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Sustaining Improvement in Numeracy: Developing Pedagogical Content Knowledge and Leadership Capabilities in Tandem

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Sustainable improvement in student learning achievement in numeracy requires a deliberate focus on two complementary strands of educational endeavour: the practice of effective teaching of mathematics and the exercise of high level school leadership capabilities. In this article, the authors describe the context and findings from their research in schools in low socioeconomic communities in suburban, regional and remote areas of Australia. The research project, Leading Aligned Numeracy Development (LAND), investigates the nature and relationship between the development of teachers' pedagogical content knowledge in mathematics and the exercise of educational leadership by principals and teacher leaders (as members of school based teams), and the consequences of this interplay for student learning achievement in numeracy. Preliminary findings indicate that sustained improvement in numeracy demands a concerted and strategic focus on identifying, developing and supporting effective teacher leaders in order to embed authoritative and agreed pedagogical principles for the teaching of mathematics at the school level. Further, the study has found that successful school leadership teams (including principals, other school executive and teacher leaders) are able to maintain this focus through developing their own pedagogical content knowledge, while continuing to build community, organise for teaching and learning, and inspire vision in their school settings.

Background

In July 2008, the Australian Government announced its intention to fund the conduct of a series of pilot research projects in low SES school communities. The purpose of the pilot projects was to find out what is needed to improve the learning achievement of students in most need. The following is an excerpt from information provided by Australian Government Department of Education, Employment and Workplace Relations (DEEWR):

> At its Meeting of 11th June the Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA) agreed to submit proposals for literacy and numeracy pilots in low SES school communities.
>
> The pilots will focus on reforms that accelerate progress towards the Council of Australian Governments literacy and numeracy targets, particularly for low SES school communities or disadvantaged students. They will inform the National Action Plan for Literacy and Numeracy announced in the 2008-09 Budget and the development of a National Partnership (NP) to address disadvantage in low SES school communities.

The Australian Government invited pilot proposals from states, territories and non-government school systems. Pilots began in early 2009 and were supported

for up to two years with funds (up to $30 million) drawn from the National Action Plan for Literacy and Numeracy.

The 'Leading Aligned Numeracy Development' (LAND) pilot research project was funded under this initiative as a partnership between the Australian Catholic University and the Northern Territory, South Australia and Western Australia Catholic education authorities. Its purpose was to inform the Australian Government, as well as partnering and other education authorities, about key teaching and learning characteristics and leadership factors necessary to effect sustainable improvement in student achievement in numeracy.

The LAND project was founded on the premise that attention to both the *numeracy* and *educational leadership* dimensions is needed to bring about long term development in student learning achievement in numeracy. It has two complementary dimensions:

1. The identification, development and support of effective teaching and student learning achievement in *numeracy*; and
2. The exercise and development of *educational leadership* in and between classrooms, schools, and central offices to align purposes, priorities, policies, programs, organisational arrangements and community relationships in order to spread and sustain effective practices in numeracy teaching and learning.

Educational leadership in the LAND project is defined as a process of making a meaningful and positive difference to the life and learning of others (Gaffney, Cummings, Ennis, & Turner, 2010). This definition incorporates the possibility of leadership arising from positional authority as well as from other bases of power. For example, the hierarchical position of the principal presents a possibility for leadership, as does the expert power of the teacher. In the latter case, we define teacher leadership as a process of facilitation to achieve whole-school success. It applies the distinctive power of teaching to shape meaning for children, youth, and adults. It also contributes to long-term, enhanced quality of community life and learning (based on Crowther Kaagen, Ferguson & Hann, 2002). Therefore, we regard leadership as a key organisational feature of schools that can be practised by individual members of school communities as well as by groups acting as leadership teams. The focus of the LAND project is on the development and actions of school leadership teams.

There are three related themes to the LAND Project:

- characteristics of effective teaching and learning in mathematics;
- development of teacher pedagogical content knowledge and school-wide pedagogy in mathematics; and
- educational leadership, school improvement and the development of quality teaching and student achievement in numeracy.

Each of these themes has an associated research base. These are explained in the following sections.

