e.g., head of curriculum, master teacher, head of department), and 7 principals. A further nine interviews were conducted with members of Cluster B, comprising 15 teachers, 5 school curriculum leaders, and 6 principals. In addition, individual interviews were conducted with 5 regional leaders who were responsible for designing and delivering the professional development initiative. Interviews lasted from 30-80 minutes, and were audio-recorded and later transcribed. The first two authors conducted the interviews. They asked school-based participants whether or not the cluster model worked well for them, why they joined the cluster initiative, how this approach compared with their previous experience of professional development, what changes they had seen in students and teachers, and what they considered to be factors contributing to the sustainability and scaling up of the initiative. Regional leaders were additionally asked about the origins of the cluster model and circumstances that led to its development and spread. All participants were asked what advice they would give to colleagues in schools outside the region who might be interested in trying the cluster model, and especially any pitfalls that should be avoided.

Interview responses to each question were transferred to spreadsheets that allowed for question-by-question collation of responses from every school in a cluster. Separate spreadsheets were created to record responses from principals and teachers/school curriculum leaders to allow aspects of leadership and collective action to be identified. An inductive content analysis identified common categories in responses to each question, initially for one cluster. These categories were then applied to responses from participants in the second cluster, and refined or expanded to accommodate any differences in responses. Thus the analysis looked for coherence within a cluster and then across clusters. For each cluster, a summary of response categories was created for all teachers/school curriculum leaders and all principals, together with a record of the number of schools represented in each category. The analysis thus captured the thematic range and frequency of responses across schools. These summaries, the individual interviews with regional leaders, and materials created by teachers and the facilitator were searched for evidence of aspects identified by Cobb and Jackson (2011) as being associated with a coherent instructional system, collective action, and leadership that contributed to the sustainability and scaling up of the professional development initiative.

Factors contributing to sustainability and scaling up

Our analysis uncovered many complexities and interlocking factors contributing to the effectiveness of this initiative. These are progressively identified and discussed in building a rich picture of its implementation over time and across clusters of schools.

A coherent instructional system

The core features of the professional development initiative were driven by goals for student learning aligned with the Australian Curriculum: Mathematics (ACARA, n.d.b), expressed through the mathematical proficiency strands of fluency, understanding, problem solving and reasoning. There are tensions in representing the interdependence between these proficiency strands and the more traditional content strands of the curriculum that often result in an over-emphasis on fluency to the detriment of higher-order processes involved in problem solving and reasoning (Goos, 2018). Thus one of the *explicit goals for students' mathematical learning* (Cobb & Jackson, 2011) was to develop these capabilities alongside fluency and understanding. From the perspective of regional leaders, there was an explicit parallel goal for teachers in building their curriculum knowledge:

We've got to make sure we take our teachers through the deep understanding of the Australian Curriculum. So they can design, and they can then provide opportunities for kids within the curriculum. [Regional leader]

While principals were concerned about lifting NAPLAN performance, they had also identified growing student negativity towards mathematics that was manifested through lack of interest and engagement, behaviour problems, and absenteeism from mathematics lessons. Consequently, a second goal for student learning was to improve their mathematical dispositions.

Drawing on relevant mathematics education research literature, the regional education officer who led the initiative designed a series of whole-day workshops that addressed teachers' beliefs, knowledge of mathematics and how children learn mathematics, and pedagogical practices. An overview of one year's workshop plans is presented in Figure 1. The workshops introduced teachers to a repertoire of practices for revealing and diagnosing students' thinking; modifying tasks in order to support reasoning and problem solving; orchestrating productive mathematical discussions; building positive student dispositions; and designing assessments that align with the Australian Curriculum achievement standards, are accessible to all students, and elicit a range of student performances (Dweck, 2000; Smith & Stein, 2011; Sullivan, 2011; Sullivan, Clarke, & Clarke, 2013). Participating schools undertook to release several teachers for these cluster workshops 3 times per term. The workshops thus constituted one vehicle for communicating *a vision of high quality instruction that specifies practices leading to attainment of student learning goals* (Cobb & Jackson, 2011).

