Addressing the 'Dip' in Lower Secondary Mathematics Learning through School-based Projects: A Case Study of One School's Approach

Judy Anderson
The University of Sydney

Introduction

There is a growing body of evidence that the mathematical performance of students plateaus between ages 11 and 14 (Ryan & Williams, 2007). Others suggest there is a "sharp falloff" (National Mathematics Advisory Panel, 2008, p. xiii) or a "dip" (Siemon, Virgona & Corneille, 2001, p. 3) in mathematics achievement in the middle years of schooling. Possible factors impacting on the lack of progress for students are inadequate assessment practices and inappropriate pedagogy. In any particular Australian secondary school, the students entering their first year of secondary education (Year 7) usually come from several primary schools. The primary curriculum is flexible enough to allow for different learning approaches in mathematics, which leads to a range of understanding. Finding ways to assess mathematics knowledge and developing lessons, which support the diverse needs of **all** students is a real challenge for teachers.

In the Australian context, several approaches have been used to inform teachers' assessment and pedagogical practices. One approach is to analyse students' results from large-scale testing in order to explicitly focus on the areas of greatest need. A second approach is to identify and assess low achieving students using a task-based interview protocol followed by the use of focused learning activities in classrooms (e.g., the *Counting On* program, NSW DET, 2002; Perry & Howard, 2002). A third is to design school-based projects, which attract additional funding provided by the Australian Federal Government; projects which are supported and administered through school systems in each of the Australian States and Territories.

An example of the third approach is the *Years 5-8 Mathematics Project* (Anderson & White, 2007) developed initially by a Catholic school system to enable schools to address the issues in the upper primary and lower secondary years. Schools were invited to develop school-based projects identifying particular needs. After a successful application for funding, one school developed assessment strategies to identify learners' needs in fractions in the first year of secondary school.

This paper presents background information about the focus on middle years mathematics and numeracy in Australia as well as relevant research into the identification of issues in early secondary mathematics learning. A description of the systemic approach to teacher-led change through school-based projects is presented with the use of a case study school to exemplify the types of approaches taken by project schools.

The Context for the Study

In Australia, the debate surrounding mathematics and numeracy achievement has been similar to that experienced elsewhere. There is a growing recognition of the need for greater proficiency and that early intervention provides the best chance of success for children at risk of failure. The concern about numeracy by Australian governments was first highlighted in the *National Literacy and Numeracy Plan* (DETYA, 2000), which provided a framework for improving the literacy and numeracy outcomes of all students. This plan embraced the development of national benchmarks for students in Years 3, 5 and 7 (Curriculum Corporation, 2000), as well as the need for assessment and reporting against

these benchmarks. Each State and Territory has collected student achievement data for the federal government using Basic Skills Tests with results published each year providing evidence of a plateau, if not a dip, in the results from Year 3 to Year 5 to Year 7. Concern about the proportion of students not meeting the minimum standards appears regularly in media reports.

There has been an increase in research and school-based projects focusing on numeracy in the middle years of schooling, typically including Years 5 to 8 (Luke et al., 2003). So, why is it important to look at this particular group of students? It is in this age group that students experience a range of changes to their social and emotional well being. In addition, most move from primary to secondary schools with very different learning environments and frequently with different school cultures. However, it is not just changing school environments which is problematic since teachers from the schools which span the full range of schooling from Kindergarten to Year 12 frequently implement special programs to address the changes in the middle years; evidence suggests such programs still do not solve the problem.

Research in several countries has identified a 'dip' in numeracy and mathematics achievement in the lower secondary years (e.g., Ryan & Williams, 2007; Siemon, Virgona & Corneille, 2001). To address this dip, many numeracy projects have been conducted throughout Australia. Some have been implemented at the level of state-based jurisdictions while others have been organised in schools or in clusters of schools. The good news is that many projects have been successful in creating a climate of change in schools and they have highlighted the potential amongst the teaching profession (Vincent, 2004). However, the positive results from the school-based projects have not always been reflected in improved student learning outcomes.