Characteristics of Effective Teaching and Learning in Numeracy

The Early Numeracy Research Project (Clarke et al., 2002) identified highly effective teachers of mathematics in the early years of schooling. The key measure of effectiveness was growth in student mathematical understanding as revealed in student interview assessment data from over 11 000 students. Extensive lesson observations and interviews with these effective teachers by the research team identified 25 characteristics of effective teaching of mathematics in the early years of schooling (McDonough & Clarke, 2003). These are listed in Table 1. The LAND project investigated the application of this research base to students from Kindergarten to Year 8 in low SES schools.

Development of Teacher Pedagogical Content Knowledge and School-wide Pedagogy in Numeracy

Two related findings from research into numeracy development and school improvement indicate that:

a) there are significant numbers of Australian primary teachers who would benefit from professional learning in pedagogical content knowledge; and
b) translating effective practice, based on informed pedagogical content knowledge, from classroom to classroom requires the development of shared principles for numeracy teaching and collective responsibility for promoting student learning achievement across the school.

The former finding was a recurrent theme in the recent *National Numeracy Review Report* (Council of Australian Governments [COAG], 2008), supported by the Australian Government. The latter finding has been a feature of international school improvement research evident in the work of Andrews, Conway, Dawson, Lewis, McMaster and Morgan (2004) and Crowther et al. (2002).

This research presents a view of pedagogy which has three dimensions: teachers' personal pedagogy, authoritative pedagogy, and school-wide pedagogy. The relationships between these components constitute the concept of *three-dimensional pedagogy*, shown in Figure 1 (note: 'SWP' refers to 'school wide pedagogy).

Table 1
Effective teachers of mathematics in the early years of schooling

Theme	Characteristics
Mathematical focus	• focus on important mathematical ideas • make the mathematical focus clear to the children
Features of tasks	• structure purposeful tasks that enable different possibilities, strategies and products to emerge • choose tasks that engage children and maintain involvement

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Theme	Characteristics
Materials, tools and representations	• use a range of materials/representations/contexts for the same concept
Adaptations/ connections/links	• use teachable moments as they occur • make connections to mathematical ideas from previous lessons or experiences
Organisational style(s), teaching approaches	• engage and focus children's mathematical thinking through an introductory, whole group activity • choose from a variety of individual and group structures and teacher roles within the major part of the lesson
Learning community and classroom interaction	• use a range of question types to probe and challenge children's thinking and reasoning • hold back from telling children everything • encourage children to explain their mathematical thinking/ideas • encourage children to listen and evaluate others' mathematical thinking/ideas, and help with methods and understanding • listen attentively to individual children • build on children's mathematical ideas and strategies
Expectations	• have high but realistic mathematical expectations of all children • promote and value effort, persistence and concentration
Reflection	• draw out key mathematical ideas during and/or towards the end of the lesson • after the lesson, reflect on children's responses and learning, together with activities and lesson content
Assessment methods	• collect data by observation and/or listening to children, taking notes as appropriate • use a variety of assessment methods • modifying planning as a result of assessment
Personal attributes of the teacher	• believe that mathematics learning can and should be enjoyable • are confident in their own knowledge of mathematics at the level they are teaching • show pride and pleasure in individuals' success

