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# Australasian Journal of Special Education



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CONTENTS

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**CONFERENCE PAPER**

# Supporting Students in the Middle School Years with Learning Difficulties in Mathematics: Research into Classroom Practice

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The aim of this article is to promote discussion and professional development around the topic of learning difficulties in mathematics, particularly as these pertain to teaching and learning in the middle school years. The article has three sections. In the first section, a review of literature about learning difficulties (LD) in mathematics is presented. Definitional issues are discussed, key underlying causes of LD in mathematics are highlighted and common 'learner characteristics' of middle-years students with LD in mathematics are identified. The second part of the article is an overview of a responsive intervention currently being developed to support middle-years students with LD in mathematics. This section describes the implementation of the *QuickSmart* mathematics intervention with 42 participating students and 12 comparison students enrolled in five schools from a rural area of New South Wales. The results of pre-intervention and post-intervention assessments, using both standardised and achievement-based measures are reported. The findings indicate that the *QuickSmart* intervention approach improved students' mathematical knowledge, skills and understandings. In the third section of the article research-validated, curriculum-relevant strategies from the *QuickSmart* mathematics program are described.

Inclusion makes considerable demands on teachers as they cater for a range of student abilities and needs in their classrooms. It is challenging to provide appropriate instructional adjustments and still meet system demands for comprehensive, appropriately paced instruction and accurate reporting to parents (Evans, 2007). As students with learning difficulties have complex learner characteristics, it

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is not surprising that teachers are at times bewildered by the wide range of learning needs displayed by their students and by the concomitant demands on their professional knowledge (Westwood & Graham, 2003).

It is important for teachers to understand the major obstacles to successful academic engagement that students with learning difficulties (LD) experience so that they can select appropriate instructional approaches that will ensure success. As researchers, over the last seven years, we have engaged in programmatic research focused on designing responsive interventions that provide information about effective teaching and learning of basic academic skills. In this article, we describe an intervention that aims to support students with LD in mathematics through an extended instructional program.

## Learning Difficulties in Mathematics

Like most areas related to learning difficulties and learning disabilities, learning difficulties in mathematics is a topic beset by definitional difficulties. These are mostly associated with terminology that varies from country to country but also emanates from the profusion of terms used to describe mathematics learning. In general, the terms 'learning disability in mathematics' or 'mathematics disability' are used to describe a population of students who achieve poorly in mathematics, due to specific or general cognitive deficits. In Australia, 'learning difficulties' is used as a non-categorical term applied to all students who achieve poorly in mathematics regardless of the cause. However, 'developmental dyscalculia' is another term, used to describe the specific problems with mathematical understanding encountered by those who experience severe difficulty due to inefficiencies in neurological processes. Clearly, terminology and diagnostic labels vary across contexts. A recent description of the similarities and differences between Australian and North American special education terminology is provided by Graham and Bailey (2007).

Additionally, there is a range of terms used within the field of mathematics education that pertain to various aspects of mathematics learning, for example, numeracy, number sense, arithmetic and calculation, which further add to confusion regarding a definition of learning difficulties or disabilities in mathematics. In the remainder of this article the term 'learning difficulties (LD) in mathematics' will be used generically to describe students with a history of persistent difficulty and lack of success in school learning in this subject area. The ability to be fluent in basic calculations and the use of number will be the focus of this discussion.

The extent of LD in mathematics for Australian students is difficult to ascertain, with estimates varying from 5 to 20% depending on the definitions used. These rates tend to be higher in rural and remote areas of Australia and for Indigenous students. Gender-based performance differences are not pronounced (Doig, 2001). Generally, it is accepted that 5–10% of students have significant difficulties in mathematics (Geary, 2003; Louden et al., 2000; Pincott, 2004) but classroom teachers and some state and national testing data indicate that up to 20% of students experience delays

and difficulties in mathematics (Louden et al., 2000). The co-morbidity of LD in reading and mathematics has been shown to be more than 60% (Gersten & Chard, 1999), indicating that at least part of the difficulty experienced by many students with LD in mathematics can be attributed to poor language and literacy skills (Westwood, 2001). Currently, the prognosis for many middle-years students with LD in mathematics is that they will fall increasingly behind their normally achieving peers over time (Cawley, Parmer, Yan & Miller, 1996; Swanson & Hoskyn, 2001).