Session 1	Mathematics: Rationale & Aims What pedagogies, activities and beliefs are needed for high quality teaching?	7	Number Facts: Evidence based practices Anchoring basic facts to enable efficient problem solving and a positive disposition
Session 2	Using the standards to track and monitor student progress	8	Mental computation: How to encourage the right knowledge and disposition to become confident with Number

Session 3	Annotating student work samples to focus and align feedback	9	Differentiation: Using questioning to activate the proficiencies and general capabilities
Session 4	Cognitive activation tasks: Extending and enabling students	10	Numeracy & STEM literacy: Tasks to make it real for every student every day
Session 5	Cognitive activation tasks: Context, complexity and literacy demands	11	Creating assessment-capable students with tasks
Session 6	Planning school routines for the right interventions at the right time	12	Designing the right assessment tasks to align professional judgements
A typical agenda			
8.30-9.00: Each school communicates to the group what they have been enacting in class from the previous workshop. Short term wins and barriers are shared and discussed.			
9.00-11:00 Teachers moderate activities and assessment tasks with the Regional expert.			
11:30-1:00 Teams of teachers observe their activities in class and reflect on the words and actions that are needed to differentiate and engage all students.			
1:30-2:30 Teachers frame this session to raise or share issues around curriculum implementation.			

Figure 1. Overview of a year's workshop plans

Teachers and principals were asked about the impact of this approach on students' learning of mathematics, with the most common response category referring to positive changes in students' dispositions. One principal's comment exemplifies the responses of several participants:

Kids will tell me they love maths! That's probably been the first time in my career that's happened. [Cluster B, School 6]

Teachers in at least half the schools said they noticed greater enjoyment, engagement, confidence, and enthusiasm for mathematics amongst their students. For example, several teachers told us that students would now cheer when the teacher announced it was time for mathematics:

I set myself the challenge at the start of this year that I was going to attempt some kind of inquiry or open-ended question every maths lesson. So we call it messy maths and they have a scrapbook. I'll say to the kids all right, let's get our messy maths books out and they cheer. [Teacher, Cluster B, School 4]

This comment also illustrates the attention given to addressing students' fear of failure in mathematics. Teachers were now emphasising thinking processes more so than getting the correct answer and encouraging students to view mistakes as opportunities for learning and windows into their thinking (Dweck, 2000). According to one teacher, "now mistakes feel awesome" [Cluster A, School 3].

Teachers in more than half the participating schools also mentioned quantitative and qualitative changes in student talk, with less whole class teaching and more small group discussion to allow students to explain their thinking and engage in "deep mathematical conversations" [Cluster A, School 5] with peers.

Teachers in every school claimed that their new instructional practices, initially modelled and discussed in the professional development workshops, led to these changes in student mathematical learning. One described it as being "just a completely different way of teaching" [Cluster A, School 1]. Others commented on what they were learning about student thinking and how they were encouraging this:

I have been amazed by what the kids have been able to do because I would have thought [they] weren't capable of doing it – which just wasn't true. Because the kids have shown it in what they've been doing and I'll go and talk to the kids and say to them, "explain to me how you got that answer". Even the preps can do it, it really is amazing. [Teacher, Cluster B, School 4]

Teachers in almost all schools identified a distinguishing feature of the cluster professional development model as the opportunity to develop resources themselves, in collaboration with colleagues, that could be trialled in their classrooms immediately and then brought back to the next cluster meeting, along with sample student work, for refinement.

