INTRODUCTION

Students experiencing learning difficulties are part of almost every school community. The term learning difficulties (LD) refers to notably low achievement, relevant to same age-peers, in academic skills. Learning difficulties result from a variety of causes and manifest in a wide range of individual learning needs, yet, among older students with LD, there is a common, key skill deficiency in ‘the basics’ of reading and mathematics. That is, students with LD in the middle-school years are unable to perform fluidly basic academic skills – to read and understand an age-appropriate text about a known topic, or to recall and use basic maths facts readily and accurately. These limitations in basic skills impede progress and development in many aspects of learning.

Effective recall and application of basic academic skills is a key pre-requisite for school learning across the curriculum, through the middle-school years and beyond. Students who have problems with the ‘basics’ of literacy and numeracy face a myriad of difficulties in accessing the curriculum, particularly in the middle-school years (Grades 5-8), when the educational focus shifts from learning basic academic skills to using basic academic skills as a tool for further enquiry and learning.

Students who experience LD are frequently unsuccessful in achieving appropriate learning outcomes, as even very competent teachers have trouble in providing, within a normal classroom environment, the necessary support students with LD require to make progress. Even when resources are available to provide intensive support in the middle-school years, intervention programs may, at times, be poorly sequenced or inappropriately targeted, or may not draw on critical research findings.

Despite increasing gaps in achievement between LD and non- LD students in the middle-school years, most students experiencing persistent LD do show development, if delayed, in their academic skills and conceptual understandings as they progress through school. However, progress in these domains is slower than that of average-achieving students, such that the performance gap becomes wider as students become older.

Whilst the difficulties these students experience are readily observable in the classroom, knowing how to overcome the obstacles preventing these students from achieving their academic potential is an ongoing challenge for researchers, teachers and school systems. Accordingly, basic academic skills development, in older students experiencing persistent LD, in contemporary educational context, is a fertile focus for an investigation. Findings from such research may, potentially, support under-achieving students towards attaining improved learning outcomes, and provide further information about effective teaching and learning.

The research described in this thesis takes up this challenge, by investigating the effects of an intervention implemented in two schools, a primary school and a secondary school, in rural New South Wales. The intervention used focuses on improving basic academic skills through the implementation of the *QuickSmart* reading and the *QuickSmart* mathematics programs. The theoretical underpinnings of the intervention are drawn from information-processing models of cognition related to learning basic academic skills, specifically the process of developing automaticity, the construct of working memory and their roles in the allocation of limited cognitive resources.

This thesis has seven chapters. Chapter 1 presents a review of current literature about LD, focusing, when feasible, on students in the middle-school years. General information about LD is provided, followed by more specific information about LD in reading and basic mathematics. The social and emotional impact of LD for students in their middle-school years' are then considered, as well as evidence-based approaches to working successfully with them to improve learning outcomes in basic academic skills. The chapter concludes by describing an important area of focus for further investigation. Specifically, this is the impact of efficient and inefficient cognitive processes on the acquisition and use of basic academic skills.

Chapter 2 contains more detailed exploration of the issues identified in the first chapter, with a continued focus on information relevant to development of basic academic skills in reading and mathematics. The resulting summary and conclusions of the research literature are used to inform the development of the research direction of this thesis.

Chapter 3 describes the experimental design of the research. It begins with an overview of the context in which the research was to be conducted, includes a description of the mixed-methods research design selected for the study, and also identifies factors which required particular consideration in the planning stage of the research. The design of the study is then described in detail and procedures for selecting participants, and information about the instrumentation used for data collection, is provided. Towards the end of this chapter the research design is evaluated in terms of reliability and validity. As a culmination of these considerations about the research design, data analysis plans are developed.

Chapter 4 is a relatively brief chapter which describes the research procedure, specifically the *QuickSmart* intervention programs. The processes and procedures of the *QuickSmart* reading and mathematics intervention programs are described, in order to ensure clarity about the learning activities that constitute the intervention, and the teaching and learning strategies implemented in the intervention.

In Chapter 5 the quantitative results of the study are presented. The research questions are considered in turn. Descriptive and statistical analyses are reported, and the results are considered together in a summary discussion.

The profiles of participant students are presented as qualitative information in Chapter 6 to address the research theme. They are intended to complement and expand upon the results described in the previous chapter and to present a ‘real life’ description of both the difficulties in learning, and the pattern of progress, experienced by actual students in a contemporary, Australian school setting. Each of the profiles consists of a description of the student as a learner, graphs to show their progress throughout the intervention, and exit survey responses. This information is supplemented by a descriptive analysis of the participant profiles which generates some notable and relevant information about this sample of students.

The final chapter, Chapter 7, identifies possible limitations of the study, summarises the results of the research questions and the research theme, and considers their relative importance. Further discussion of the results, considered in context of the relevant research literature, is then presented, before implications for research and practice are considered. The report concludes with a summary.

In overview, the research reported in this thesis is an investigation into ways to support students with LD during their middle-school years. It is based on the common observation that the academic ‘basics’ present an obstacle to students with LD, and when encountered on a daily basis in a classroom learning environment, this obstacle has deleterious effects on learning progress. The study also rests on the premise, based on research evidence, that appropriate, targeted learning interventions have significant potential to support improved academic outcomes and improved participation in education for students experiencing LD. In turn, improved educational outcomes potentially provide many other benefits:

> For individuals, higher levels of education offer the possibility of escaping disadvantage, realising potential and personal fulfillment, securing meaningful work and achieving increased earnings. For society as a whole, levels of education are positively and strongly correlated with a range of measures of health, family functioning, children’s wellbeing, a clean environment and the absence of violent crime. For the Australian economy levels of education and training are directly related to levels of workforce participation and national productivity. (Masters, 2007)

The potential for enhanced educational outcomes to provide life-long benefits is enormous, and provides inspiration and motivation to participate in, and contribute to, teaching and conducting research focused on learning difficulties in the middle-school years.

Chapter 1

Learning Difficulties Literature Review

The quest to learn more about learning difficulties (LD) presents a diverse and interesting challenge. Although the field of learning difficulties could be viewed as a rather specific focus within the discipline of education, it is, in fact, a broad topic for investigation because of the volume of research and diversity of approaches. LD research draws on knowledge and approaches from a range of disciplines including psychology, education, and brain science research. Further, the field of learning difficulties focuses on diverse learners, who display variable characteristics and a wide range of learning needs.

The field of learning difficulties emphasises developing evidence-based recommendations for professional practice as well as on undertaking scientific enquiry. As the result of increasing social and political expectations for improving learning outcomes for low-achieving students, there is a growing demand for effective, efficient, evidence-based approaches. LD research has an important role in providing reliable information to support the literacy, numeracy and social skills development of students experiencing LD at all levels of education. Scientific enquiry in the field of LD investigates individual differences in learning and performance, generating knowledge about causes and consequences. Research in LD is also becoming increasingly informed by advances in the cognitive neurosciences which have enhanced understandings about the structure, organisation and development of the brain and the biology of learning.

The aim of this literature review was to present information about LD and to identify a focus for investigation. From the outset, an over-arching purpose for this thesis was to produce information that has utility for teachers and researchers working with students with LD in classroom or intervention settings. In order to delineate the study, the focus was limited to LD in the middle-school years and specifically, the basic academic skills of reading and mathematics.

This chapter presents an overview of contemporary literature in the area of learning difficulties and disabilities. It is divided into three main sections. The first section is concerned with defining LD, and examines cognitive and learning characteristics of middle-school students experiencing LD. The second section explores the affective impact of lack of success in academic learning by examining literature about social and emotional aspects of LD, and the influence on students' learning behaviours. The third section focuses on ways to improve learning outcomes for students experiencing LD, including identification of strategies and approaches shown to be effective in improving learning outcomes for students with LD. At the end of the chapter conclusions and issues requiring further investigation are identified.