To identify factors contributing to the plateau or dip in performance from Year 6 to Year 7, a large study conducted in Victoria used rich assessment tasks to measure student numeracy, and found that teachers in the middle years could, and should, expect a range of knowledge and understanding of up to 7 years within any class of students (Siemon et al., 2001). The study identified key factors, which need to be addressed at all levels including the provision of opportunities for success and scaffolding learning, the development of learning environments which support speaking, listening and working together, opportunities for students to link mathematical concepts and make connections between a smaller number of ideas, and a focus on emphasising conjecturing and generalising rather than just 'doing'.

One School System Approach

More recently, one jurisdiction in Australia sought to address the 'dip' in middle years achievement by developing a plan to support teachers through funded projects. An approach was adopted to improve middle-years students' numeracy development through teacher-led school-based projects spanning two years (Anderson & White, 2007). Schools were allocated funds for teachers to attend planned professional development sessions and to use time away from classes to develop plans.

The *Years 5-8 Mathematics Project* began in 2006 with 6 secondary and 21 primary schools spread across a large metropolitan area. The original conception of the project was to involve one secondary school working with 3 or 4 of its main 'feeder' primary schools to

develop strategies for addressing issues in middle years mathematics. It was anticipated that groups of teachers from the upper primary grades and the lower secondary grades would work collaboratively to review current practice and design projects to address the learning needs of their students. Meetings throughout 2006 revealed most schools developed individual plans based on analysis of large-scale testing data or surveys of staff and students at the school. Where collaboration occurred, it was frequently limited to school visits to observe lessons – an experience which challenged both primary and secondary school teachers perceptions of mathematics learning in each context (Anderson & White, 2007).

An underlying principle of the approach was the encouragement of leadership for learning (Frost & Durrant, 2003) where teachers are seen as 'change agents' in their schools, with a focus on improvement and learning. Teachers were required to develop a plan using the research approach of identifying a problem, developing an intervention, gathering and analysing data, and writing a report of the findings. All project teachers regularly came together to analyse school-based data, discuss key aspects about appropriate practice, explore the curriculum, and consider issues impacting on the numeracy development of middle years students. The resulting projects were unique, context specific and included a focus on particular content areas of the curriculum, problem solving in real-contexts, open-ended questioning, and technology-enriched learning experiences.

Using project reports, surveys of teachers, focus-group discussions and interviews, Anderson and White (2007) conducted an evaluation of the projects after the first year. Teachers reported positive overall outcomes with a high level of teacher professional learning, identification of sound pedagogical practices, engagement and ownership. The provision of funds to support time and space to reflect, read and discuss with colleagues appeared to be the greatest benefit. From student data, teachers reported increased levels of engagement, more positive attitudes towards mathematics, and improved mathematical understanding. A case study addressing a key issue in lower secondary mathematics is presented in the next section.

The Case Study – Margate School

The evaluation of the projects provided rich data about the potential of research-focused teacher-led development work to improve pedagogy and student learning outcomes. For Margate School, a focus on appropriate assessment practices which clearly identify level of understanding (in this case, fractions), provided an important benchmark against which students' knowledge, skills and understanding could be carefully assessed, and the learning needs of students addressed.

Margate school is a comprehensive, co-educational Catholic school in the outer suburbs of a large metropolitan area with approximately 950 students in grades 7 to 12 (12 years to 18 years) and 80 teachers. Most students entering Year 7 have attended one of four 'feeder' primary schools. Based on information provided by the primary schools and results from tasks completed during initial school visits, students are streamed into classes according their results in all subjects. This approach to streaming does not take into account differences between students English and mathematics performance. Students remain together for all lessons but may be relocated into another class if their performance during Year 7 indicates they have been misplaced.

The mathematics coordinator (Sally), a relatively inexperienced teacher in her sixth year of teaching at the school, is a dynamic and motivating leader. While there is a range of experience in the mathematics team, most have been teaching mathematics for less than six years. They are enthusiastic and open to new approaches, with teachers of classes at the same grade level working together to plan units of work, develop assessment strategies and evaluate programs and practices. Early in 2006, Margate school was invited to participate in the *Years 5-8 Mathematics Project*. Sally and one other teacher (Ned) attended two days of professional development, which focused on a range of content areas from the mandated curriculum in NSW. In addition, details about possible school-based projects were outlined and advice provided on ways to develop a plan for researching issues.