Students with LD in mathematics experience failure for a variety of reasons, including poorly developed number sense, poor processing abilities, language and literacy difficulties, 'maths anxiety' and inefficient memory processes (Gersten & Chard, 1999). Specific cognitive difficulties that can impede their progress include information processing and memory problems (Westwood, 2000), as well as attentional difficulties and motivational issues (Chan & Dally, 2001). 'Maths anxiety' has also been identified as a cause of learning difficulties in mathematics (Miller & Mercer, 1997). Some researchers propose that the reasons for students' failure in basic mathematics are related to teaching methods and curriculum issues, rather than factors within the learner (Pincott, 2004; Vaughn, Bos & Schumm, 2000). Poor teaching or 'dyspaedogogia' can have a significant impact, especially for students experiencing learning difficulties, to the point that ineffective instruction can lead to students developing learned helplessness in mathematics (Pincott, 2004).

The heterogeneous causes of LD in basic mathematics manifest in a range of deficits and limited proficiencies. Students with LD in mathematics, for example, may exhibit difficulties in several areas such as basic computation skills, deciphering word problems, understanding the language of mathematics and mathematical reasoning (Milton, 2000). In the area of computation, students with LD can display inaccurate or inefficient strategies, slow and error-prone retrieval of previously encountered content, and reduced or variable speed of processing (Chan & Dally, 2001). Often, inefficient, error-prone finger counting strategies dominate simple tasks that lead to poor speed and accuracy with 'the basics'. Geary (2004), is one of a growing number of researchers who suggests that disruptions to students' ability to retrieve basic facts from long-term memory might be considered a defining feature of mathematics learning disability. The consequent difficulty LD students experience solving simple arithmetic and word problems limits the availability to them of cognitive resources for engaging with the more complex aspects of mathematics problem solving (Chan & Dally, 2001; Geary, 2004).

This brief discussion of mathematics learning disabilities in the middle school years is important for both researchers and classroom teachers. The key question for both groups is whether students' difficulties are amenable to intervention. Can a well-designed intervention effect a positive change in student learning and support students' improved participation and success with basic academic skills in regular classrooms? The *QuickSmart* research program has been developed at the University of New England's National Centre of Science, Information and Communication Technology and Mathematics Education for Rural and Regional Australia

(SiMERR) in an attempt to address some of the gaps identified in research and practice for middle-years students with learning difficulties in mathematics.

## Research into Practice: The *QuickSmart* Mathematics Intervention

This research has two goals: (1) to investigate the effectiveness of an intervention designed to improve students' fluency with basic academic skills; and (2) to observe the effect of improved fluency with 'the basics' on students' performance on more demanding academic tasks, such as their performance on standardised achievement tests. An anticipated outcome of the research is that it will provide indications of effective teaching approaches for students in regular middle-years classes who experience on-going difficulties in mathematics. The research reported here focuses on the results of the intervention in schools in the New England region of New South Wales in 2005. For a more detailed report on this research see Graham, Bellert, Thomas and Pegg (2007).

## Method

A total of 42 students (22 females and 20 males) in the middle school grades (Years 5–7) with learning difficulties in mathematics were selected to participate in this study. Nine of these students identified as Indigenous Australians. The average age of participating students was 11 years and 4 months.

Ten students (five average and five high-achieving as per teacher nomination) were selected from the same schools to provide comparison group data. This comparison group of high/average-achieving students, who received classroom instruction only, was selected to provide a benchmark in terms of response speed and accuracy on the Cognitive Aptitude Assessment System (CAAS) computer assessment package (Royer, 1996) and to explore students' skill improvement on standardised test scores over time. All test results were supported by the collection of rich observational data, semi-structured exit interviews, field notes, and parent and teacher interviews. The discussion of these qualitative data, however, is beyond the scope of the current article.