Learning Difficulties in the Middle-School Years

Students experiencing LD in the middle-school years face a challenging future at school and present their teachers with a complex set of learner characteristics. In order to clarify the phenomena of LD and its impact on learning the information presented below examines some of the basic tenets of LD and attempts to describe effects of LD on student learning and performance in reading and basic mathematics.

Learning Difficulties: Definitions, Prevalence and Student Characteristics. 'Learning Difficulties' as a term lacks a clear definition (Chan & Dally, 2001) ostensibly because learning difficulties and learning disabilities (the term used in North America and Europe) stem from such a wide range of causes and result in particular manifestations for each individual. The definition of LD is linked intricately to the identification of students experiencing LD, particularly their response to intervention. However, there are cumbersome issues relating to terminology, identification, policy and funding allocation that impact not only on definitional clarity but also on students' access to appropriate support. In Australia, there is no operational definition of LD nationally and there is considerable overlap in the use of the terms 'learning difficulty' and 'learning disability' (Scott, 2004).

In the first instance, definitional precision is precluded by international differences in terminology – in Australia the term 'learning difficulties' is frequently used in educational settings whilst in North America 'learning disabilities' is used. Although there are some parallels between the definitions used in the two countries there are also significant divergences (see Graham & Bailey, 2007). In North America the term 'Learning Disabilities' also presents a myriad of difficulties because of the vagaries and antagonisms surrounding the definition (Kavale & Forness, 2000). In the United Kingdom the term 'dyslexia' is broadly used to cover what might be referred to in Australia as 'specific learning difficulty in reading' or in North America as 'specific learning disability'.

Within Australia there are even differences between professions with regard to terminology – educators generally use the term ‘learning difficulties’ but psychologists tend to use the term ‘learning disability’.

Definitions of learning disabilities and learning difficulties vary, and controversies over identification procedures persist, particularly the notion of a discrepancy between individuals’ potential and their actual performance (e.g., Fuchs & Fuchs, 1998; Scott, 2004). Issues of concern relevant to this ability-achievement discrepancy model include that discrepancies may not become apparent until the later years of primary school, and that specialist testing, such as psychological tests and standardised achievement tests, is required to determine eligibility. Kavale and Forness (2000) noted that there is clarity about what learning disabilities are not (learning difficulties are not due to visual, hearing or motor disabilities, nor to mental retardation or emotional disturbance, nor primarily the result of environmental, emotional or cultural factors). However, such ‘statements of exclusions’ (p. 240) fail to provide a sense of what is actually meant by the term ‘learning disabilities’.

Nonetheless, differentiating LD or learning disabilities from other identifiable impairments is integral not only to establishing a valid definition but also to effective identification and remediation. Swanson and Siegel (2001) posited that the concept of learning disabilities rests on two assumptions. Firstly, that these students’ academic difficulties are not due to inadequate opportunity to learn, general intelligence or to physical or emotional disorders, rather they are due to basic disorders in specific psychological processes. Secondly, that these specific processing deficits are a reflection of neurological, constitutional, and/or biological factors.

The confounding and contentious issues of terminology and identification continue to present a challenge for researchers and educators. In Australia the terminology used in this field remains confusing, and the lack of specificity in terminology has serious implications for identification of and appropriate programming for students with learning difficulties (Scott, 2004). Australian education authorities in different states tend to use existing definitions from the literature or adapt one that suits their own purposes. Sometimes the term ‘learning difficulties’ is used interchangeably with ‘learning disability’, and sometimes these two terms can refer to different groups (Chan & Dally, 2001). Other terms used in Australia to describe students with LD include ‘at educational risk’, ‘under-achieving’, ‘special needs’ (Louden, Chan, Elkins, Greaves, House, Milton, Nichols, Rivalland, Rohl, & van Kraayenoord, 2000) and 'students with additional learning needs'.

Generally, it is agreed that students with learning difficulties or disabilities have significant and pervasive problems acquiring and using some combination of listening, speaking, reading, writing, reasoning, or mathematical skills, due to underlying difficulties involving their use of language, and manipulation of abstract concepts (Swanson & Hoskyn, 1998). Most researchers agree that neurological impairment is a key factor in learning disabilities (Torgesen, 2004), although the impact of other neuro-psychological factors have also been identified (Swanson & Siegel, 2001).

In view of the above discussion, for the context of this thesis, the term 'learning difficulties', abbreviated as LD, is used to refer to notably low achievement in the academic skills of literacy or numeracy, which is not related to any disability or impairment. The heterogeneity of those affected and the resulting array of individual learning needs is acknowledged, and intrinsic cause is assumed. The term 'learning disability' is used only when that term is found in the cited source.

With such variability in definitions it is not surprising that estimates of prevalence vary. However, the percentage of students identified with LD or disabilities continues to increase. Currently, about 5-7% of the school-age population in North America is considered to have some form of learning disability (Gersten, Fuchs, Williams, & Baker, 2001; Torgesen, 2004). In Australia and New Zealand where the definition of LD is broader, at least 20% of school students are considered to have problems in academic areas. Of these students, five percent are considered to have specific learning disabilities in academic areas, most commonly in reading (Westwood & Graham, 2000). Students with LD, both general and specific, that are not related to any disability or condition, are the largest single group of students with special needs, and the size of this group continues to grow (Kavale & Forness, 2000; Westwood, 2003). However, as Kavale and Forness (2000, p. 240) pointed out, without a clear definition providing unequivocal identification criteria, statements about prevalence are but guesses and value judgments, not based on scientific fact.

Despite the lack of rigorous definition and identification criteria, classroom teachers and parents are well-placed to identify students experiencing LD. At the classroom level most students with LD struggle with some or all of the basic academic skills of reading (decoding, vocabulary and comprehending), writing (spelling, sentences and organisation) and calculating basic arithmetic procedures. For students with LD, developing and applying these skills is persistently effortful and error-prone. Further, the results of their labours are often discouraging, as their attainment levels are notably lower than those of their average-achieving peers who seem to read and calculate fluently without apparent effort.

Within the middle-school years and beyond, the significant textual, cognitive, cultural social and technological changes in the learning environment require students to develop ‘grown-up basic skills’ that enable them to “manage, use and produce mono and multi-modal texts that represent linguistic and numeric knowledge across distinctive disciplines” (as stated by Freebody, in Ellis, 2005, p. vi). Students with LD find it more difficult to develop critical skills and knowledge when they have not attained mastery level proficiency in basic academic skills.

Students experience learning difficulties for a wide range of reasons and it manifests in quite different ways for individual students. Despite these differences, there are some common ‘learner characteristics’ and barriers to learning that many students with LD exhibit. Generally, students with LD are very inefficient in the ways they go about the process of learning (Westwood, 1993). These inefficiencies pertain to cognitive behaviours such: as using inappropriate or inefficient strategies that produce high error rates and undermine confidence; having difficulty accessing and coordinating knowledge encountered previously and the flexible use of that knowledge; and displaying patterns of behaviour and thinking detrimental to learning, including effective and well-practiced avoidance strategies (Borkovski, Estrada, Milstead, & Hale, 1989; Chan & Dally, 2001; Doyle, 1983; Westwood, 1993).

Students with LD frequently display memory difficulties, including difficulty storing, manipulating or retrieving previously encountered knowledge. Short term memory, working memory and long-term memory, are all potentially implicated. In terms of processing efficiency, adolescents with learning disabilities lack the flexibility to co-ordinate several memory stores (Ashbaker & Swanson, 1996). Another cognitive characteristic, highlighted primarily by the work of Swanson and colleagues (see Ashbaker & Swanson, 1996; Swanson & Sachse-Lee, 2001; Swanson & Siegel, 2001), is the apparent relationship between inefficient working-memory function and LD.