We're not just being told what to do and being delivered as a presenter, we're then getting the opportunity to put those things into practice. Then, I suppose the added advantage of this is the resources and things that we are making. [Teacher, Cluster B, School 2]

This contrasts with most teachers' previous professional development experiences, summarised by one as "Here it is, now go and use it" [Cluster B, School 1] and by a principal as "the cattle dip approach" [Cluster B, School 2]. The consistency in interview responses suggests that the *instructional materials and tools* were designed not only to *support teachers' development of the target practices* (Cobb & Jackson, 2011) but also to build their curriculum knowledge and confidence in planning and designing their own resources, over an extended period of time. Several teachers expressed the view that their professional knowledge had been undermined when they were obliged to use the state-developed resource package supporting implementation of the Australian Curriculum:

For the last few years I haven't had to think. I haven't had to plan. It's all been done for me. So this is fabulous. This is really enthusing me as a teacher. [Teacher, Cluster A, School 1]

Similarly, in one cluster, principals of three different schools agreed that the initiative was allowing teachers to reclaim ownership of their profession. One explained this transformation in the following way:

What I'm seeing now is I'm seeing activities being held in my classes where the teachers are just taking control of their profession and they're bringing it back. [Principal, Cluster B, School 1]

The fourth and fifth elements of Cobb and Jackson's (2011) coherent instructional system are concerned with *regional professional development focused on the target practices and materials and sustained over time*, and *school-based professional learning communities*. Here it is important to emphasise that the regional professional development initiative has evolved over a five-year period into its current form. The facilitator initially worked as a numeracy coach with individual schools before one of the regional leaders proposed a cluster model that would bring together 6-7 schools in geographical proximity (Cluster A). The regional leader who had been a school principal in this alliance was responsible for initially proposing the mathematics-focused cluster model that built on the goodwill and relationships that had already been forged between the school principals. Our interview with this regional leader identified three main reasons for taking up the cluster approach: first, it allowed for more efficient use of scarce resources in the form of the small team of facilitators based in a region serving more than 200 schools; second, it "empowered principals to work together as a collective whole" for the good of all students; and finally, it supported teachers' learning by "building professional relationships – sharing work, discussing work, designing work."

One of the most valued features of the regional professional development was the facilitator – teachers and principals in almost every school said that their previous experience of working with him was the main reason for wanting to join the cluster initiative. He was admired and respected not only for his knowledge of relevant research, but also for his credibility as a classroom practitioner. One teacher maintained that “being able to see [him] in the classroom and watch the way that he teaches the kids and watch their engagement and what they learn from him was absolutely incredible” [Cluster A, School 1], while another described the motivating effect on her own practice: “It’s with our children, it’s in our school, and it’s a lesson that we can then go and have a go at because we’ve seen it in action with [him]” [Cluster A, School 4]. This view was endorsed by a regional leader who had been principal of one of the schools in which the facilitator had worked:

Just to see the change in engagement in the students, I think that was the first stepping point in getting the buy-in with the teachers. [Regional leader]

In addition to these qualities, there was uniform admiration for the facilitator’s interpersonal and leadership skills, his enthusiasm for mathematics, and his respectful engagement with teachers that signalled he valued them as professionals. One principal succinctly captured the relationship between facilitator expertise and the quality of the professional development by describing it as being “teacher driven and quality assured” [Principal, Cluster B, School 1]. In his view, this was one of the most important factors contributing to the sustainability of the initiative.

The notion of *school-based professional learning communities* underpinned the design of the initiative. In all but the smallest schools, principals were asked to release at least two or three teachers for the whole day workshops; some decided to send a teacher from each year level as well as a teacher in a middle management curriculum leadership role. There was an expectation that these participants would then share their experience with colleagues in their schools. One teacher described the transformative effect of working in such a community:

The principal decided to take it on so that we could all support each other and learn and boy, have we learnt a lot. It’s changed my whole way of thinking and I thought I was a good maths teacher beforehand. [Teacher, Cluster B, School 3]

Aligning assessment with student learning goals, as an element of the instructional system proposed by Cobb and Jackson (2011), is central to the professional development workshops, in two ways. One of the first activities implemented with teachers involved developing diagnostic tasks that focused on key mathematical concepts, such as place value, in order to identify what students already knew and where there were gaps in knowledge so that teachers could plan instruction accordingly. Teachers have now developed diagnostic tasks for all curriculum topics and year levels in the F-10 Australian Curriculum: Mathematics (ACARA, n.d.b), and these tasks are available for sharing between, as well as within, clusters in the region. This process has also contributed to teachers reclaiming their professional knowledge of assessment and reducing their reliance on the state-developed resource package for supporting implementation of the Australian Curriculum. As one teacher explained:

We’re trying to get away from the [resource package] because we’re saying that we want these diagnostics to inform your teaching. So we don’t want you doing all this stuff that the kids already know, we want you teaching what the students *need* to know. [Teacher, Cluster B, School 3]

The final element of Cobb and Jackson’s (2011) coherent instructional system offers *additional supports for struggling students*. It appears that such supports were integral to the new teaching practices promoted by the professional development initiative, especially in terms of

encouragement for students to explain their thinking. Several teachers noticed that lower achieving students flourished in this environment:

Something else I've noticed is interesting and quite possibly challenging for some is that that idea of talking about it and changing someone's mind and that, the lower level kids are probably succeeding more with that and with challenging questions and open ended questions. They are, I think, succeeding more with that than some of the higher level kids because the higher level kids are used to just, "I got the right answer, there you go, I'm done." But now they're being challenged to explain why and [...] some of them are finding that a bit confronting. They just want to be right and be done with that. [Teacher, Cluster A, School 5]

Collective action: Coaching and teacher networks

The analysis presented so far has provided a glimpse of possibilities for collective action afforded by this professional development initiative. *Coaching* is a form of job-embedded support that gives teachers access to more accomplished colleagues who can work with them on problems close to practice (Cobb & Jackson, 2011; Garet et al., 2001). This was the approach initially taken by the regional education officer who later led the cluster initiative, and it proved effective in establishing his credibility with teachers and principals and motivating change. Teacher networks were consistently identified by teachers, principals, and regional leaders as being central to the sustainability and spread of the professional development initiative. Networks took different forms, extending beyond the professional development workshops and into schools. One regional leader suggested that such networks helped teachers to feel safe and supported in order to take risks in changing their practice. A principal explained that networking between schools provided the impetus for teachers to accept the need for change:

For those teachers to be able to sit down with other teachers from other schools and look at some really best practice. We know that's being quality assured by [facilitator]. So the activities that he's bringing in, the teachers then realise actually this is a doable activity. This is something that they're doing in [School 4]. This is something that's happening in [School 5]. So we can't go "Oh our kids can't do that," because, well, it's happening in the schools all around us. [Principal, Cluster B, School 1]

Principals were also aware of the value of networks in deprivatising practice. For example, it was becoming common for teachers to ask if they could visit a colleague's classroom in their school to see an idea in action, and principals saw this as an opportunity to build a culture of distributed leadership and accountability around reciprocal lesson observation and feedback. Some teachers were also visiting other schools in their cluster to observe colleagues, with support from principals in arranging timetables and supervision of their classes.

For teachers, the most powerful form of networking involved working with colleagues in other schools who taught the same year level. One teacher affirmed the novelty and value of this opportunity as follows:

To be able to sit down with other year three teachers and discuss what you're finding, how they're responding to number lines or what commonalities are there in problems areas. That's phenomenal. We've never had a chance to be able to do that before. [Teacher, Cluster B, School 4]

Networking was a powerful and efficient way to share resources that were created in the professional development workshops. Over time, each school cluster in the region decided to focus on one issue and prepare appropriate resources: for example, Cluster A developed diagnostic tasks

through an iterative process of design, trialling, and refinement, and then shared these through an online portal accessible to other clusters. These resources are then downloaded, adapted, tested, and refined once more by teachers in different clusters. Through this collaborative process teachers throughout the region became accountable to each other for designing resources that could subsequently be modified by colleagues for use in different contexts. This recontextualisation of resources illustrates the notion of “spread” that Coburn (2003) argues is essential for scaling up educational reforms. One principal described the significance of inter-cluster networks in the following terms:

We’re not talking about breaking down classroom walls here. We’re breaking down school fences. [Principal, Cluster B, School 1]

Instructional leadership: School and regional

The support that teachers gain from their *school leadership* is crucial to sustaining and scaling up professional development programs (Tirosh et al., 2015). All the regional leaders we interviewed emphasised that principals are the key leaders within the school who are responsible for this support. They explained that in order for a school to join a cluster, the principal must commit to nominating a contact person from the school who works with the facilitator, selecting a team of teachers to release from classroom duties so they can attend the professional development workshops at least three times each term, and funding teacher release from their school budget. As a sign of their commitment to and valuing of the initiative, principals were expected to attend at least part of each professional development workshop and to advocate for the initiative to all teachers in their schools. Principals also took turns at hosting the professional development workshops in their schools, thus providing opportunities for all cluster members to visit every school in the cluster.