Pre-intervention and post-intervention testing of both the selected *QuickSmart* students and the comparison students was completed using the standardised Progressive Achievement Tests (PAT) (Australian Council for Educational Research [ACER], 1997) in mathematics and a bank of mathematics tasks from the CAAS computer assessment package (Royer, 1996). The CAAS system times how rapidly students respond into a microphone once a number sentence appears on the computer screen. An instructor scores each response for accuracy. The results are automatically averaged and made available in either a graph or report form that is easily interpretable by both students and teachers. The CAAS is a unique component of the *QuickSmart* program. It provides ongoing monitoring of students' basic academic skills during lessons and supports the research focus of the *QuickSmart* intervention when used for data collection at pre-test and post-test.

*The QuickSmart Intervention*

Students participated in three 30-minute lessons per week for approximately 26 weeks over three school terms of structured intervention activities in small groups of two students. An experienced teacher or teacher's aide delivered the program under the supervision of a trained teacher to ensure the fidelity of the intervention. An overview of the intervention lesson format is provided in Figure 1.

## Results

Information related to students' accuracy and information retrieval times as measured by CAAS tasks was collected to provide a measure of students' levels of automaticity of basic academic skills. It is important to note that the development of students' fluency with number facts was a clear, but not the sole, focus of the intervention. Students' pre-test and post-test standardised PAT scores were also gathered. These scores were used as an indication of students' capacity to engage successfully with more complex mathematical tasks.

*Standardised Test Scores*

The Progressive Achievement Tests (ACER, 1997) in mathematics were administered to students participating in the *QuickSmart* program and also to the high/average-achieving comparison group. Versions of the standardised tests were

**What Do We do in *QuickSmart* Mathematics Lessons?**

1. **Knowledge and Understanding Check** (5 minutes).
   *Review and show your understandings of the Focus Number Facts.*
2. **Flashcards** (5 minutes).
   *How fast and accurate can you be with the Flashcards?*
3. **Speed Sheet Challenge** (5 minutes).
   *Take the challenge with the current set of Focus Number Facts.*
4. **Independent Work Sheets/Strategy Development** (5 minutes).
   *Practice the focus number facts on relevant work sheets or later in the program learn about a new, smart strategy.*
5. **Assessment** (5 minutes for each *QuickSmart* student)
   *Do an assessment with CAAS and record your results.*
6. **Games** (5 minutes) *Play fun and focused activities like 3-in-a-Row, Double O, Same Sums and QuickSmart Bingo.*

Figure 1. An overview of the *QuickSmart* mathematics lesson.

matched to the students' grade levels. Increased scores on standardised tests is a stringent way to measure improvement in the performance of students with learning difficulties (Simmerman & Swanson, 2001 ). In this study, 32 of the 42 participating *QuickSmart* students (76%) increased their post-test percentile rank scores and two students retained the same score. The remaining students decreased their percentile scores by a maximum of 4 points. Individual improvements of up to 42 percentile points were noted.

Table 1 displays the pre-test and post-test standardised test scores of the *QuickSmart* and comparison students. These results illustrate the extent of the performance gap that exists between students with LD and their high/average-achieving peers. At pre-test the *QuickSmart* students' average scores were 35.01 percentile points lower than those of the high/average-achieving comparison students' scores. At post-test, their average scores were 21.06 percentile points lower. Small and unequal sample sizes precluded further quantitative analyses of data comparing the *QuickSmart* and comparison groups.

Paired sample *t*-tests indicated that the *QuickSmart* students' post-test scores were significantly higher than their pre-test standardised scores ($t$ (1, 41)=6.8, $p$=.000). In contrast, the comparison students did not make significant gains on the standardised measures of mathematics ($t$ (1, 9)=0.46, $p$=.65) over 26 weeks. These findings can be interpreted as support for the position that improving students' accuracy and automaticity of basic facts in mathematics, which was a focus of the *QuickSmart* program, can result in increased performance on standardised tests designed to measure proficiency on complex skills. Though the sample size of average-achieving students is small; the gap between their achievement and that of the *QuickSmart* students had not continued to widen but had narrowed dramatically over the course of the intervention.

