WHAT'S HAPPENING IN AUSTRALIAN MATHEMATICS PROFESSIONAL LEARNING?

Dr Robyn Reaburn
University of Tasmania, Launceston

Professor Sue Kilpatrick
University of Tasmania, Launceston

Associate Professor Sharon Fraser
University of Tasmania, Launceston

Professor Kim Beswick
University of Tasmania, Launceston

Dr Tracey Muir
University of Tasmania, Launceston

The project, Towards Educating Mathematics Professionals Encompassing Science and Technology (TEMPEST), examines the extent and quality of professional learning (PL) opportunities for teachers of mathematics. Teaching of Science, Technology, Engineering and Mathematics (STEM) has become a focus of the Australian Government as these subjects are seen as essential to the future Australian economy. It is a professional requirement that teachers undergo PL. Many teachers of mathematics are not mathematics specialists and therefore it is essential that PL is of high quality. One aim of the TEMPEST project is to provide a quality framework to ensure the standard of any PL offered. Before developing this framework, 65 experts who deliver, design or facilitate mathematics PL for teachers were surveyed to determine the current state of mathematics PL in Australia. This paper summarises and analyses their responses. It describes current PL including year level focus, format (one-day workshop, weekly sessions for example) and type of teacher targeted. The paper reports gaps in PL currently offered throughout the country. Some gaps were identified by the expert respondents, while others emerged from analysis of the survey data. Gaps are reported in terms of target teacher audience, year level focus, location and PL format.

Introduction

Science, technology, engineering and mathematics (STEM) are considered essential to meet the challenges that Australia will face in the future (Office of the Chief Scientist, 2013). In particular, if sustainable economic growth is to be achieved, Australia will need a "higher level of ingenuity and innovation" (Office of the Chief Scientist, 2013, p. 5). In response to this perceived need, the Australian Federal Government has placed a priority on increasing the uptake of STEM subjects in primary and secondary schools (Australian Government, Department of Education and Training, 2015). Mathematics is key as it is regarded as underpinning performance across the other STEM fields (Australian Academy of Science, 2016).

There is concern about the relatively low achievement of Australian students in mathematics as measured by international tests (Australian Mathematical Sciences Institute [AMSI], 2014). For example, the Trends in International Mathematics and Science Study (TIMSS, 2011) showed that, in terms of achievement, Australia ranked 12th out of the 34 participating countries in Year 8 mathematics, and 18th out of the 45 participating countries in Year 4 mathematics. The results for Year 4 indicated Australia was "considerably higher than the centrepoint" and it was considered to be "improving" (p. 40). The results for Year 8 showed that Australia was neither improving nor declining. The Programme for International Student Assessment (PISA) indicated that the Australian average was “significantly higher” than OECD average (Thompson, De Bortoli, & Buckley, 2013, p. 22), nevertheless, 30% of the Australian students in the TIMSS study scored below minimal competency.

In addition, the 2011 TIMSS study showed that there is a reduction in the proportion of students who indicated they liked mathematics between Year 4 and Year 8; in Year 4 the proportion of students who liked mathematics was 45%, with a further 33% who “somewhat” liked mathematics (TIMSS, 2011, p. 330). In Year 8 the proportion who liked mathematics was 16%, with a further 40% who “somewhat” liked mathematics (p. 333). A similar story is seen with confidence in mathematics. In Year 4, 38% of students were confident in mathematics, with 41% “somewhat” confident (p. 336), while by Year 8, only 17% of students were confident in mathematics, and 46% were “somewhat” confident (p. 338). It is reasonable to assume that students’ dislike of mathematics and lack of confidence in their ability to study it successfully have contributed to the decline in the number of students opting to study the most demanding mathematics subjects in Year 12. According to AMSI (2014) this figure dropped by 22% from 2000 to 2012. The Australian Council of Learned Academies (ACOLA) (2013) reported similar declines in the proportions of Year 12 students studying science subjects. ACOLA (2013) made two recommendations of relevance to the study described in this paper. They are to:

- Lift the quality of STEM teaching at all levels of schooling to ensure students understand and are inspired by science and mathematics.
- Ensure useful, meaningful and high-quality resources are easily accessible to support STEM teaching and learning at all levels of schooling.