Principals described differing strategies for identifying the teachers who would participate in the professional development workshops and then share their knowledge with other staff in the school. One began by sending an experienced teacher, a beginning teacher, and the school’s curriculum coordinator, and found this provided an ideal blend of experience and enthusiasm that was effective in engaging other staff. Other principals in larger schools selected a teacher from each year level, and rotated teachers through these roles with the aim of eventually giving all staff an opportunity to participate in the professional development workshops. A curriculum leader in one of the Cluster A schools took a more strategic approach, initially targeting teachers thought to be most resistant to change:

The resisters, as we would call them – I was pretty strategic at the start of this project and I invited them to be part of the first term, first cabs off the rank. They changed their mindset in those days. With me doing planning with them and valuing their contributions and I mean it is a game of chess sometimes. If you play it well, then things tend to work out and those – there were two big resisters in that first and one that was a really quiet teacher, quietly going about his business but doing it really, really well. So those two big resisters were then the biggest fans and brought most of the others on board. [Curriculum leader, Cluster A]

Regional leaders, however, suggested that the preferred approach was to select two or three core participants to attend every professional development workshop in order to build consistent mid-level leadership in the school, together with one or two additional teachers who changed with each workshop.

An important element of school leadership involved providing time and opportunities for the cluster team to share their knowledge with other staff members who had not attended the

professional development workshops. This form of within-school networking was enabled by giving teachers time “offline” to meet with year level colleagues and dedicating a segment of every staff meeting to reporting on the latest cluster meeting. This was happening in most schools, but not all, as these teachers pointed out:

We’re pushing it now to say we want the rest of our colleagues to be given time so that we can share this information and try and bring about some transformations. [Teacher, Cluster B, School 4]

If we’re not seen coming back to the school and sharing in the whole staffrooms, it’s kind of still hard to share. Because there is no mechanism when you get back to school. [Teacher, Cluster B, School 5]

Regional leadership was significant in sustaining and scaling up the cluster model. Principals appreciated the clear goals communicated by regional leaders and consistent provision of quality support in the form of the professional development facilitator who worked with clusters of schools across the region. Regional leaders were also aware of the need for time and patience to enable change:

We know the schools who do move along in a considered way, in an evidenced way, in a supported way and a safe way and in a patient way – that they take their time. They don’t rush in. They’re methodical. They’re collaborative. They’re considered. I think patience and time are a big part of it. They’ll improve. You see it in data across all of my schools. If you analyse what they’re doing you can see the patterns occurring. [Regional leader]

Regional leadership was instrumental in supporting new organisational structures that aimed to enhance the sustainability of the cluster model. After the first year of implementation, Cluster A principals agreed to co-fund part of the salary of one school’s curriculum leader to enable her to coordinate and manage the cluster’s activities. This person is preparing to take on some of the responsibilities of the regional professional development facilitator, suggesting an eventual shift in reform ownership from the system to the school level (Coburn, 2003). Regional leaders are keen to replicate this structure in other clusters so that the role of the facilitator can change to supporting cluster coordinators rather than teachers:

They need to build that middle management structure. They need to distribute the leadership so that we can eventually make [facilitator] obsolete. We don’t need [him] anymore, and we become a sustainable model. [Regional leader]