Relative to students in the early school years, students with LD in the middle-school years can perhaps be viewed as a neglected group because of a general priority to direct remedial and intervention resources to younger students. Early identification and intervention is widely acknowledged as good practice, and the premise underlying early intervention, that younger children are more likely than older children to accelerate to keep pace with their peers, is sound.

However, Deshler (2005, p.122) expressed concern that, as compelling as the case for early intervention can be, if that case is made at the expense of addressing the equally problematic and unique set of problems presented by older-age individuals, the long-term effects of putting "all our field's eggs into the early identification and intervention basket" are devastating for thousands of individuals with LD. Further, Swanson and Hoskyn (2001) noted that the challenges faced by adolescents with LD increase as they face the demands of middle and high school, and that the gap between academic performance of students with and without LD increases across adolescence. Despite the fact that intervention for these students is potentially difficult to implement sustainably (Vaughn, Klingner, & Hughes, 2004), there is evidence to support the assertion that effective interventions have a positive, discernable impact on student learning outcomes, as is shown in the following section.

The information above, about issues of definition and identification in LD, the prevalence of LD and the displayed learning behaviours of students experiencing persistent LD, is intended to provide a background from which more specific exploration of the topic of LD can be pursued. In the following two sections details about LD in reading and LD in mathematics are examined. Where possible, the discussion highlights matters pertaining to students in the middle-school years.

Learning Difficulties in Reading. Learning difficulties in literacy includes difficulties in writing, speaking, listening and reading. Reading is the most common area of LD (Westwood & Graham, 2000). The impact of poor reading skills becomes increasingly obvious during the middle-school years: "If reading accuracy is not mastered effectively by mid-primary school, however, it becomes one of the most powerful blocks to academic and life progress that a person can experience" (Galletly & Knight, 2004). This section considers underlying factors that contribute to LD in reading, and theoretical perspectives that frame reading research. LD in word reading, comprehension and reading fluency are discussed.

One of the most important and currently influential discoveries in LD and reading research has been that deficits in phonological processing are related to reading problems (Hempenstall, 2004; Swanson, 1999; Torgesen, Wagner, & Rashotte, 1994). In fact, Adams (1991, p. 392) claimed that the discovery of the importance of phonemic awareness is the "single most influential advance in the science and pedagogy of reading" in the last century. However, other researchers more recently have cautioned that the importance of phonological awareness may have been overstated in the literature (Swanson, Harris, & Graham, 2003). Nonetheless, phonological processing is an important area of research in reading LD, and is briefly explored below.

Phonological processing involves the use of information about the sounds of language in processing oral and written language. It requires awareness and understandings about the sound structure of language (Torgesen & Morgan, 1990). Research has linked deficits in phonological processing to problems in sight word recognition, spelling, oral reading and reading comprehension (Stanovich, 1986; Swanson, 1999; Tractenberg, 2002; Westwood, 2003). Students who enter school with high levels of phonological and phonemic awareness, or who acquire them quickly, make good progress in early reading in an alphabetic language such as English (Adams, 1990; Juel, 1988; Stanovich, 1986). For young students with delays in phonological processing, well designed, targeted phonemic awareness interventions in the early school or pre-school years, potentially have a very positive impact on ameliorating LD in reading (Blachman et al., 1999; Byrne, Fielding-Barnsley, & Ashley, 2000) Notably, phonemic awareness interventions decline in effectiveness after the first or second grade (Fawcett, 2002).

Stanovich used information from phonology-based research and emerging ideas about modularised processes in reading to develop his single core deficit hypothesis (Stanovich, 1986). His proposal was that reading difficulties are characterised by a common underlying deficit in phonological processing. He argued that both "garden variety" poor readers (those with a more general deficit) and dyslexics (with specific deficits) are impeded by a single core deficit, in the specific domain of phonological processing (Stanovich, 1992).

Stanovich's hypothesis can be seen as a reaction to the 'top-down', whole language, approach to reading instruction that emerged in the 1970s. In contrast to the underlying framework of the whole language approach (see Tunmer & Chapman, 1999), the work of Stanovich and others highlighted the phenomena that reading acquisition in less skilled students is not based on their inability to use context to facilitate word recognition but, conversely, on their inability to recognise words without the use of context clues (Stanovich, 1992). Good readers rely on an advanced level of phonological recoding ability – the ability to translate letters and letter patterns into phonological forms (Tunmer & Chapman, 1999). Consequently, able readers quickly learn to recognise words without the need to refer to the context for clues. Poorer readers devote more cognitive resources to the local level of word recognition and rely more heavily on contextual mechanisms, thereby simultaneously stressing their already inefficient comprehension systems (Stanovich, 1980). These findings have significant implications for instructional approaches to support young, at-risk readers (see Rowe, 2006)

Stanovich (1986) coined a phrase, "The Matthew Effect", as a metaphor for describing the effects of learning disabilities, essentially implying that as the "rich" (able readers) get richer, the "poor" (poor readers) get poorer. In this metaphor, poor phonemic awareness skills at school entry are likely to cause students to lag behind in learning the processes of reading, whilst effective readers get better and better with their increasing reading proficiency (Thompson & Nicholson, 1999). With each passing year students who experience LD in reading fall further and further behind their peers.

Another area of research that provides insight into learning disabilities in reading is that of naming speed. The work of Denckla and colleagues (Denckla & Rudel, 1976) in the field of neuroscience during the 1970s highlighted that the speed of naming a colour (or a similar task) was predictive of reading skill (Wolf, 1991; Wolf, Miller, & Donnelly, 2000). Over the next two decades researchers collected information about the role of naming speed in reading disabilities, and concluded that early failure in the sub-processes used in naming speed may disrupt the process of successful reading (Deeney, Wolf, & O'Rourke, 2001; Swanson & Siegel 2001; Wolf, Miller, & Donnelly, 2000).

Building on research into the predictive role of naming speed and reading failure, Wolf and colleagues (Deeney, Wolf, & O'Rourke, 2001; Wolf, 2001; Wolf 1999; Wolf & Bowers, 2000; Wolf, Miller, & Donnelly, 2000) expanded Stanovich's single phonological core deficit model into the "double deficit hypothesis". This posits that students with the most debilitating learning disabilities have deficits in both naming speed and phonological awareness, whilst others with less severe learning disabilities have deficits in either phonological awareness or naming speed, both of which can lead to impaired comprehension. This hypothesis, that rapid naming and phonological processes are the results of independent processes, was supported in a meta-analysis investigating correlation between phonological awareness, rapid naming and reading comprehension by Swanson and colleagues (Swanson, Harris, & Graham, 2003).

Wolf’s work has provided evidence to support an emphasis on word reading and reading fluency as a valid component of effective remediation for students experiencing LD in reading (see Chard, Vaughn, & Tyler, 2002; Torgesen, Rashotte, & Alexander, 2001). Oral reading fluency is ordinarily perceived as the ability to read aloud smoothly and accurately. However, there are still no consensual definitions of ‘fluency’ that encompass its relation to the set of time-related terms frequently associated with it, for example, automaticity, speed of processing, reading rate/speed and word recognition proficiency (Wolf & Katzir-Cohen, 2001).

Adequate oral reading fluency requires sub-skills of phonological segmentation and recoding, as well as rapid word recognition (Fuchs & Fuchs, 2001). Efficient, low-level word recognition facilitates higher-level, integrative comprehension processing of text, a key point in the theoretical argument that fluent oral reading from text serves as a performance indicator of overall reading competence (Fuchs & Fuchs, 2001). An instructional focus on oral reading fluency incorporates word-level reading using connected texts, or in some cases, list words, at a level of task difficulty appropriate for the reader.