Professional Learning

PL includes, but is not limited to, the processes described in the literature as professional development, staff development and in-service education. PL can include co-teaching, formal and informal mentoring, reflecting on lessons, engagement with online materials and discussion, and engagement with curriculum materials (Desimone, 2009). In this paper PL refers to instances where teachers meet for specific workshops outside of the teacher’s own classroom, run by leaders with specific expertise (Garet, Porter, Desimone, Birman, & Yoon, 2001).

Much PL is undertaken on an ad hoc basis, however, and whereas there is evidence to suggest that PL can result in increased teacher knowledge and skills, and improvement in practice (Desimone, 2009; Garet et al 2001), not all PL results in this improvement. In a synthesis of research related to effective PL, Muir and Beswick (2007) identified three key principles for effective PL:

- PL is more likely to be effective if it addresses teachers’ pre-existing knowledge and beliefs about teaching, learning, learners and subject matter.
- PL is more likely to be effective if it provides teachers with sustained opportunities to deepen and expand their content and pedagogical knowledge.
- Effective PL is grounded in teachers’ learning and reflection on classroom practice.

In addition to passing on facts, teaching requires the ability to assist students to obtain a deep understanding of what they learn (Garet, Porter, Desimone, Birman, & Yoon, 2001). Teachers are required to be “immersed in the subjects they teach, and have the ability to communicate basic knowledge and to develop advanced thinking and problem-solving skills among their students” (Garet et al, p. 916). PL is regarded as influential in the development of these abilities in teachers. In addition, there is evidence of a strong relationship between PL for teachers and school improvement (Sykes, 1999, as cited in Sowder, 2007). Masters (2010), for example, identified that improvements in student learning are dependent upon ongoing improvements in pedagogy and that outstanding schools have teachers who are highly committed to the continuous improvement of their own teaching. The importance placed on PL is reflected in the requirement for teachers to attend PL for continuing teacher registration (e.g. see NSW education, nd) and it is claimed that this PL is "fundamental to school and organisational improvement" (Professional Learning Institute, nd, para. 1).

As the name suggests, initial teacher education (ITE) programs cannot be expected to prepare teachers for a life-time of teaching mathematics (Watson, Beswick & Brown, 2012). Schifter (1995, as cited in Sowder, 2007) has described four stages in the development of conceptions of mathematics teaching, each more complex than the last. In the first stage mathematics teaching is regarded as an "accumulation of facts, definitions, and computational routines" (p. 195). In the second and third stages mathematics teaching is seen as a student-centred activity, while in addition, in the third stage there is "activity directed towards systematic structure and validity" (p. 195). In the fourth stage mathematics teaching is regarded as a "systematic inquiry organized around investigation of 'big' mathematical ideas" (p. 195). PL can thus be regarded as a process by which mathematics teachers can be assisted to move from Stage 1, where much in-school mathematics teaching presently takes place (Sowder, 2007), to Stage 4, to enable students to gain a deep understanding of mathematics.

Complexity is added to the PL environment for mathematics, however, where many primary and secondary teachers of mathematics, particularly in rural and regional Australian schools, are not STEM graduates (Harris, Jensz & Baldwin, 2005; Lyons, Cooksey, Panizzon, Parnell & Pegg, 2006; Office of the Chief Scientist, 2014). These out-of-field teachers lack not only relevant content knowledge, but also the necessary pedagogical content knowledge to teach mathematics effectively (Marginson, Tytler, Freeman & Roberts, 2013; Hobbs, 2013). These teachers, and others, require ongoing PL, consistent with the literature which recognises that effective PL is more than a single session or presentation (Meiers & Buckley, 2009).

Nevertheless, much PL involves attendance at one-off workshops or conferences, and is unlikely to result in sustained changes to practice. Activities that take place over a period of time and that have a longer number of contact hours have been judged by teachers to increase their knowledge and skills and this in turn is more likely to result in changes in teachers' practice (Garet et al., p. 933). Another factor contributing to the effectiveness of PL is *coherence*; if the PL is connected to other PL experiences, is aligned to assessments and promotes professional communication, then the teachers are more likely to change their practice (Garet et al., p. 934). The Australian Association of Mathematics (AAMT) recognise this in their Position Statement on Professional Learning where they state that "all educators of mathematics must have the opportunity to access high quality professional learning that promotes a culture of inquiry into teaching practice" (p. 1). Their position on what constitutes effective mathematical PL is consistent with the literature in the identification of the following factors: relevant, collaborative, evidence-based, sustained and evaluated. Of particular relevance to this paper are the recommendations that PL should immerse educators in research-based knowledge of the mathematics required for teaching and how students learn mathematics. In addition, PL should be part of a continual and ongoing process of learning and improvement. According to the Australian Association of Mathematics Teachers, evaluation of PL should be both formative and summative in nature and this is reflected in the design of the TEMPEST project (Australian Association of Mathematics Teachers, 2010).