There are some indications that regional leaders are able to balance competing priorities, emphasising both instructional improvement and instructional management. Cobb and Jackson (2011) suggested that an instructional improvement orientation focuses on teachers and their development while an instructional management orientation instead emphasises redeploying resources to meet state-mandated mathematics objectives. Both orientations are important, but they need to be carefully coordinated with the aim of enabling students to succeed in learning mathematics. One way in which this is achieved involves helping schools to see improvements in student learning and using this evidence to motivate continuing participation and spread of the initiative. Figure 2 shows 2014-2017 trends in the average combined mean scale scores of Year 3 and Year 5 students in NAPLAN numeracy tests, comparing performance across Australia, in the relevant state jurisdiction, and in all clusters of schools participating in the regional professional development initiative. Figure 3 depicts comparable trends in the average percentage of students in the upper two NAPLAN achievement bands. These graphs were produced from ACARA data available to the third author in his capacity as a regional education officer (See ACARA, 2016, for more information on interpreting NAPLAN results.) These graphs therefore depict NAPLAN

numeracy trends since the year before the cluster-based professional development initiative began. Such trends are closely monitored by state education departments as an indicator of not only student performance but also teaching quality and school effectiveness. In 2015, NAPLAN performance in the region (Mean Scale Score of 863; 22.6% of students in upper two bands) was well below the state (878; 27.2%) and national average (891; 30.7%). However, the region's rate of improvement since the initiative began in 2016 is noticeably greater than that for the state or Australia as a whole, thus lending support to the approaches adopted by participating schools. This evidence has also been used to gain professional recognition for two of the school clusters through awards for excellence in professional practice made by the Australian Council for Educational Research and the state education department. As Tirosh et al. (2015) have explained, promoting these visible improvements to student learning can contribute to sustaining and scaling up a professional development program.

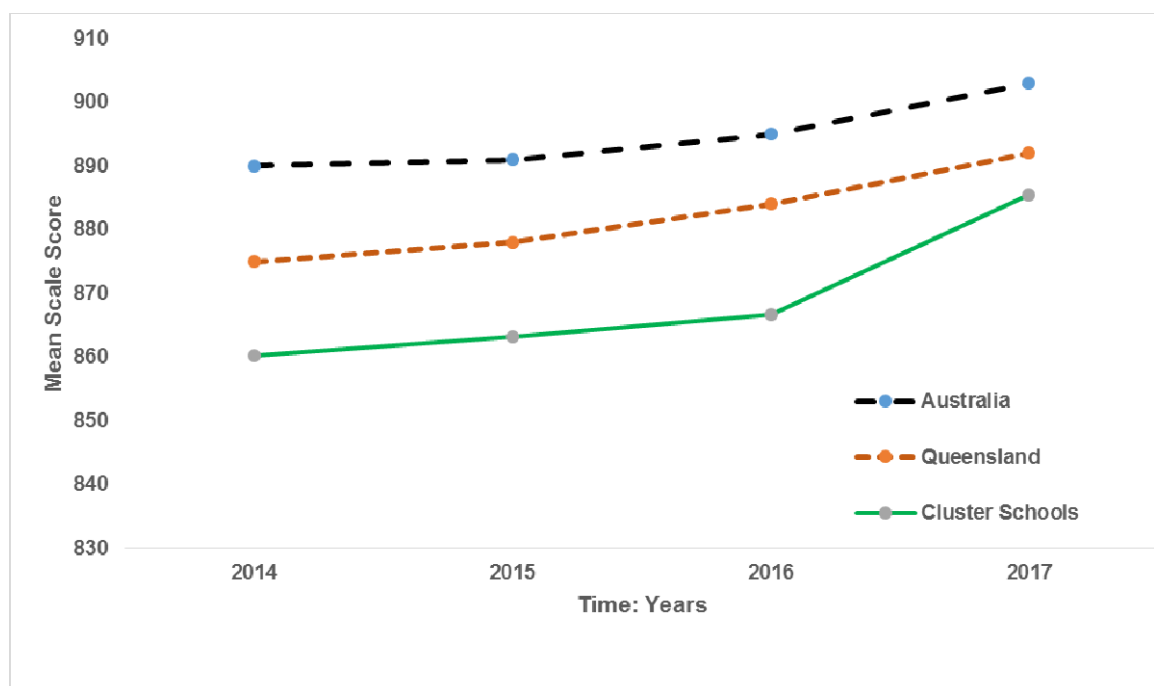


Figure 2. Comparison of NAPLAN mean scale scores (combined Year 3 and Year 5)