The curriculum for Kindergarten to Year 10 is divided into 5 content strands (Number; Patterns and Algebra; Data; Measurement; and Space and Geometry) and one process strand (Working Mathematically). To support teachers planning, the content is presented as a developmental continuum of learning with key ideas articulated for every two years after the first year of schooling (Kindergarten). The curriculum is packaged into two booklets, one for primary school teachers and the other for secondary mathematics teachers. When planning, most teachers focus on the key ideas for the two-year stage of their students even though the advice in the documents is to consider the stage before and after since not all students learn at the same rate.

Sally and Ned decided to focus on Year 7 students' understanding of fractions from the Number strand of the curriculum. For the last few years, they had noticed students were not ready to engage with the content on common fractions presented in the age-appropriate stage from the lower secondary curriculum (Stage 4). Until the new syllabuses were released in 2002, the primary school curriculum had little common fraction content (Anderson & Wong, 2007). With the release of the latest syllabuses (BOS NSW, 2002a; BOS NSW, 2002b), the expectations for common fraction learning has been significantly increased so that students in Years 5 and 6 (Stage 3) learn to add and subtract fractions, place fractions on a number line, and multiply fractions by whole numbers.

Developing common fraction understanding is one of the most challenging areas of the mathematics curriculum (National Mathematics Advisory Panel, 2008; Ryan & Williams, 2007). However it is critical that students have a solid foundation of fraction understanding before they are able to engage with the abstract ideas of algebra. Sounding a word of warning about our expectations of the development of fraction knowledge, Ryan and Williams (2007) suggest:

> … concepts such as that of the fraction $\frac{1}{2}$ and $\frac{1}{4}$ continue to develop over a prolonged period of schooling and 'having the concept' is often a slippery idea; concept acquisition is always a work in progress, and a lot depends on the context of the concept, the model or representation, and the mode of assessment of the task. Indeed, conceptions of fractions continue to develop with that of proportions right through secondary school … (p. 69).

Perhaps primary school teachers understand these concerns since Anderson & Wong (2007) reported teachers' level of discomfort with the increased expectations of common fraction understanding in the new syllabuses. As a consequence teachers tend to rely on textbooks and worksheets to support student learning.

For Sally and Ned, the approach adopted by primary school teachers does not seem to have worked as the Year 7 students they encounter have little understanding of common

fractions. Added to the dilemma of limited understanding, there is not a uniform approach to teaching fractions in the four main primary schools sending students to Margate school. To address the issue, Sally and Ned wanted to assess each student's knowledge, skills and understanding of fractions so they would know where to begin planning lessons and units of work. With the assistance of a Numeracy Project Officer employed by the school system, they developed a pre-test based on fraction content from the primary curriculum (Stages 2 and 3). The pen-and-paper test was administered to their two Year 7 classes. To alleviate pressure and encourage students to be honest about their level of understanding, the 'test' was labelled "Show Me What You Know" with students encouraged to provide feedback about their mathematics learning experiences in primary school.

Assessment and Pedagogy for Common Fractions at Margate School

Analysis of students' responses revealed many misconceptions and little understanding of particular fraction representations. Figures 1 to 3 are examples of the items on the test. While these items do match with syllabus expectations at Stages 2 and 3, Ryan and Williams (2007) suggest they are not necessarily straight forward with students typically finding circle models easier to work with and multiplicative thinking involving ratio taking longer to learn than syllabus writers might anticipate.

Q1) In the diagrams below, what fraction of each shape has been shaded?

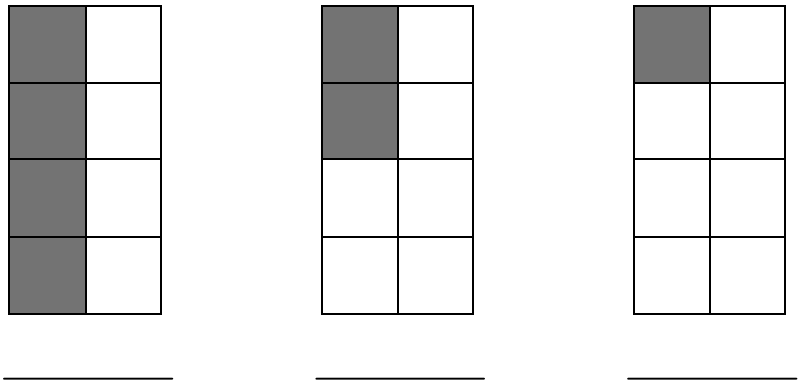

Figure 1. Question 1 on the pre-test (Stage 2 or Years 3 and 4 of primary schooling)