While there is no shortage of literature related to effective PL, what is perhaps less well known are teachers' and others' perspectives of gaps in PL that is offered. Beswick (2014) provided an isolated example of our knowledge in this area. She described three PL programs for teachers: a six-day program for teachers of the middle years, a three-year program for teachers of the middle years, and a one- to three-day program for teachers of all years in geographically isolated areas. In these programs teachers were asked to identify the areas in which they felt that they needed to increase their knowledge and skills. These teachers identified the need for more knowledge in the areas of ratio and proportion, fractions and decimals, pattern and algebra, connecting numeracy with the curriculum, and in the use of technology in mathematics classrooms. What is even rarer than teachers' perspectives, are accounts of PL needs from the perspectives of those who provide and source PL for teachers and schools, which is the focus of this paper.

The TEMPEST Project

The Towards Educating Mathematics Professionals Encompassing Science and Technology (TEMPEST) project is a national project funded by the Australian Government Department of Education and Training under the Australian Mathematics and Science Partnership Program (AMSPP). It is about ensuring that the PL available to mathematics teachers meets needs, through improving existing PL resources and programs used by teachers. The initial stage of this project was to audit PL programs for teachers of mathematics and to identify gaps in provision. This paper reports on the results of the audit.

Method

The participants in this study were volunteers who were identified as being providers of PL from all state and the ACT Departments of Education, Government Schools, Catholic Schools, VET providers, Independent Schools Associations, and other professional associations. The Head of the Education Department, TAFE and school systems in each State and Territory were sent letters outlining the aims of the project and asking them to identify individuals they deemed to be experts in PL, and to forward an email to these people with an anonymous link to an online survey platform. A survey was chosen because it makes available a quick response and allows the collection of qualitative and quantitative information in an anonymous format (Burns, 2000; Creswell, 2012).

The participants were asked about their highest education level, their workplace type, and their type of work in relation to PL: design, deliver, evaluate or source PL. They were then asked to describe up to seven PL programs they had designed, led and/or facilitated. Specifically, they were asked to indicate the year level of each PL program, and the type of content (mainly mathematics content, mainly pedagogy, a combination of mathematics content and pedagogy, and other). They were then asked to indicate the target audience of each PL program, the options being early childhood teachers, primary teachers, middle year teachers, secondary mathematics teachers, out of area mathematics teachers, beginning teachers (1-3 years post qualification), experienced teachers, school leaders and teacher assistants. Information was gained about the place where the programs took place (school, online, provider venue, multiple locations, intra-state, inter-state, other), session frequency (one off, weekly, fortnightly, monthly, annually and other) and length for each of the PL programs (one hour, two hours, half day, day, two to three days, four to five days, other). They were then asked, in an open question format, to identify areas in which PL was not being delivered but was needed. The gaps were then coded according to thematic categories (Miles & Huberman, 1994; Saldana, 2009).

Results

Characteristics of respondents

There were 65 respondents of whom 43 were female, 20 were male. There were two non-responses to the gender question. Respondent qualifications and workplace types are summarised in Tables 1 and 2.

Table 1
Highest education level obtained by participants

Education level	Number of participants
Doctorate	7
Master Degree	15
Bachelor Degree	40
Advanced Diploma	2
Diploma	1
Total	65

Table 2
Workplace type of participants

Workplace Type	Number of participants	Percentage
Department of Education	19	29.2
Independent Schools Association	3	4.6
Government School	13	20.0
Catholic School	10	15.4
VET	4	6.2
Private Company	1	1.5
Self-Employed	1	1.5
Other	1	1.5
Work in a School	2	3.1
Work for an education authority or association	2	3.1
No response	9	13.8
Total	65	

Of the participants, 24 (36.9%) said that they designed and developed PL programs, 35 (53.8%) stated that they delivered PL programs, 6 (9.2%) that they evaluated PL, and 4 (6.2%) that they sourced PL for others.

Characteristics of the PL described

Characteristics of the PL that respondents described are presented in Tables 3 to 7. In each case, because participants were asked to nominate more than one PL program, the total number of PL programs is greater than the number of participants.