For students with LD, under-achievement in reading frequently involves difficulties with reading comprehension. Reading comprehension is the complex outcome of the process of constructing meaning from print. Reading comprehension can be conceptualised as an interactive process requiring the dynamic combination of a reader’s background knowledge with the information decoded from text (Graham & Bellert, 2004). Successful comprehension requires students to coordinate many complex skills and to participate actively in their own learning. Grammatical skills and vocabulary knowledge are likely to be important influences on the development of reading comprehension skills, and such skills assume greater importance at later stages of development (Muter, Hulme, Snowling, & Stevenson, 2004). Gough and Tunmer (1986) in their simple model of reading proposed that the facility to comprehend what was read depended on both decoding words and oral language comprehension.

Although word recognition skills are necessary (but not sufficient) for reading comprehension, phonological processing skills are thought to be relatively unimportant for reading comprehension (Muter et al., 2004). Students' successes in comprehension are also influenced by how interesting and relevant they find the text they are reading, their competencies in recognising, decoding and pronouncing words fluently and accurately, their awareness of the different purposes associated with reading, and facility with comprehension monitoring strategies (Gersten, Fuchs, Williams, & Baker, 2001; Swanson, 1999). Reading comprehension for students with LD has been shown to be amenable to intervention (see Swanson, 1999).

Language (talking and listening) and processing difficulties, associated with LD in reading and reading ability are predicted by different facets of children's underlying language skills (Muter et al., 2004). Children with reading LD generally have vocabulary delays, verbal memory difficulties and poor verbal reasoning skills (Al Otaiba & Fuchs, 2002; Hay & Fielding-Barnsley, 2006; Torgesen, 2002). Delays in vocabulary development that are likely to result in deficits in phonological awareness and vocabulary knowledge have also been identified as an important predictor for reading comprehension (Muter et al., 2004). Clearly, knowledge of words is influential in appropriate reading development.

Consistent with the identification of naming speed, phonological awareness and vocabulary as key deficits in reading disability, Torgesen (2002) emphasised that word-level reading problems are a consistent stumbling block to reading growth for children with reading LD. Encouragingly, intervention in the form of intensive, preventative instruction can bring the word-reading skills of students with LD into the average range. However, there remains a proportion of readers with LD, especially older students with severe reading disabilities, who do not respond to intervention (Torgesen, 2002).

In review, much reading and LD research in the past twenty years has re-directed emphasis away from contextual and environmental aspects of LD in reading to focus on more 'bottom-up' processing, or efficient processing of sound-symbol associations. For young readers experiencing, or likely to experience, LD in reading, explicit instruction in phonological processes is a substantiated, effective focus of preventative and remedial approaches. A focus on word reading is similarly warranted in older readers experiencing LD in reading. Research about the role of naming speed in reading has led to increased understanding about the role of reading fluency in proficient reading. Language development (in younger students), vocabulary and reading comprehension have also been identified as crucial components of effective reading. Effective reading intervention approaches, particularly those relevant for older readers, are explored later in this chapter.

Learning Difficulties in Mathematics. Attempts to define learning difficulties in mathematics or numeracy are confounded by the lack of a clear definition of LD, as referred to above, and the profusion of terms used, for example, mathematics disability, learning difficulty in mathematics (or numeracy), developmental dyscalculia (for a comprehensive description see Munro, 2003a) or innumeracy. Additionally, there are 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, calculation. These further add to potential confusion.

Consequently, for the purposes of this research the term 'learning difficulties (LD) in basic mathematics' is generally used to describe students' histories of persistent difficulty and lack of success in school learning in this subject area. An area of particular interest in this research is the ability to carry out basic arithmetic calculations so, where possible, this aspect of mathematics learning is highlighted. The term numeracy, defined as "having and being able to use appropriate mathematical knowledge, understanding, skills, intuition and experience to meet the general demands of life at home, in paid work and for participation in community and civic life" (AAMT, 1997 in Siemon & Griffin, 2000), is sometimes used interchangeably with the term 'mathematics'. The following section provides an overview of some important theoretical aspects and research findings regarding LD in mathematics.

Characteristically, many students who have LD in mathematics have poor number sense. Number sense refers to a student's fluidity and flexibility with numbers. Number sense also requires a certain amount of motivation to form connections between new information and previously acquired knowledge (Gersten & Chard, 1999; Reys, Barger, Dougherty, Hope, Lembke, & Weber, 1991). Number sense is viewed as critical to conceptual understanding. Many children enter school with informally acquired number sense concepts, whilst others require formal instruction to develop the ideas. Gersten and Chard (1999) posited that there is increasing empirical support for a relationship between the lack of number sense and LD in mathematics, analogous to that of phonemic awareness and LD in reading. However, this analogy is viewed by Howell and Kemp (2004) as premature, because number sense needs to be defined more clearly, and the empirical evidence to validate the role of number sense in mathematics achievement is, as yet, insufficient.

The co-morbidity of LD in reading and mathematics has been shown to be more than 60% (Gersten & Chard, 1999). The prevalence of LD in basic mathematics for Australian students is difficult to ascertain because of issues of definition and identification as previously expounded. There is some research to indicate that 5 - 10% of students have significant difficulties in numeracy (Geary, 2003, 2004; Louden et al., 2000; Pincott, 2004). Australian prevalence estimates suggest 10% to 30% of students experience difficulties in mathematics (van Kraayenoord & Elkins, 2004). Gender-based performance differences appear not to exist (Doig, 2001).

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). There is evidence to suggest that the instruction given in mathematics is relatively poor (Miller, 1999), especially that delivered to students experiencing difficulties (Westwood, 1993, 1999). Ineffective instruction can lead to students developing learned helplessness in mathematics (Pincott, 2004). However, a 'poor fit' between the learning characteristics of students with mathematics LD and the kind of instruction they receive (Kroesbergen & van Luit, 2003), instructional design deficits in text books (Fuchs & Fuchs, 2001), as well as curriculum design deficits may be more responsible for students' failure than poor performance by individual teachers.

In the past twenty years the instructivist/constructivist debate about effective instruction in mathematics has shadowed the similar debate about literacy instruction. As a reaction against the prevailing instructional approach of the twentieth century which saw mathematics being taught as simply a set of facts, rules and procedures (Mastropieri et al., 2004), constructivist learning approaches promoted the 'process approach' or 'enquiry-based method'. Constructivism has influenced syllabus frameworks and teaching approaches in Australia (Evans, 2007; van Kraayenoord & Elkins, 2004) and North America (Mastropieri et al., 2004). Influential educationists and researchers have expressed concern that such an approach is ineffective or insufficient for students with LD in mathematics (Baker, Gersten, & Lee, 2002; Kroesbergen & van Luit, 2003; Mastropieri et al., 2004; Rowe, 2006; Westwood, 2000). In contrast, the teacher-directed direct instruction approach has been widely and effectively implemented with students of all ages who experience LD (Adams & Carnine, 2003). Further information about effective instructional approaches for students with LD in mathematics are explored later in this chapter.

Factors intrinsic to the student have been identified in research looking at causes of LD in mathematics. Students may have LD in numeracy because of a variety of causes associated with learning and cognitive factors (Westwood, 2000). These include information processing and memory problems, reading, language and meta-cognitive difficulties, and attentional and motivational issues (Louden et al., 2000; Mastropieri, Scruggs, Davidson, & Rana, 2004). Frequently, at least part of the difficulty experienced by students with LD in mathematics, can be attributed to poor language and literacy skills (Westwood, 2001). 'Math anxiety' has also been identified as a cause of LD in mathematics (Miller & Mercer, 1997 as cited in Pincott, 2004).