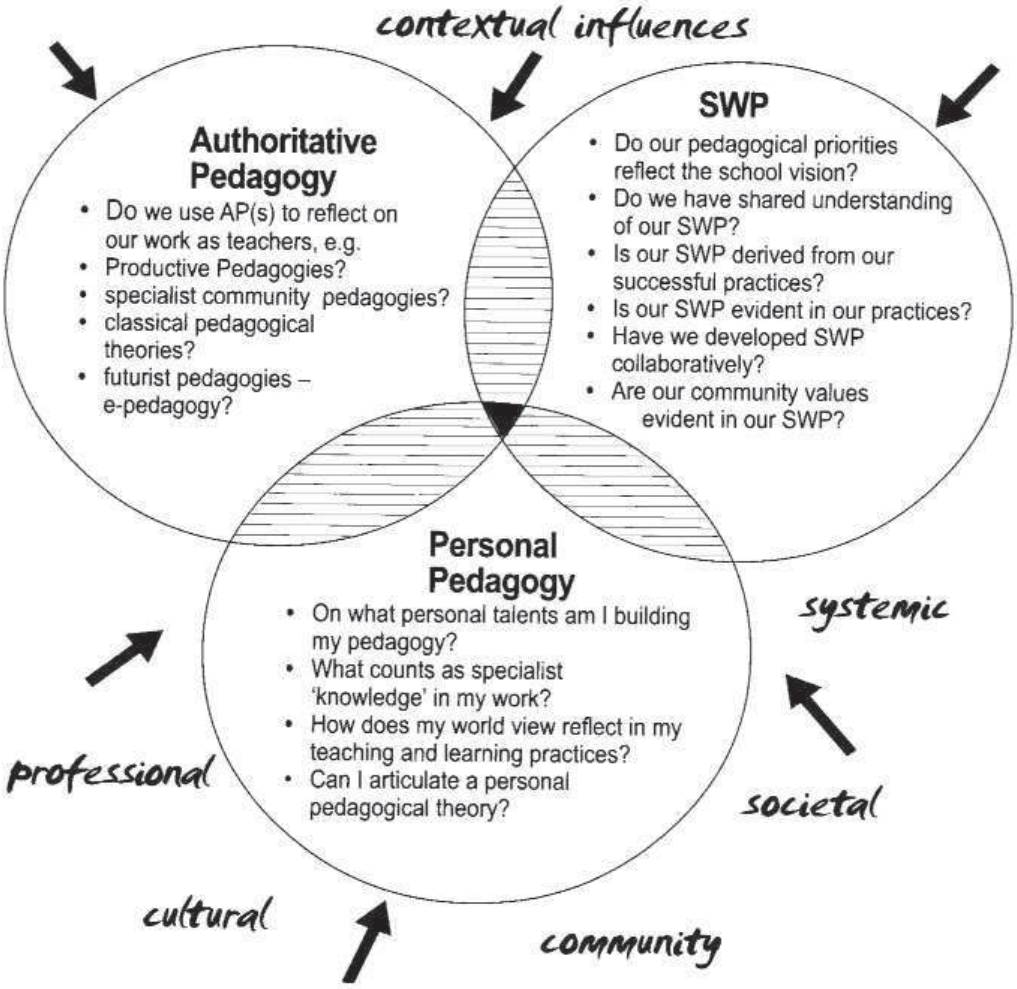

Figure 1. Three-dimensional pedagogy (3DP) (Andrews et al., 2004, p.15)

The LAND Project was designed to investigate how developing teachers' pedagogical content knowledge can be linked and applied to the development of shared principles of numeracy teaching implicit in the *three-dimensional pedagogy* model. This involves a three step process of teacher participants (i) increasing awareness and development of their personal pedagogy, (ii) identifying how their developing pedagogy relates to that of colleagues, and (iii) informing discussions of their shared understandings and approaches to numeracy teaching by reference to research literature of effective teaching of mathematics.

Educational Leadership, School Improvement and the Development of Quality Teaching and Student Achievement in Numeracy

International research (Barber & Mourshed, 2007) points to high quality teaching as the most significant 'within school' factor affecting student achievement. For quality teaching to be developed and sustained, teachers require a school-learning environment characterised by:

- clear goals and expectations;
- strategic resourcing;
- informed and coordinated planning and evaluation of teaching and curriculum;

- promotion and participation in teacher learning and development; and
- orderly and supportive policies and organisational structures and processes (Robinson, 2007).

The creation and sustaining of such environments requires school leaders who have the knowledge, skills and understandings to promote and support quality teaching, foster appropriate organisational arrangements and build effective community links and relationships. These features are evident in the five areas identified in the MCEETYA paper underpinning the Literacy and Numeracy Pilots:

- student-centred approaches and interventions;
- investments in teacher capacity;
- leadership and whole school approaches;
- use of broader community and parental engagement strategies; and
- effective use of student outcome data.