Q15) a) $3 \times \frac{2}{5} =$ b) $\frac{1}{5}$ of $30 =$

Figure 2. Question 15 on the pre-test (Stage 3, Years 5 and 6 of primary schooling)

Q20) a) $\frac{4}{5} + \frac{3}{5} = \frac{3}{5} + \frac{4}{5}$ True or false?

Figure 3. Question 20a on the pre-test (Stage 3, Years 5 and 6 of primary schooling)

After the pre-test, students discussed the items and described their experiences from primary school – it became clear they had limited understanding of the primary school common fraction content. In addition, a sample of students representing low, medium and high achievement on the test were interviewed and video-taped as they attempted similar questions and problems involving common fractions. One of the problems presented to students was:

> If you have 3 chocolate bars and 4 children, work out the equal share that each child would get from these 3 chocolate bars.

The same test was used as a post-test after the unit of work on common fractions. Students were aware that the same 'test' would be used and were encouraged to revisit the questions before taking the post-test. For most items in the post-test, there was an increase in student understanding. However the three items in Figures 1 to 3 still created issues for many students.

Addressing the Learning Needs of Students

Student results from the pre-test and diversity of responses to the problems in the interviews was a "learning curve" for Sally and Ned. They were surprised by the diversity of knowledge, skills and understanding but were now much more informed about the issues associated with learning common fractions and the challenge to develop focused learning experiences for their students. In the past, they had assumed the students had far greater understanding of the primary school curriculum and had not taken the time to investigate the students' knowledge in a meaningful way.

The data convinced Sally and Ned to modify their programs by planning from the primary school content for fractions. In addition, they purchased more resources for teaching common fractions with models other than circles and developed a range of appropriate games and tasks. Textbooks were now used for homework rather than as a focus for teaching and learning in lessons. Experiences for students were far more 'hands on'. Sally reported the students were more engaged in lessons – from pre-test responses, the students were aware how much they needed to learn. In lessons, students "told us how they learnt", realising the teachers needed to know if they were to plan lessons which addressed their needs. Students were keen to do the post-test to see how many of the questions they could now do. The following two quotes from students reveals they enjoyed doing both assessments:

> I really like the pre-tests because I can see what I already know and it makes me feel smarter (Year 7 student).

> Post-tests are good. I get to see what I've learnt and what I have to remember more for my tests (Year 7 student).

Sharing the results from their investigation with three other teachers of Year 7 classes led to the development of more focused units of work, pre- and post-testing in all of the Year 7 mathematics classes in all topics which followed. Lessons for Year 7 classes now include more concrete experiences and more discussion and group work, with students openly sharing their primary school experiences and the challenges they have faced in learning particular topics in the curriculum. The mathematics teachers have since trialled the approach in other year groups with similar results.

The success of the project has influenced the practices of other teachers at Margate school as well as teachers from other primary and secondary schools in the district. Teachers' comments reinforced the success of the project:

> I wouldn't have known that this huge difference in ability existed in my classroom without first pre-testing. It has allowed me to modify the content for individual students who are working at different levels (Teacher of Year 7 Mathematics)
>
> I was able to self evaluate and reflect on what strategies had worked best for my students. It wasn't about what the students didn't learn, but rather what I needed to do to help them learn (Teachers of Year 7 mathematics)

Improvements identified in post-test results led to presentations at a school staff meeting where Sally demonstrated to teachers of English, science, history and geography that the pre- and post-testing approach has had significant benefits for teachers and students. By considering the content of the primary school curriculum in their subject, teachers have become aware of knowledge, skills and understanding they either assumed the students knew or did not know was included in the primary curriculum. Other faculties at Margate school have now adopted similar assessment practices.