### *Cognitive Aptitude Assessment System Data*

The CAAS system records data relating to students' retrieval times and accuracy levels on key academic tasks. For the *QuickSmart* mathematics group the tasks used were addition number facts, subtraction number facts, multiplication number facts, division number facts and triple addition tasks (e.g., 7+4+3). Assessments on all of these tasks were completed before and after the intervention with students from the *QuickSmart* group and the comparison group. In addition, students in the

Table 1. Pre- and post-standardised test scores for *QuickSmart* (QS) and comparison students

| PAT Mathematics Scores (in percentiles) | *QuickSmart* students ($n$=42) | | Comparison students ($n$=10) | |
|---|---|---|---|---|
| | M | SD | M | SD |
| Pre-test | 21.67 | 16.7 | 56.68 | 25.4 |
| Post-test | 44.24 [a]** | 20.1 | 65.30 | 14.7 |

[a] $t_{(1, 41)}$=6.8; $p$=.000; **$p$<.001.

intervention group completed CAAS assessments on a relevant task as a usual part of their *QuickSmart* lessons.

The main purpose for including a small sample of comparison students in the study was to provide a benchmark of the level of performance *QuickSmart* students should aspire to from their same-age peers in terms of response speed and accuracy on basic academic skill tasks. Figure 2 contrasts the average performance profiles of the *QuickSmart* ($n$=42) and comparison students ($n$=10) before and after the intervention.

Comparison of all the pre-test and post-test mathematics graphs depicted in Figure 2 shows that the average performance of *QuickSmart* students improved markedly in terms of their immediate recall of basic mathematical facts and the accuracy of their answers. For example, with regard to multiplication number facts, the students in the *QuickSmart* group were able to respond in an average time of 2.2 seconds by the end of the *QuickSmart* program. At the beginning of the intervention, these same students took an average of 3.5 seconds to answer each number fact. The students' accuracy also improved from an average of 76% at the beginning of the program to 89% for correct multiplication number facts at the end of the intervention.

Overall, Figure 2 illustrates how mathematics students' average information retrieval times decreased from pre-test to post-test and how concomitant accuracy