These heterogeneous causes of LD in basic mathematics manifest in a range of deficits or limited proficiencies. Memory deficits, inadequate use of strategies and deficits in generalisation are general characteristics of students with mathematics LD (Kroesbergen & van Luit, 2003). Students may exhibit difficulties in several areas such as basic computation skills, word problems, the language of mathematics and mathematical reasoning (Milton, 2000). In the area of computation, students with LD commonly display inaccurate or inefficient strategies, slow and error-prone retrieval of previously encountered content, and reduced or variable speed of processing (Louden et al., 2000).

Difficulties with arithmetic, and recall and application of previously encountered knowledge, are readily observed and significant characteristics of LD in mathematics. Geary (2004) stated that disruptions in the ability to retrieve basic facts from long-term memory might, in fact, be considered a defining feature of arithmetical mathematics learning disabilities. The consequent difficulty students with LD experience solving simple arithmetic and word problems limits the cognitive resources available for the more complex aspects of mathematics problem solving (Chan & Dally, 2001; Geary, 2004).

Not surprisingly, the gap in academic performance between students with LD in basic mathematics and their normally achieving peers widens during the middle-school years. This was demonstrated in a study by Cawley, Parmer, Yan, & Miller (1996) which showed that at age nine the difference in mathematics test performance between LD and non-LD groups exists but it is not very large. At age fourteen years the discrepancy on mathematics test performance has increased to four years, indicating that in mathematics in the middle-school years gains in achievement obtained by non-LD students in one year take students with LD approximately four years to achieve. In Australia, students with LD in mathematics in their eighth year of school have achievement levels up to five years behind their average-achieving peers (Pegg & Graham, 2007).

In review, problems with storing and accessing basic mathematical facts and procedures are characteristics of students with LD in mathematics (Geary, 2004), which becomes increasingly evident in the middle-school years. Identified causes of LD in mathematics include poorly developed number-sense, memory difficulties, language and communication disorders, deficiencies in attentional processes and motivation problems (Mastropieri et al., 2004). As many of the underlying causes of LD impact across a range of learning domains, LD in mathematics and LD in reading are often co-morbid.

Students who experience LD in reading and/or mathematics present pervasive challenges to educators and researchers. These challenges become greater as students get older and fall increasingly behind their same-age, non-LD peers. The most conspicuous difficulties displayed by students with LD in the middle-school years are persistent difficulties with basic academic skills such as reading and calculating. Typically, students with LD use inefficient approaches to learning, and have low expectations of success which drain motivation.

As educators, parents and students are aware, learning does not occur in isolation from social and emotional development. During the middle-school years all students begin to deal with the rather intense social and emotional challenges of puberty. At this time, when social emphasis shifts from family to friends and society, students can be sensitive about issues such as ‘normality’ and ‘abnormality’ (Fuller, 2002). Having the daily experience of poor achievement in basic academic skills, frequently played out in front of peers, can be a considerable trial for students with LD. In the following section the impact of such experiences on the learning behaviour and affective characteristics of students experiencing persistent LD is explored.

Learning Difficulties ─ Social and Emotional Perspectives

Students experiencing LD are affected by a range of social and emotional factors which can act as further obstacles to learning progress. Whilst it is likely that some students with LD come to school with delayed social skills and immature emotional development, other students experience difficulties in the affective domain because of LD, and this potentially has a further, negative impact on academic attainment. In this section the affective consequences of experiencing persistent LD are explored in three parts, through the examination of research about social competence, anxiety, and motivation, the 'self systems', and learned helplessness.

Social Competence, Anxiety and Motivation. Social competence is a broad term used to describe individual social behaviour. Vaughn and Hogan (1990) described social competence as consisting of four components – social skills, relationships with others, age-appropriate social understandings and the absence of maladjusted behaviours. Students with LD demonstrate overall low social skills (Elbaum & Vaughn, 2003) and many are unpopular with their peers because they have difficulty with social encoding, or reading social cues.

Additionally, students with LD tend to choose less competent solutions to social problems or difficulties (Wong, 1996), and they often have poor relationships with their peers (Knight, Graham, & Hughes, 2004; Westwood, 2003). They also experience low levels of peer acceptance because of low achievement, difficulty processing information and difficulty expressing information (Vaughn & Hogan, 1990). Research by Ladd (1990, in Knight, Graham, & Hughes, 2004) showed that children rejected by their peers had less favourable perceptions of school and lower levels of academic performance. Thus, for many students with LD, poor social competence is a confounding factor that decreases the likelihood of successful school experiences.

Anxiety and stress-related behaviours have been shown to be present in students with problems in reading (Kos, 1991 in McCray, Vaughn, & Neal, 2001). Anxiety is an emotional state that can monopolise and therefore reduce cognitive capacity. Performance anxiety and fear of participating in a task or activity is a characteristic displayed by many students with LD (Westwood, 2003).

Galletly (1999) used the metaphor of a 'fat happy cup', accompanied by a cartoon drawing, to illustrate optimum processing capacity required when learning to read, and then describes the effect of anxiety on the capacity to think and process information as follows: “Our cup shrinks when we are stressed, nervous or feeling a failure. It becomes a sad, skinny cup. We fit less in and make more mistakes” (p.21). When students with LD exclaim that they ‘just can’t think’, in reality it may well be that all they can think of is their anxiety about performing or failing. In such instances, cognitive capacity may be consumed by emotional reactions rather than thinking processes.

Fear of failure can be viewed as a common ‘side-effect’ of repeated poor achievement at school. It can have far-reaching effects on learning for students with LD. Students with LD are more vulnerable to failure experiences, both academic and social (Elbaum & Vaughn, 2003). Students with LD can become victims of ‘the failure cycle’ – failure, frustration, feelings of inadequacy, withdrawal and avoidance of the task, leading to a repeat of the failure experience (see Westwood, 1995). Consequently students with LD commonly experience lack of practice, negative attitudes, and behaviours that are detrimental to further learning (Chan & Dally, 2001; Westwood, 2004). Unfortunately, for most children with LD, failure begins early in their school career (Westwood, 2004).

Students who are under-achieving or frequently experience failure at school generally lack motivation for school work. This does not imply that students with LD choose to be unmotivated; although some teachers have a tendency to blame a student’s learning problems on a lack of motivation. Motivation is not an innate trait of learners but rather a variable that is significantly influenced by outside factors. Thus intrinsic motivation is a product of the interaction among students and various school situations (Westwood, 2004).

Research by Biggs (1995, in Westwood, 2004) showed that motivation is diminished by irrelevant or boring tasks, frequent experiences of failure, negative criticism and information overload. Essentially, a student who is poorly motivated to do a task does not value the task or believe in their potential ability to complete the task successfully. This lack of intrinsic motivation, a learning variable described in ‘Expectancy-Value Theory’ (Atkinson, 1966 in Westwood, 2004) predicts low effort and low achievement, which, in turn, negatively affects future learning experiences.

In review, levels of academic achievement and participation for students in the middle-school years with LD can be further compromised by poor social competence, anxiety about learning and concomitant poor motivation to attempt or complete academic learning tasks. In such circumstances, students' self perceptions are likely to be affected. In the following section the poor self-system variables of students with LD is shown to be a further barrier to effective, successful learning.