These areas are reflected in the models of school improvement described in the research by Caldwell and Spinks (2008) and Crowther et al. (2002) and in the conceptual framework of the *Leaders Transforming Learning and Learners* project (Bezzina, 2008). These address the issues of governance, transformation, teacher leadership and shared pedagogy and embed notions of moral purpose, alignment and multi-level leadership. The relationship between the models is shown in Figure 2.

School Leadership capabilities identified through the research of the *Australian Catholic University Flagship for Creative and Authentic Leadership* (2007) can be aligned with these models and have also been incorporated in Figure 2. The term 'capabilities' is defined as:

> ... qualities which integrate knowledge, skills and attitudes in such a way that they can be used appropriately and effectively in new and changing circumstances. (Stephenson, as cited in Duignan, 2006, p. 120).

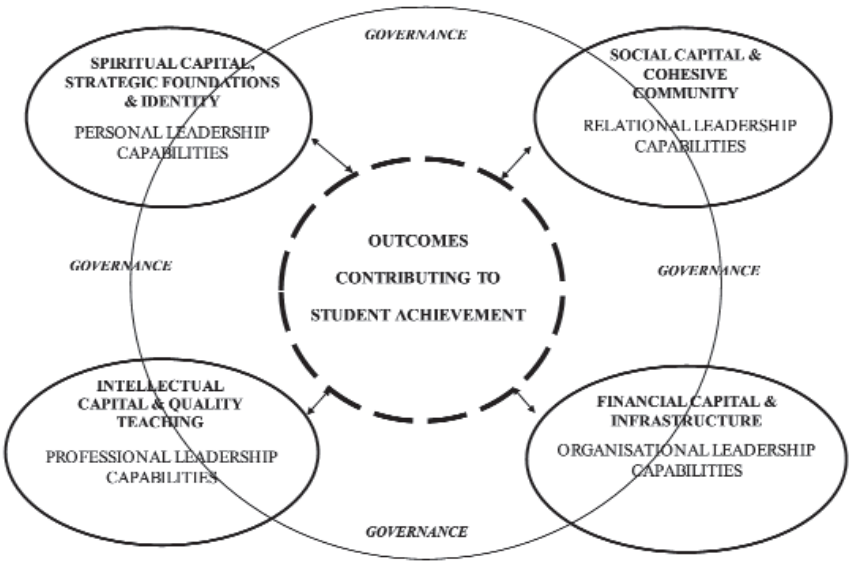

Figure 2. School transformation, leadership capabilities and governance framework. (Sources: ACU Flagship for Creative and Authentic Leadership, 2007; Caldwell & Spinks, 2008; Crowther et al., 2002)

Methodology

The LAND project employed a mix of traditional and innovative research methods. These were designed and refined and delivered by specialist academic staff from the Australian Catholic University [ACU] in the areas of educational leadership and mathematics education working in close collaboration with teachers, school leaders, and central office personnel in partnering Catholic education systems across Australia.

There were four low socio-economic school community pilot sites selected for the LAND project: (i) remote Northern Territory Indigenous Catholic Community Schools, (ii) remote Kimberley schools (iii) inner-industrial area and outer suburban Adelaide schools, and (iv) outer suburban Perth schools. Each pilot site consisted of a cluster of (4-5) schools together with a central office [i.e. a Catholic Education Office (CEO)]. There were 17 schools in total, comprising 16 primary schools, and 1 secondary school. There were three staff (1 school executive member and 2 teachers) involved per school. These educators and central office staff at each site worked with ACU researchers to analyse the outcomes and issues surrounding student numeracy learning achievement. They advised and collaborated with the ACU research team in trialling programs designed to develop their leadership capabilities and pedagogical content knowledge in mathematics teaching.

These programs had two integrated strands: *numeracy* and *educational leadership*. Both strands included a mix of workshops and professional applications supported by site visits. The numeracy strand focussed on developing educators' pedagogical content knowledge while the leadership strand highlighted key capabilities of leaders, understandings of schools as organisations, the dynamics of educational change (including place of self knowledge, values and emotion in such processes), evidenced-based decision making, and the nature and value of reflective professional collaboration. The numeracy strand and the educational leadership strand were brought together through a series of workshops (called *School Development and Alignment* workshops) designed to deepen understanding of the relationship between sustaining high levels of numeracy and the exercise of educational leadership.