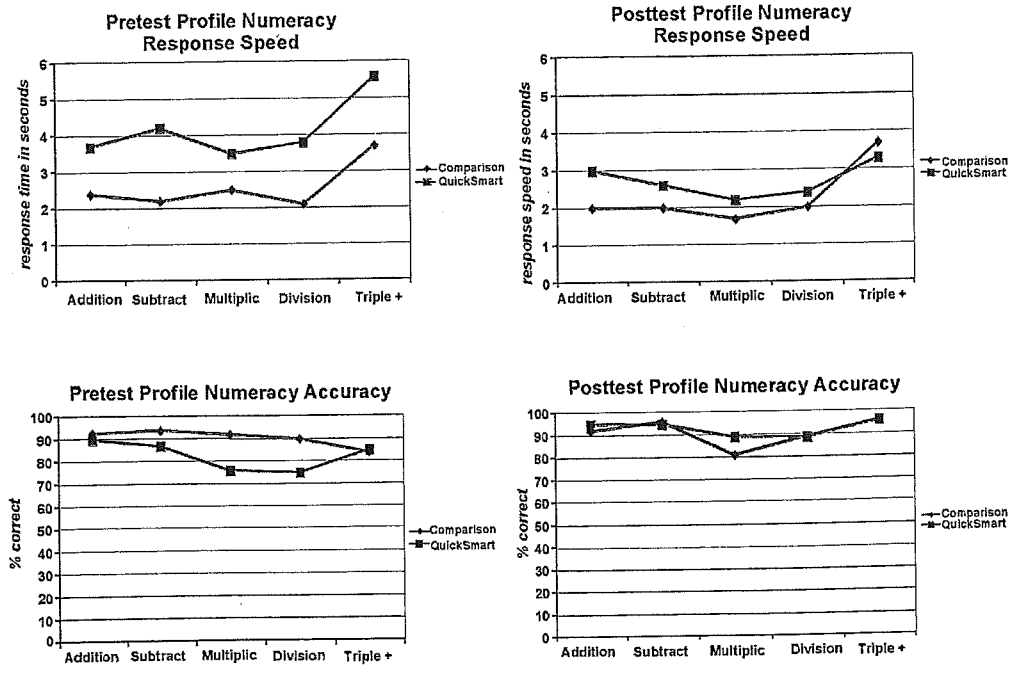


Figure 2. Response speed and accuracy profiles of *QuickSmart* numeracy intervention and comparison students

levels increased in comparison to the performance of high/average-achieving peers. Figure 2 confirms that on CAAS mathematics post-tests there was little difference between the *QuickSmart* and comparison groups. The *QuickSmart* students' improvement in accuracy levels was particularly noticeable. Again, these graphs are indications of how *QuickSmart* students were able to 'narrow the gap' in terms of basic academic skills by becoming 'quicker' with fact retrieval and 'smarter' at strategy use.

Though further work with a larger cohort of comparison students, a control group to address concerns about external validity, and more rigorous statistical analyses are necessary, this study demonstrates that carefully designed explicit interventions of sufficient intensity and duration, such as *QuickSmart*, have promise. The research program clearly indicates that instructional approaches including direct instruction, specific feedback and the provision of frequent opportunities for practice can enhance learning outcomes for middle school students experiencing difficulty in mathematics.

## Effective Teaching Strategies and Approaches in Mathematics Classrooms, Years 5–8

In this concluding section of the article, two research-validated, curriculum-relevant strategies from the *QuickSmart* mathematics program will be described in detail. These instructional approaches are deliberate practice and focused feedback. In addition, a summary table that displays classroom strategies for teachers to use with students with learning difficulties is presented in harmony with the 2007 AASE conference theme of *Teachers make it happen: From research to classrooms.*

### *Deliberate Practice*

Practice, in terms of repeating similar procedures or exercises, has value in terms of establishing routines for certain activities and reducing cognitive load. However, practice that is too infrequent, poorly targeted or continued without evaluation does not necessarily lead to ongoing improvement. The term 'deliberate practice' is drawn from research that has explored expert performance in a range of areas outside of education (Ericsson, Krampe, & Tesch-Romer, 1993). Deliberate practice within an education context has four key aspects. Deliberate practice is a highly structured activity that has been specifically designed to improve the current level of performance; (ii) allows for repeated experiences in which the individual attends to critical aspects of tasks; (iii) involves specific tasks that are used to overcome weaknesses; and (iv) enables performance to be monitored carefully to provide feedback.

Students are often motivated to exert effort because focused practice improves their performance in ways they can see and feel. Evidence of this improvement is available to observers and to the students themselves. Deliberate practice of basic

mathematical facts, procedures and strategies plays an important role in effective teaching for students in the middle school years with LD.

*Feedback*

Like practice, feedback is an integral part of effective teaching and learning. This complex feature of teaching and learning is fundamental to improvements in student achievement. Feedback is a teacher behaviour that powerfully enhances student learning outcomes (Hattie, 2005 ). However, particular features of feedback make it especially effective (e.g., Hattie & Timperley, 2007). Feedback needs to be carefully defined and used thoughtfully in order to engender student improvement. Hattie identified the four levels of feedback in his model as: (i) feedback about the self, unrelated to performance on a task; (ii) feedback on self-regulation so that the student knows how to complete the task with less effort and more success; (iii) feedback aimed at how the task is completed. This includes feedback on strategic levels of understanding and how to process information required to complete the task; and (iv) feedback about the task that allows students to acquire more, different, or improved information.