The Self System. Perhaps one of the strongest influences on the affective circumstances of students with LD is the 'self-system', encompassing as self-concept, self-esteem and self-efficacy (Wong, 1996). These concepts can be defined as follows:

> Self-concept refers to a person's awareness of his or her own characteristics and the way he or she is like and unlike others. Self-esteem refers to the value a person puts on oneself and one's behaviour. Perceived self-efficacy refers to a person's judgments of a competence to execute courses of action required to deal with prospective situations. (Bryan, 1991, in Wong, 1996, p.95)

Self-concept has long been considered an important variable, one that mediates other significant outcomes such as academic achievement (Elbaum & Vaughn, 2003; Hay & Ashman, 2003). It is a multi-dimensional construct with links to students' motivation, achievement, confidence and psychological well-being (Hay, 2005). Research on self-concept, which typically relies on self-rating instruments, indicates that children and adolescents with learning disabilities tend to have lower academic self-concept than their normally-achieving peers, but equally as good self-concepts in non-academic areas (Wong, 1996).

In a meta-analysis of interventions focusing on self concept, Elbaum and Vaughn (2001 in Elbaum & Vaughn, 2003) found that students with LD who have very low self-concept can benefit from interventions but that the effectiveness of different types of interventions varies with age. For younger students the most effective interventions were those focusing on academic skills. For older students, programs that also enhance social skills and interpersonal problem solving were found to be more effective.

Positive self-esteem is an essential human need (Maslow, 1987). Seligman (1995) proposed that self-esteem does not exist as an independent characteristic; rather it is almost entirely created by an individual's experience of success and failure. Accordingly, low self-esteem is not usually the cause of a learning or behaviour problem, but rather it occurs as the result of repeated lack of success (Westwood, 2004).

Accordingly, in order to address the need for self-esteem in students, especially those with LD, they need more than self-esteem building activities or programs. To develop self-esteem and maintain motivation students need to have abundant opportunity to be successful in academic, social and physical tasks (Ormrod, 2000). Self-esteem in schools can be undermined by a variety of factors including labeling students as failures, using ability-grouping practices and setting unsuitable tasks that result in frequent failure (Westwood, 2004).

Self-efficacy is another aspect of the 'self system' which interacts with failure experiences, motivation, self-concept and self-esteem to have a strong impact on the learning progress of students with LD. Self-efficacy essentially refers to the student's pre-task judgments about their own performance (Harris, Reid, & Graham, 2004). In displaying a lack of self-efficacy students with LD generally pre-judge their own performance poorly, and they may also have unrealistically high pre-task expectancies which can lead to lower self-efficacy following failure (Harris, Reid, & Graham, 2004).

The lack of self-efficacy that leads students with LD to believe that they are unable to succeed has a highly debilitating effect on academic performance (Diener & Dweck, 1978). Self-efficacy influences performance because it affects choice of activities, the amount of effort expended and persistence in the face of difficulty (Harris, Reid, & Graham, 2004). Poor results and too much criticism reduce self-efficacy and lower a learner's aspirations (Biggs, 1995), and conversely, achievement, praise and acknowledgement contribute to positive beliefs about self-efficacy (Westwood, 2004).

In review, self-concept, self-esteem and self-efficacy are closely linked concepts which largely determine students' perceptions of themselves as learners. Students who experience persistent LD very often know that their achievement levels are below that of their peers, in some cases, despite additional effort. In such circumstances, motivation to attempt and persist with challenging tasks is likely to be compromised and students may come to believe that their attempts at learning will result in failure. This attitude of learned helplessness is explored in the following section.

Learned Helplessness. Social competence, anxiety, fear of failure, self-concept, self-esteem and self-efficacy are all very much linked to the concept of learned helplessness, a condition that arises when a person expects that his or her responses cannot control or influence outcomes (Westwood, 2004). Learned helplessness was first observed in animals – following the administration of an unavoidable shock, many non-human species did not avoid that shock when provided with an opportunity to do so (Weiner, 1992). Similar behaviour has been commonly observed in humans. Seligman (1975) analysed this phenomenon and proposed that when the likelihood of a desired reward is not thought to be improved through personal responding, a state of helplessness follows. The observed symptoms of learned helplessness in humans include lack of persistence in the face of failure, negative expectations about the future, a tendency not to develop a strategic approach to learning, avoidance strategies and a generally negative affect (Weiner, 1992; Westwood, 2004).

Not surprisingly, learned helplessness has adverse consequences for cognition, learning and motivation, and is a serious obstacle to successful learning (Weiner, 1992; Westwood, 2004). The research of Dweck and colleagues (e.g., Diener & Dweck, 1978; Dweck & Repucci, 1973; Bush & Dweck, 1976) has been influential in the application of learned helplessness theory to child development and LD (Carnino, 1981). Specifically, these researchers determined that the roles of success and failure attributions are important determinants of behaviour. In other words, perceiving that one is unable to surmount failure can have a debilitating effect on performance whilst perceiving that one is able to avoid or escape failure can have facilitating effects on performance (Diener & Dweck, 1980). Thus, it is perceptions, rather than reality, that are critical because they influence self-concept, expectations for future situations, feelings of potency and subsequent motivation (Hunter & Barker, 1987).

Attributions for success or failure can be inferred to be determined by ability and effort, task ease or difficulty, luck, mood and help or hindrance from others. These inferences are at least in part, based on information variables such as past performance and social norms (Weiner, 1992). Attribution theory suggests that students are not motivated to persist in learning if they have attributed success or failure to forces over which they have no control (e.g., luck, ability, task difficulty, teacher preferences). Conversely, students maintain motivation because of attributions to factors they can control, for example, effort or the use of successful strategies (Weiner, 1992; Westwood, 2004).

Children with learning disabilities tend to have maladaptive attribution patterns (Wong, 1996) which undermine motivation, limit interest patterns, heighten negative affect (i.e., loss of self-esteem) and retard intellectual growth (Carnino, 1981). Accordingly, students with learning disabilities may attribute failure to lack of ability, and success to luck or teacher favour. In contrast, non-learning disabled students infer that their success is due to ability and effort, and that failures are due to deficient effort (Wong, 1996). This is where the 'helpless' behaviour of learned helplessness is evident – if students perceive that they cannot achieve success in a task because of factors beyond their control, then their participation and performance on the tasks are lessened. In such situations, students believe that no matter what they do, they will still fail in a task. Thus, maladaptive attributions, whereby an individual 'blames' the uncontrollable factors for their success or failure, often trigger learned helplessness.

In review, learned helplessness is a way of thinking about learning that impedes participation and success. Students with LD, particularly older students who have experienced persistent failure in academic tasks, may be prone to developing this characteristic. A learner's perception that they will not succeed at a task regardless of the effort invested, results in reduced motivation and performance. In this way, attribution of causality is a determinant of learned helplessness. Students experiencing learned helplessness attribute their performance outcomes to factors beyond their control, promoting their perception that their own actions cannot influence performance outcomes.

A key conclusion from the above discussions is that experiencing persistent LD is likely to have a negative impact on students' social and emotional outlook, particularly with regard to their perceptions of themselves as learners. This self-perception is a powerful indicator of attainment. Students experiencing LD are at risk of experiencing reduced social competence, anxiety about learning and reduced motivation. Further, they are vulnerable to diminished academic self-concept, poor self-esteem due to repeated failure and a lack of self-belief, all of which can lead to further failure experiences. This negative affective cycle can contribute to students with LD developing the debilitating mindset of learned helplessness.

A key to overcoming this negative cycle is for students with LD to have repeated, authentic experiences of academic success. This can be achieved in the regular classroom when a teacher uses instructional strategies that are effective for students with LD, and provides appropriate adjustments to learning tasks. Well-designed, evidence-based interventions which target areas of academic difficulty for students with LD also have great potential to both improve achievement of learning outcomes, and to overcome negative affective factors. Ways to improve learning outcomes for students with LD are discussed below.