Of the 208 PL programs reported, 37 (17.8%) were described as focussing on mathematics content, 30 (14.4%) on pedagogical practice, and 119 (57.2%) on both mathematics content and pedagogy. A further eight (3.8%) sessions did not fit into any of these categories.

The participants were asked to indicate the year levels of teachers for which each of the PL programs they described was designed and this is summarised in Table 3. The type of teacher targeted in each PL was also described and this information is summarised in Table 4.

Table 3
Target year level of teachers

Year Level	Number of PL Programs	Percentage
Early childhood	2	1.0
Primary	76	39.4
Middle School	11	5.7
Secondary	49	25.3
Senior Secondary	23	11.9
Other	32	16.7
Total	193	

Table 4
Target audience

Type of Teacher	Number of PL programs	Percentage
Early Childhood	24	9.4
Primary	37	14.4
Middle	34	13.2
Secondary	36	14.0
Out of area	23	8.9
Inexperienced	28	10.9
Experienced	28	10.9
School leaders	26	10.0
Teacher Assistants	13	5.1
Other	8	3.2
Total	257	

The frequency of the PL programs, and the time span of these programs are shown in Tables 5 and 6.

Table 5
Frequency of PL programs

Frequency	Number of PL programs	Percentage
One-off	65	36.2
Weekly	6	3.3
Fortnightly	4	2.2
Monthly	16	8.9
Annually	45	25.0
Other	44	24.4
Total	180	

Table 6
Time Span of PL programs

Time Span	Number of PL sessions	Percentage
One hour	28	15.5
Two hours	51	28.0
Half day	22	12.1
Day	42	23.1
Two to three days	25	13.7
Four to five days	3	1.6
Other	11	6.0
Total	182	

The participants were also asked to indicate the location of the delivered PL programs, and this information is summarised in Table 7.

Table 7
Location of PL

Location of PL	Number of programs	Percentage
School	55	31.0
Online	16	8.9
Provider venue	44	24.7
Multiple locations	42	23.6
Inter-state	6	3.4
Other	3	1.7
Unsure	12	6.7
Total	178	

Gaps in PL

The gaps in PL provision identified by the participants were organised into five themes: teaching level of target audience, teacher characteristics, teacher skills, teacher knowledge, and problems with PL, such as access to PL and suitability of the format of PL. Fifty-four of the 65 participants nominated at least one gap in PL.

Teaching level of target audience

The teaching level of the target audience refers to whether the PL should be aimed at teachers of early childhood and primary students or for teachers in secondary school; six participants indicated that there should be more PL for teachers in primary education, one indicated there should be more PL for early childhood teachers, and five participants nominated secondary mathematics teachers as needing more PL.

Teacher characteristics

In this category, one participant nominated teachers who are not primarily trained as mathematics teachers (out of area) as needing more PL, and five suggested that more PL was needed for early career teachers.

Teacher skills

This category refers to suggested PL that is designed to increase specific teacher skills. Results in this category are summarised in Table 8.

Table 8
PL Teacher skill gaps

Teacher skills	Number of nominations	Percentage
Pedagogy	8	34.8
Proficiency strands in the Australian Curriculum*	2	8.7
Assessment	2	8.7
Technology	3	13.0
Differentiation/Interventions	6	26.1
Gifted and Talented students	2	8.7
Total	23	

* Understanding, fluency, problem-solving, reasoning (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2015, p. 6)

Teacher knowledge

Several participants nominated more PL was required to increase mathematics content knowledge and these answers are summarised in Table 9; these nominations are summarised in Table 9.

Table 9
PL content knowledge gaps

Content knowledge	Number of nominations	Percentage
Content knowledge (unspecified)	5	33.3
Statistics and probability	4	26.7
Measurement and geometry	2	13.3
Number and algebra	1	6.7
Australian curriculum	3	20.0
Total	15	

Problems with current PL

Several of the participants indicated that they were concerned about current PL. Three indicated that they were concerned with the lack of access and the costs of PL for teachers who live in more remote areas. Two participants indicated that they were concerned with the quality of some PL that is delivered, and two participants indicated that they thought the PL did not give enough time for peer learning and for teachers to share with others. In addition, two participants reported a concern that too much time was spent on NAPLAN.