Data have been collected from fifty-one (51) participants during the workshops and through visits to the 17 school sites over the period from March 2009 to August 2010. Data collection instruments included surveys, coded observation sheets and diary notes. The surveys sought information on participants' sense of efficacy with numeracy teaching and educational leadership at the commencement of the project, and then following the third workshop. Observation sheets and diary notes were used by ACU researchers during each workshop and school visit to record features related to teachers' individual exercise of leadership, and the development of the LAND school team leadership capability. These data were drawn from workshop presentations (including videos) made by each school and from discussions with LAND school teams on site, and classroom visits. School based student numeracy data were

also collected. Types of data included National Assessment Plan for Literacy and Numeracy [NAPLAN] results for years 3 and 5 students, and classroom-based assessments involving externally validated instruments (e.g., Schedule for Early Number Assessment [SENA] testing) as well as teacher judgements of student numeracy achievement growth.

The data were examined using content analysis techniques involving the unitizing of information, and the establishment and sequences of categories (Carney, 1972). Categories were developed using the principles proposed by Holsti (1969) that they should reflect the research purpose, be exhaustive and mutually exclusive and derive from a single classification principle.

Findings

The findings to this point in the project indicate that sustained improvement in numeracy is supported by two main factors: (i) the priority given at school and central office level to identification, development and support of teacher leaders who work with colleagues to embed authoritative and agreed pedagogical principles for the teaching of mathematics in their school, and (ii) school leadership teams (including principals, other school executive and teacher leaders) that are able to maintain this priority. These teams were found to lead through developing their own pedagogical content knowledge, while working to build community, organise for teaching and learning, and inspire vision in their school settings. Evidence relating to each of these factors is presented in the following sections.

Evidence of Priority on Teacher Leadership

Schools experiencing improvement in student numeracy achievement, as measured by a combination of teacher-based assessments (e.g., SENA testing) and external testing (e.g., NAPLAN), are making deliberate efforts to develop teacher leadership. This is evident through recognition by the principal of a particular classroom teacher or teachers as having leadership potential for developing the quality of teaching and student achievement in numeracy. In all cases, principals have invited these teachers to become part of their school's LAND leadership teams.

Related evidence of the priority given to teacher leadership at the school level includes the appointment of teacher members of LAND school leadership teams to positions of responsibility for mathematics and numeracy teaching and learning within the school. Such positions are characterised by

a) a time allowance and other supporting organisational arrangements (such as a mathematics curriculum resource allowance and associated budgetary responsibility);
b) expectations and support for leading the provision of professional learning of colleagues in mathematics and numeracy teaching and learning. For example, this is taking place through the deliberate redesignating and quarantining of staff meeting time away from

mundane administration and towards the development of the school's 'professional learning community';

c) responsibility for the tracking of student achievement in numeracy across the school and using evidence of student learning as the basis for analysing, evaluating and changing teaching practice. This is enabling the evolution of whole school approaches to assessment and reporting and the development of a valid evidence base for teacher collaboration and support; and

d) keenness to work with teaching colleagues and school executive in developing shared understandings and principles of effective teaching in mathematics. This is increasingly referred to by teacher leaders as a set of 'agreed pedagogical principles' or 'charter' for the teaching of mathematics at their school.

Comments from teacher leader participants made during school presentations at workshops highlight the presence of these characteristics and include, for example:

> There are more manipulatives in the classrooms, teachers were keen to talk and numeracy has an equal priority in the school and I think that's really important too. So instead of just having our literacy PLCs [professional learning community meetings] we now have numeracy PLCs and so the talk amongst teachers has been I think one of the really, really big things and then that takes it back into their classrooms.

> I think the involvement of the whole staff, that's the teaching assistants and the teachers, has been the most valuable part. I have seen them grow in confidence in numeracy and developed great rapport with the children through numeracy.

> We just allocated definite PLC times from the time we had the induction with LAND. We then spent the next term on a fortnightly basis to get together and start working on and sharing what we were doing in the classroom, and how this matched the LAND expectations, particularly the 25 characteristics of effective mathematics teaching, and then shared what we were doing and kept that conversation going ...