Implications and Recommendations

The school-based project at Margate School has revealed important issues for teachers in the lower secondary years of schooling. For secondary school teachers, knowledge of the primary school mathematics curriculum is essential including how students learn key concepts, and the errors and misconceptions associated with each topic. Each student's level of understanding needs to be established through appropriate assessment if the needs of students are to be met. Making assumptions about students' knowledge, skills and understanding does not save time but potentially creates more issues for student achievement in mathematics. It is possible that the plateau or dip in performance is a consequence of students disengaging from learning because they either do not have the foundation knowledge to learn new concepts, or they already understand and are wasting time.

Developing learning environments where students are free to talk about their experiences from primary schooling, share their concerns with teachers, and describe how they best learn new ideas, has the potential to change students' attitudes and beliefs about mathematics. While assessment is crucial, students do not need the pressure of 'taking a test'; negotiating a process of "show me what you know" has been very productive for the teachers of Margate School. Students have been engaged in a partnership with their teachers, providing feedback on new pedagogical approaches, which include greater use of concrete materials and collaborative group work.

Sally's leadership of the project and time for teachers to plan and work together have contributed to its success. She has led by example, encouraged staff to become involved, discuss outcomes and share resources, with all teachers in the mathematics faculty now using pre- and post-testing. However, she acknowledges they still have more to learn and not all of the students' learning needs have been met. With the encouragement and support of the Principal as well as the Learning and Teaching Coordinator, she has influenced teachers from other key learning areas to adopt similar approaches.

School-based projects have the potential to provide a renewed focus on the early secondary years of schooling, particularly when many schools focus much of their energy on the upper secondary years where high-stakes testing occurs. Added to the issues in the early secondary years, less qualified and less experienced teachers are frequently allocated to teach mathematics classes in the important early secondary years when students need

substantial support to address the 'dip' in achievement. More research is needed but school-based projects provide important research potential for further investigation.

References

Anderson, J., & White, P. (2007). *Evaluation report of the Year 5 to Year 8 mathematics project for the Catholic Education Office, Sydney*. Leichhardt, NSW: CEO Sydney.

Anderson, J., & Wong, M. (2007) *Teaching common fractions in primary school: Teachers' reactions to a new curriculum.* Proceedings of the Australian Association for Research in Education's 36th Annual International Education Research Conference. Adelaide, Australia.

Board of Studies NSW (BOS NSW) (2002a). *Mathematics K-6 Syllabus*. Sydney: BOS NSW.

Board of Studies NSW (BOS NSW) (2002b). *Mathematics Years 7-10 Syllabus*. Sydney: BOS NSW.

Curriculum Corporation (2000). *Numeracy Benchmarks Years 3, 5 & 7*. Carlton, Vic.: Curric. Corporation.

Department of Education, Training and Youth Affairs (DETYA) (2000), *Numeracy, A priority for all: Challenges for Australian Schools*. Canberra: Commonwealth of Australia.

Frost, D., & Durrant, J. (2003). *Teacher-led development work*. London: David Fulton Publishers.

Luke, A., et al. (2003). *Beyond the Middle: A report about literacy and numeracy development of target group students in the middle years of schooling, Volume 1*. The University of Queensland.

National Mathematics Advisory Panel (2008). *Foundations for success: The final report of the National Mathematics Advisory Panel.* U.S. Department of Education: Washington, DC.

NSW Department of Education and Training (NSW DET) (2002). *Counting On: Re-connecting conceptual development*. Sydney: NSW DET.

Perry, B., & Howard, P. (2002). A systematic program for students who are experiencing difficulty with mathematics as they transition from elementary to high school in Australia. In B. Barton, K. C. Irwin, M. Pfannkuch & M. O. J. Thomas (Eds.), *Mathematics Education in the South Pacific*, (Proceedings of the 25th annual conference of the Mathematics Education Research Group of Australasia, Auckland, pp. 543-550). Sydney: MERGA.

Ryan, J., & Williams, J. (2007). *Children's mathematics 4-15*. Berkshire, UK: Open University Press.

Siemon, D., Virgona, J., & Corneille, K. (2001). *Successful interventions numeracy research project: 5-9. Final report*. RMIT University.

Vincent, J. (2004). The numeracy research and development initiative projects. *Australian Primary Mathematics Classroom*, 9(4), 4-9.