Improving Teaching and Learning Outcomes for Middle-School Students Experiencing Learning Difficulties

This section describes key, evidence-based components of effective teaching in classroom and intervention settings, both of which have an important role in improving learning outcomes for students with LD in the middle-school years. This discussion is divided into three parts. The first reviews research into effective teaching and learning approaches for students with LD Parts two and three provide overviews of intervention research in reading and mathematics respectively, particularly as they pertain to students with LD in the middle-school years.

Effective Teaching and Learning for Middle-School Students Experiencing LD. The impact of poverty, disadvantage and low student ability levels on the learning achievements of students is implicitly understood by most educators. Whilst it is important to acknowledge these factors, in an educational setting they are not factors that educators can readily influence. However, a key factor in improving achievement levels, for which educators do have influence, is effective, quality teaching. Teacher proficiency and other teacher-controlled factors can, and do, have influence on students' attainment level at school and beyond. That is, educational effectiveness for all students is crucially dependent on the provision of quality teaching by competent teachers (Darling-Hammond & Bransford, 2005; Hattie, 2003, 2005; Hill & Crévola, 2003).

Accordingly, regardless of student and environmental factors, classroom instructional processes are a major variable influencing student achievement, and this is particularly the case for student with LD (Hattie, 2005; Mastropieri & Scruggs, 2002; Sanders & Rivers, 1996; Schacter & Thum, 2004). Whilst some may suggest that competent learners can be successful with varied instructional quality, students with LD are particularly vulnerable to poor pedagogy (Strain & Hoyson, 2000), and are more likely to benefit from effective teachers (Sanders & Rivers, 1996). For all students, high quality teaching is a powerful influence on student achievement (Hattie, 2003).

Definitions of effective teaching vary, and the terminology used to describe effective teaching is not always consistent. Effective teaching may vary in its delivery in different subject areas and for students of differing abilities. Westwood (1993) defined effective teaching as the clear teaching of important skills, information and appropriate strategies. Effective teaching approaches, particularly direct instruction, highlight the need for teachers to take an active role in imparting information and skills, while still providing opportunities for active participation by students. Instructional strategies that rely on teacher behaviours, such as providing students with explicit examples of proficient performance before they commence a task, and providing ample guided and independent practice opportunities, are common features of effective instruction for students with LD. More detailed examples of effective instructional strategies for students with LD are presented in Appendix A.

Importantly, evidence is emerging (see Baker, Gersten, & Lee, 2002; Ellis, 2005; Pincott, 2004; Rowe, 2006), in both reading and mathematics LD research, that student-centered or discovery-learning instructional approaches are not particularly effective in improving learning outcomes for students with LD. However, this is not to say that students with LD should never participate in constructivist-type learning activities, or that non-LD students do not require direct instruction. Under particular conditions both these approaches have merit in their own right. For students with LD constructivist learning activities can be effective, provided that prior instruction in the relevant basic knowledge and skills has been provided. However, there are clear indications in the literature that classroom teachers can facilitate learning for students with LD by ensuring that their pedagogy and classroom routines reflect a planned and structured approach to teaching and learning which incorporates, but does not solely rely on, direct, explicit instructional strategies.

Whilst effective teaching for students experiencing LD difficulties involves more than direct instruction (also referred to as explicit instruction), direct instruction does have a considerable role to play in effective teaching for students with LD (Ellis, 2005). Direct instruction "is a systematic method for presenting learning material in small steps, pausing to check for understanding and eliciting active and successful participation from all students" (Rosenshine, 1986, p.60). Direct instruction is especially applicable when teaching new or difficult information and when content is critical to subsequent learning (Mercer, Jordan, & Miller, 1996).

In a series of influential meta-analyses Swanson and colleagues (e.g., Swanson 1999, Swanson, Carson, & Sachs-Lee, 1996, Swanson & Hoskyn, 1998) established that two models of instruction, direct instruction and strategy instruction, had greatest potential to improve learning outcomes, and that when combined these approaches are particularly powerful and effective. Although most of the meta-analyses were linked to reading (these are more closely examined in the following section), Swanson et al. (1996) found no significant differences across domains of reading, spelling and mathematics, implying that direct instruction and strategy instruction are generally effective for students experiencing LD, regardless of the domain. The findings are increasingly applied generically to LD interventions, perhaps because they seem to 'make sense' to both classroom teachers and researchers. That is, effective teaching for students with LD requires emphasis on content (direct instruction) and on teaching 'how to' (strategy instruction).

Ostensibly, direct instruction and strategy instruction may appear to come from different educational perspectives with direct instruction linked to behaviourist approaches and strategy instruction linked to cognitive approaches. However, strategy instruction and direct instruction have many commonalities (Swanson, 2001), and share many similar techniques (Dole, Duffy, Roehler, & Pearson, 1991).

Strategy instruction encompasses a range of instructional approaches for teaching cognitive, meta-cognitive and self-regulation strategies. The use of mnemonics and graphic organisers is common in strategy instruction (see Larkin & Ellisy, 2004). Examples of cognitive strategy instruction include elaboration strategies such as paraphrasing and summarising, promoting the use of effective learner behaviours like underlining, note-taking and selecting the main idea, and organisational strategies such as diagramming or using mnemonics (McInerney & McInerney, 2002). Providing information about how to approach a task is referred to as meta-cognitive strategy instruction, which is concerned with students' awareness of their own thinking and their ability to regulate strategy use. Meta-cognitive strategies include strategies for planning, monitoring and test-taking strategies (McInerney & McInerney, 2002). Self-regulation strategies aim to support students manage their behaviour and approaches to tasks to promote more effective learning.

Effective teaching for students with LD in the regular classroom requires frequent adjustments to instructional strategies and/or learning content. Whilst direct instruction and strategy instruction are necessary in effective teaching for students with LD in regular classroom, they are not sufficient – other adjustments to the content and delivery of instruction are also required. To do this, effective teachers make use of pedagogical content knowledge, i.e., knowing which method to use with particular content in a specific context with an individual or group of students (Shulman, 1987), to guide their decisions about appropriate adjustments. Pedagogical content knowledge enables teachers to differentiate or adapt teaching and learning experiences to provide genuine learning opportunities for the range of ability levels in inclusive classrooms.

Differentiated instruction (variously referred to as curriculum differentiation, adaption, modification or adjustment) is both a way of thinking about teaching and learning and a collection of strategies (Heacox, 2002). Differentiation occurs mainly in terms of content, process and product (Tomlinson & Allan, 2000), and also in terms of a variety of other factors including classroom management and environment, and assessment and grading (Westwood, 2001).

Modifying content by adjusting the level of task difficulty, so that students with LD have an opportunity to develop and practice desired skills or strategies successfully, rather than unsuccessfully attempting difficult tasks, is an important means of curriculum differentiation. This is because controlling the level of task difficulty has great potential to influence student learning outcomes positively (Swanson & Hoskyn, 2001; Vaughn, Bos, & Schumm, 2000). Other examples of curriculum differentiation include accepting alternative formats for responses, incorporating the use of adaptive technology, and adjusting directions and instructions, for example, by providing repeated, explicit instruction about the content to a small group of students.

Any informed, contemporary discussion about classroom supports and appropriate adjustments for students with LD, especially in the context of consideration about service provision for students with additional learning needs, requires consideration of the framework called Response to Intervention (RTI) (see Fuchs & Fuchs, 2006; Gersten & Domino, 2006: Vaughn, 2003). A key premise of the RTI framework is the multi-tiered model which presents effective literacy instruction as, firstly, the core reading program for all students, secondly, supplementary instruction for children with early reading difficulties, and thirdly, intensive intervention for children who still struggle. Within this model children are identified as experiencing LD when they fail to progress at an appropriate rate, rather than waiting until they are identified using psychometric testing. Also, curriculum-based assessments are used to inform instructional decision-making.