> Quite often you will find that we have kids coming in ... [that] are so far behind whether they have poor attendance or whatever else, they just aren't on those charts. So we thought about developing a checklist. Having each class do a checklist that would show where each child was, and at the end of the year the teacher marks that checklist and writes a report with the aim that any new teacher coming in would look at that chart and see exactly where each child is. That took a lot of effort ... a lot of getting together – we had a series of meetings with teachers, exactly working out what we really wanted to do with it.

This emphasis on developing teacher leadership should not be seen, in any way, as an abrogation of responsibility by principals for the quality of mathematics teaching and learning in their school. In fact, the opposite is true, as evidenced by the following comment by a teacher leader:

> What's exciting about what LAND is doing ... is that it has brought teachers and principals together and we are talking about mathematics and numeracy development. I haven't seen that happen in a long time.

Evidence of School LAND Team Leadership Capability Development

The other factor making a major contribution to improved numeracy achievement evidenced to this point in the project has been the development of the leadership capabilities of the school LAND teams. Observational data recorded during workshops presentations and school site visits and subsequent content analysis has identified four dimensions of leadership capability. These dimensions are based on the *School Transformation, Leadership Capabilities and Governance Framework*, featured earlier in Figure 2:

a) Personal – developing shared purpose, e.g., enlivening the school's vision for mathematics teaching and learning;
b) Professional – valuing teaching and professional learning, e.g., supporting mathematics teaching and the development of shared understandings and pedagogical principles of numeracy development;
c) Organisational – organising curriculum and infrastructure, e.g., managing the organisational support for mathematics teaching and learning; and
d) Relational – engaging community, e.g., developing community for improving numeracy development in their schools.

Evidence to this point in the project indicates that developing leadership capabilities in each of these dimensions is associated with particular contributing factors. These are described in Table 2. The contributing factors associated with the development of leadership capability identified in Table 2 highlight the complexity of bringing sustained school-wide improvement in student numeracy achievement. Each of the dimensions of leadership capability are not only important in their own right, but are also connected with the development and practice of leadership actions in other dimensions. In other words, capability in one dimension can support the development of capability in another. For example, we are finding that school LAND teams that are effective in engaging the community are also achieving greater success in developing shared purpose. Alternatively, school LAND teams where there has been less direct principal involvement or more turnover of team membership are not developing shared purpose, valuing teaching or organising the curriculum and infrastructure to the same level as LAND teams with stable membership and direct and ongoing principal involvement and support.

Table 2
Development of school LAND team leadership capabilities and contributing factors

Leadership Capability	Contributing Factor
Personal – Developing shared purpose to improve numeracy	Stability in school LAND team membership, and direct involvement by the principal is facilitating more pronounced growth in shared purpose and expectations
Professional – Valuing teaching & professional development	Access to a blend of timely external expertise, and internal context knowledge and 'follow through' is sustaining the school-wide focus on numeracy development
Organisational – Organising curriculum and infrastructure	Having a dedicated position (as a school LAND team member) responsible for (i) curriculum and resource planning, and (ii) coordinating and validating student assessment is reaping benefits
Relational – Engaging the community	School LAND teams that address both the educational-professional and the community-relational leadership dimensions are building stronger community (including assistant teacher) engagement, and realising greater learning gains for students

Conclusion

The challenge of improving student numeracy achievement in low SES school communities is multi-faceted. It requires attention to the quality of mathematics teaching and learning across the school, and the development and exercise of leadership capabilities that support it. The LAND project is researching ways in which leadership practised by principals and teachers can make a positive and meaningful difference to the teaching practices and sense of efficacy of teachers, and thereby improve students' numeracy achievement.

The combination of research and development in educational leadership and mathematics education is highlighting the need for those in positional authority to understand the nature of effective teaching, learning and assessment in numeracy; as well as the value of classroom teachers being involved in school-wide discussions, planning and leadership of professional learning to bring it about. The LAND project is working to bring the worlds of the school administrator and the classroom practitioner together in ways that allow each to not only appreciate the role and significance of the other, but also provide opportunities for them to practise and experience real educational leadership together.

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