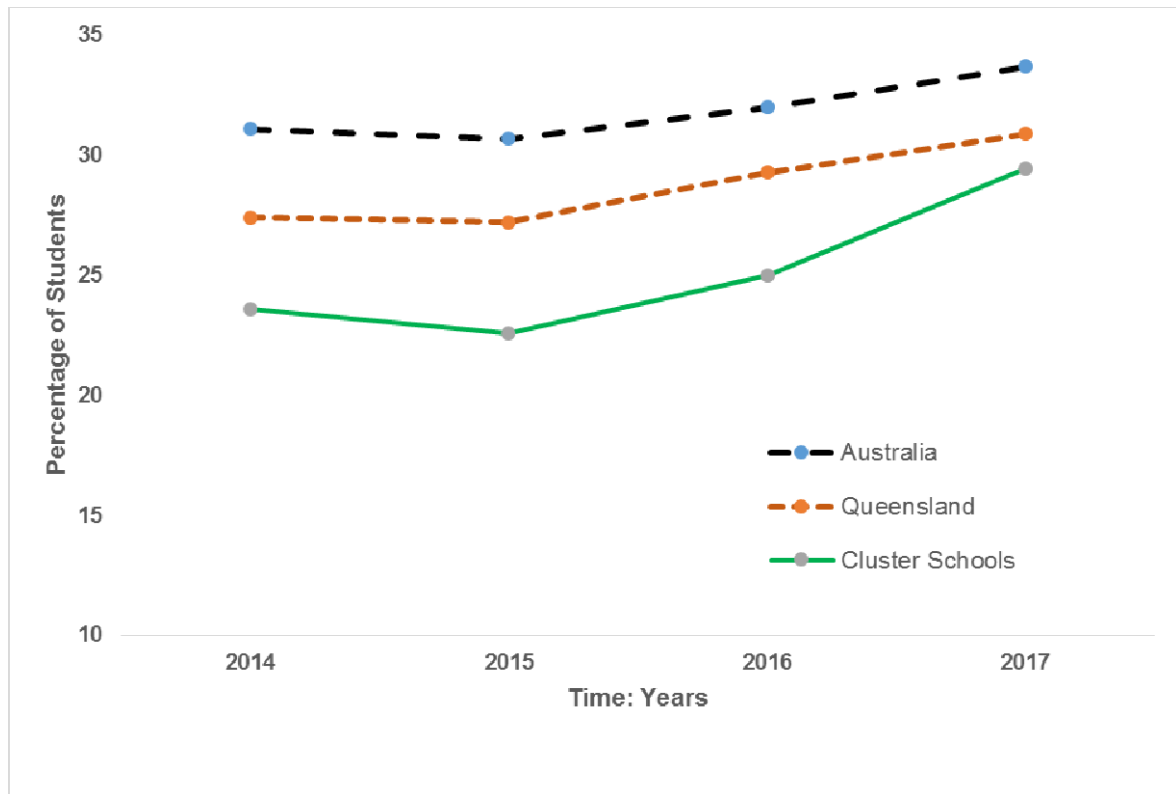


Figure 3. Comparison of percentage of students in upper two NAPLAN bands (combined Year 3 and Year 5)

Discussion

In the field of mathematics teacher education, it has been said that researchers have dual roles of “intervening and investigating... of improving and understanding” (Adler, Ball, Krainer, Lin, & Novotna, 2005, p. 371). In our study, however, researchers were not formally involved in the design or delivery of the professional development intervention, but sought only to identify and understand the factors that contributed to its sustainability and scaling up. Yet the intervention itself was unquestionably research-informed, and this “seeding” of the professional development environment with validated research knowledge helped to convince school principals of the quality and value of the initiative. A skilled and knowledgeable facilitator with credibility as a classroom teacher and support from regional education department leaders was also crucial in engaging teachers in professional development that aimed to meet their needs in addition to the needs of the system. Teachers and principals reported substantial changes in teacher beliefs and classroom practices, as well as improvements in students’ dispositions towards mathematics. There is also emerging evidence of improvement in students’ NAPLAN numeracy results that exceeds any improvements observed in the state as a whole or across Australia. These findings suggest that the professional development initiative was effective in integrating top-down and bottom up approaches to educational reform, balancing the education system’s priorities against teacher’s expressed needs in order to achieve change that has been sustained and scaled up to a large number of schools (Begg et al., 2003).