Hattie's position is that these levels of feedback are least effective at the first level, powerful at the second and third levels in terms of deep processing and task mastery, and most powerful at the fourth level when information is used to improve strategic processing. Effective classroom teachers provide information to students on what they understand or do not understand, why the student is correct or incorrect, what needs to be changed or improved, and what information needs to be focused on or practised in order to improve. This form of feedback is linked to formative assessment practices, where the teacher uses assessment information to focus and guide teaching approaches.

Without doubt effective teachers can and do make a difference to the participation and achievement of middle-years students with learning difficulties in mathematics. To achieve this classroom teachers need to use strategies and approaches that enable students to 'work around' their cognitive obstacles and to develop their procedural fluency. In an attempt to translate research into practice, we have listed, in Tables 2 and 3, generic examples of how teachers can provide such instructional adjustments in regular middle-school mathematics classes.

## Conclusion

In terms of both research and resources learning difficulties in mathematics are very much under-considered compared to learning difficulties in reading. Fortunately, in recent years, researchers, school systems and classroom teachers have become more focused on identifying and implementing approaches that support students with LD in mathematics. In this article we have described some of this emerging work as it relates to students in the middle school years. Although these students can have

Table 2. Effective teaching strategies for addressing cognitive factors of learning difficulties

| Obstacle: cognitive factors | Effective teaching strategy (adjustment) |
|---|---|
| Inappropriate or inefficient use of strategies | Model efficient strategies in a supportive environment<br>Use teacher and peer 'think-alouds'<br>Teach by showing, demonstrating, peer modelling<br>Encourage reflection and talk about learning processes |
| Difficulty recalling knowledge | Explicit, repeated review and practice<br>Make strong connections with prior knowledge and current interests<br>Use mnemonics and other memory aids |
| Limitations in working memory | Teach cognitive strategies/procedures (repeatedly)<br>Use advanced organisers (preview and pre-teach)<br>Chunking content and tasks into achievable steps<br>Use graphic organisers (search the Web for math graphic organisers)<br>Provide scaffolds and pro formas, e.g. for Newman's problem-solving steps |

Table 3. Effective teaching strategies for addressing difficulties with basic mathematics

| Obstacle: basic skills | Effective teaching strategy (adjustment) |
|---|---|
| Poor basic math skills | Frequent review and practice of basic facts<br>Teach and practise similar facts together (+/-; x/÷)<br>Maintain the focus on practice activities over an extended period of time<br>Use timed practice activities so students can beat their 'personal best' times<br>Frequent, intense, short bursts of practice<br>Use a variety of practice approaches, e.g., flashcards, speedsheets, games, repeated and timed practice on appropriate worksheets, peer activities, etc.<br>Teach (repeatedly) and display counting and grouping strategies<br>Relate basic math facts to basic living skills—money, measurement, card games, cooking, etc. |
| Limited competence and confidence in mathematics problem solving | Teach a 'step-by-step' approach, e.g:<br>• Identify the problem<br>• Draw the scenario<br>• Select a strategy to solve the problem<br>• Put the information into an algorithm<br>• Calculate<br>• Evaluate<br>Teacher and peer modelling, followed by guided and independent practice<br>Explicitly teach strategies such as:<br>• Use models, number lines or concrete materials<br>• Look for key words<br>• Make a drawing or diagram<br>• Act it out/visualise<br>• Remove irrelevant detail<br>Construct a table or graph<br>Pre-teach and frequently practise key words for each new mathematics topic as well as generic math prefixes and suffixes, e.g., deci-, centi-, milli-, -meter, -gram, pent-, etc. |

difficulties with cognitive processes, very poor fluency in basic academic skills, and are likely to be several years behind their non-LD peers in achievement, effective instruction can make a positive difference. In the classroom, intervention takes the form of adapted instructional approaches that enable students to participate and experience success. In a complementary way, basic academic skills interventions like *QuickSmart* are a significant tactic in the growing repertoire of approaches that address the needs of students with learning difficulties in mathematics.

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