Discussion and conclusion

The vast majority (75.4%) of PL experts who contributed to this audit worked in schools, for school associations or for education authorities (Table 2). They described PL provision that is dominated by programs targeting primary and secondary mathematics (65% of the PL described) (Table 3). The results suggest that those responsible for providing, facilitating, and sourcing PL should be made aware of the apparent gaps in mathematics PL provision for out of area teachers, early childhood teachers, and Teaching Assistants.

Only 10.9% of the PL described targeted inexperienced teachers and 8.9% targeted out or area teachers (Table 4). Previous research (Hobbs, 2013) suggests that inexperienced and out of area teachers need support to employ effective pedagogies and to identify resources they can use successfully with their classes. This is especially concerning because many of these teachers work in rural schools, isolated from specialist colleague teacher support (Harris, Jensz & Baldwin, 2005; Lyons, et al., 2006). Three participants indicated that they were concerned with barriers that prevented teachers who work in more remote areas from accessing PL.

In view of the fact that PL identified as being effective has relatively long contact hours (Garet et al., 2001), it is of particular concern, therefore, that 15.5% of the nominated programs took 1 hour or less to deliver, with a further 28.0% taking 2 hours. In total, approximately 55% of the programs that were described were delivered over a time period of one half-day or less (Table 6). Spaced learning, or PL that is delivered in spaced sessions over a period of time, has also been associated with effective PL, so it also of concern that approximately 36% of the programs that were described consisted of one-off sessions (Table 5).

The vast majority of participating PL experts worked in schools or education systems, nevertheless, only 31% of the identified PL programs were delivered in schools, and the extent to which these programs were embedded in a classroom is not known. Classroom embeddedness is a feature of effective practice (Bruce, Esmonde, Ross, Dookie, & Beatty, 2010) and may consist of coaching, mentoring, and teacher meetings that may all take place within a school (Croft, Coggshall, Dolan, Powers & Killion, 2010). It should be noted that as such PL does not usually involve presenters from outside a school, these forms of PL do not meet the definition of PL used in this study and hence were not represented in the audit.

In terms of the target audience for current PL programs the smallest proportions of programs were for out of area teachers (8.9%) and early childhood teachers (9.4%). In spite of this, each of these areas was only nominated once as being a gap in PL provision. PL for Teacher Assistants made up 5.1% of the current PL, yet there were no nominations of PL for Teacher Assistants in the gaps. This suggests that Teacher Assistants may be neglected when it comes to the delivery of PL. Previous research indicates that even though teachers appreciate the presence of Teacher Assistants in their classrooms, the presence of Teacher Assistants can lead to decreased mathematical outcomes for students (Webster, Blatchford, Bassett, Brown, Martin, & Russell, 2010). It has been suggested that this may, in part, be attributable to the lack of sufficient training of these TAs (Webster, Blatchford, Bassett, Brown, Martin, & Russell, 2010).

The nominated gaps covered both mathematics content and pedagogy. Lack of knowledge of mathematical content is of particular concern with teachers who have not specialised in mathematics, but can be of concern for mathematics specialists as well as their specialist studies may not have covered all areas of mathematics that are in the school curriculum. In addition, the issue of how to teach the content (pedagogy) arises in any teaching area. It is not surprising that there were eight nominations referring to pedagogy and 15 nominations referring to content knowledge.

There are also indications that the PL providers were aware of the need to be responsive to changes in curriculum and teaching in modern classrooms. There were three nominations that suggested that teachers needed more PL in regard to the Australian Curriculum. There were also three nominations regarding the use of technology in mathematics instruction and this area was also identified as a teaching need in the study by Beswick (2014).

The audit described in this paper recognises that there is an abundance of resources, including PL, that is available to teachers but that these resources are not prioritised toward groups identified as most in need of mathematics PL, readily accessible, of appropriate duration, or of uniformly high quality. The findings from the audit will inform the prioritisation of PL to be sourced and/or developed by TEMPEST and made available freely to Australian teachers through AAMT's online portal. In addition, TEMPEST has developed a framework for planning effective PL and assessing its quality, the Quality Professional Learning Framework (QPLF). Based on the summary of effective PL provided by Watson et al. (2012), and drawing on the experts' responses reported here, the QPLF is intended for use by PL developers and deliverers with a view to enhancing the quality of PL provision. The QPLF is accompanied by an aligned evaluation tool, intended for use by facilitators at the completion of their PL to enable ongoing improvement of offerings. Although both instruments were developed with an initial focus on teachers of mathematics, we believe that they will be applicable more broadly.

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