The framework for our analysis drew on Cobb and Jackson’s (2011) theory of action for improving the quality of teaching at scale and previous research on effective professional development (Garet et al., 2001) and scaling up of sustainable interventions (Coburn, 2003; Roesken-Winter et al., 2015; Tirosh et al., 2015). The framework thus gave attention to structures

and systems within which teachers work as well as the content and organisation of the professional development workshops. Applying the three elements of our framework – a coherent instructional system, collective action, and leadership – to our interview and other data allowed us to develop a rich account of what makes the initiative effective and why it has grown over time. Just as Garet et al. (2001) found in their US study, a *coherent instructional system* that focused teachers on how children learn mathematics, encouraged active learning through lesson observation and collaborative planning, and aligned activities to the requirements of the Australian Curriculum proved to be powerful in promoting teacher learning. *Collective action* via coaching and networking was highly valued by teachers and principals as a means of sharing practice within and between schools, and between school clusters. Effective *leadership* at the school and regional levels created structures for collaboration and sharing of knowledge, and for making change visible (Tirosh et al., 2015).

Coburn's (2003) alternative conceptualisation of scaling up educational reform articulates four dimensions that direct attention to depth, sustainability, spread, and shift in ownership. Depth concerns the nature of change, which we claim in our study was evidenced by self-reported changes in teacher confidence, knowledge, and pedagogy. However, a limitation of our study was that we did not undertake classroom observations or interviews with individual teachers to ascertain the degree of change, how tasks were implemented, and how students responded. Coburn argues that such methods are necessary to discover whether there has been "deep and consequential change in classroom practice" (p. 4). Nevertheless, unlike many other research studies that are not designed to assess whether change has persisted over time, our study makes a contribution to knowledge by providing evidence of the sustainability of the initiative, having traced its origins and growth. Coburn's notion of spread opens up new ways of thinking about scaling up as involving adaptation to different contexts rather than only superficial replication in more schools. We argue that the spread of this professional development initiative was at least partly attributable to the way it offered teachers a principled and flexible repertoire of strategies rather than prescribed methods and mandated resources. It remains to be seen whether continued scaling up to more school clusters, and possibly to other regions in the state, will allow for faithful implementation of the initiative's underpinning norms and values. This is also related to the dimension relating to shift in ownership. Some shifts from system to school ownership have already occurred, with plans in place for further devolution of the facilitator role to school-based curriculum leaders. A challenge here will be to assure the quality of professional development facilitation so that the strong research base of the initiative is maintained.

Concluding comments

This study offered a rare opportunity to investigate an established, large-scale mathematics education reform initiated and sustained by a state education system at a regional level and involving a large number of schools and teachers. It goes some way towards addressing the call made by Beswick et al. (2016) for researchers to give more attention to issues of scale and sustainability of professional learning initiatives. Although the study was exploratory and thus limited in the claims that can be made about teacher change, it does point to some future challenges and further questions that need investigation. First, the school cluster model made it possible for teachers to work collaboratively with year-level colleagues in other schools, thus creating powerful between-school teacher networks. What can be done to encourage this kind of networking? Second, an essential element of the cluster model is provision of structured time and support for teachers to share their knowledge with colleagues in their own school. How can

principals be persuaded that this is an important investment? Finally, the expertise and credibility of the regional professional development facilitator is crucial to assuring the research-based quality, consistency, and continuity of the initiative. How can this role be sustained and scaled up to build leadership capacity in others?

Acknowledgement

The authors wish to thank the teachers, principals, school curriculum leaders and regional leaders who participated in this study and shared their experiences with us.

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