Although the research focus in RTI is on early identification of younger students with reading difficulties, it is relevant to this broader discussion because it both emphasises the importance of effective, evidence-based approaches to classroom teaching, and acknowledges that classroom teachers alone cannot provide the intensity of support required to effectively support students who are struggling with basic academic skills. Effective teaching and learning requires professional development of teachers, sustained and systematic support from school leaders and school systems, and, in turn, support through government policy and budget decisions.

In review, classroom teachers, when supported locally and systemically, are well placed to effect significant influence on the attainment levels of all their students. Regardless of inherent student or environmental characteristics, good teachers have the power to make a positive difference to educational and life-long outcomes of students who experience persistent LD. Effective teaching for students with LD is teacher-led and relies considerably on direct instruction and strategy instruction.

The focus on inclusive educational settings that has emerged over the past two decades has led to educational administrators placing increasing responsibility on classroom teachers to cater for the needs of students with LD (Westwood, 2001). Whilst this change may have led to a welcome, enhanced focus on appropriate pedagogy and inclusive settings, there are those who question whether this “utopian vision of a shared education for all” (Westwood, 2001, p.5) is the best way forward for students with LD and their teachers:

> At present the zeitgeist suggests that the regular classroom is the place where all learning disabled children should be educated. However, the needs of children with LD for instruction that is more explicit, more intensive, and more supportive than normal are going to be very difficult to meet in most regular classroom settings. (Torgesen, 2004, p. 31)

Clearly, there is a need for an additional tier of support for students experiencing LD. Targeted interventions which provide more specific and intensive teaching and learning experiences have great potential to offer additional support. Encouragingly, there is evidence to indicate that LD interventions are effective and have solid potential to make a positive difference to student learning outcomes (Swanson & Hoskyn, 2001). In the following sections intervention research in reading and mathematics are reviewed.

Reading Intervention Research. This overview of evidence-based research interventions aims to identify components of effective interventions designed to improve reading competence for students with LD beyond the early years of schooling. The research reviewed here focuses on reading comprehension, word reading and reading fluency with reference to language processes and vocabulary. It refers to meta-analyses, reviews and selected experimental studies.

As a result of the history of one hundred years of reading research and twenty years of credible research into reading disabilities, there are many thousands of experimental study reviews (Lovett, Barron, & Benson, 2003) available to inform research about reading and developing reading skills. More recently the availability of meta-analysis, a technique for statistically combining the results of several studies that address a common research topic, has enabled results of many studies to be considered together. In a meta-analysis, research studies are collected, coded, and interpreted using statistical methods similar to those used in primary data analysis. The result is an integrated review of findings that is more objective and exact than a narrative review (Glass, 1976). Meta-analysis can ascertain the major sources of variability contained in the intervention and the magnitude of the effect on students' learning. The results of individual studies are converted to a standardised metric called effect size. Effect sizes range from naught (no observable effect), or even negative numbers, to one or greater, and can be thought of as standard deviation unit, or z-score (Forness, 2001).

Swanson and colleagues' series of meta-analyses of research in word reading and reading comprehension (e.g., Swanson, 1999, Swanson, Carson, & Sachs-Lee, 1996; Swanson & Hoskyn, 1998), in addition to the significant findings in support of direct instruction and strategy instruction referred to in the previous section, provided a solid foundation of evidence-based information about effective reading intervention for students with LD. These reviews of 180 studies, focused on experimental interventions for participants with LD, aged from kindergarten to adult. Results showed a mean effect size of .79 for treatment versus control conditions. This is an optimistic finding as it indicates that, with appropriately targeted and implemented interventions, much can be done to attain improved reading outcomes for students with LD.

These authors' meta-analyses reported that 12% of variables in student achievement outcome were attributable to a set of key instructional components which include control of task difficulty (by sequencing and scaffolding content to enable participants to experience success), small interactive groups (with student groups of 6 or less) and directed response/questioning (where students learn self-questioning and meta-cognitive strategies). Word recognition and reading comprehension interventions that include these components produce the strongest impact on student learning (Vaughn, Gersten, & Chard, 2000).

Further, analysis of results related to the superior effectiveness of direct instruction and strategy instruction indicated that interventions that included a combination of direct instruction and strategy instruction yielded larger effect sizes than those based on direct instruction alone or strategy instruction alone. A trend was also identified which showed that for improving word recognition direct instruction models yielded larger effect sizes than competing models.

In another meta-analysis, Swanson and Hoskyn (2001) identified instructional components and looked for instructional factors that predicted positive outcomes specifically in relation to adolescents with LD. The study provided evidence that educational intervention for adolescent students with LD produces 'positive effect sizes' (Swanson & Hoskyn, 2001, p. 116). Instructional components that enhanced intervention outcomes for adolescents with LD were advanced organisation and explicit practice. Advanced organisers included statements directing students to preview material before instruction begins, directions to focus on particular information, and stating the objectives of the instruction. Explicit practice includes distributed review and practice, repeated practice, sequenced reviews and daily or weekly reviews (Swanson & Hoskyn, 2001, p.111).

Similarly, Mastropieri, Scruggs, Bakken, and Wheldon (1996) undertook a meta-analysis of reading comprehension literature. They concluded that reading comprehension interventions had potentially powerful positive effects with a mean effect size of .98 reported. Interventions in reading comprehension potentially have powerful positive effects on reading comprehension attainment for students with learning disabilities (Mastropieri, Scruggs, Bakken, & Weldon, 1996). Gersten, Fuchs, Williams, & Baker (2001) examined instructional methods for improving the comprehension of narrative texts and expository texts. Strategy instruction, particularly the use of 'story-grammars' where story structure is taught as an organisational framework to support comprehension of narrative texts, was highlighted as "best practice" in this review. This finding is consistent with Swanson's (1999) conclusion that advance organisation is a key component in effective LD interventions. Other factors identified as important to effective reading comprehension interventions include longer treatment duration to better ensure long-term maintenance, and the use of peer-mediated instructional activities.

In Chard, Vaughn, and Tyler's (2002) synthesis of research on reading fluency interventions, a strong link was made between reading fluency, theories of automaticity in reading (La Berge & Samuels, 1974) and modularised processing (Perfetti, 1985). This synthesis of reading fluency intervention studies highlighted the effectiveness of repeated reading as a key strategy for intervention, as it leads to improvements in both accuracy and rate of reading, and ultimately leads to better understanding of text. Repeated reading focuses on developing students' rapid processing of print through providing multiple opportunities to read familiar text passages. The synthesis also indicated that explicit modelling of fluent reading, corrective feedback and advancing through progressively more difficult texts based on performance, are essential components of effective reading fluency interventions.

Repeated reading as an effective strategy for improving reading fluency is a consistent theme reported in the current research literature (Fawcett, 2002; Galbraith & Clayton, 1998; Levy, 2001; Torgesen, Rashotte, & Alexander, 2001). Fawcett (2002) also noted that repeated reading interventions are both effective and cost-effective because they require no particular training or materials; they can be carried out in the classroom and can be delivered by parents or tutors. Other reading fluency strategies include partner or buddy reading, tape assisted reading and various forms of reading aloud to an adult (see Winebrenner, 1996).

The Neurological Impress Method (NIM), an approach to reading fluency, was first reported by Heckelmann (1966) although he did not claim to have invented the strategy. NIM requires an (adult) tutor to read a suitable text together, aloud, with a student. The tutor reads a little louder and a little faster than the student, who also reads aloud, trying to keep up with the tutor. Several strategies are employed to support the student as they read and the student is not under pressure to remember the words on the page. This relatively simple to implement strategy was investigated by Flood, Lapp, and Fisher (2005) with 20 participant students. They found that NIM, supplemented by a re-tell activity to aid comprehension, works effectively as a means for increasing fluency for children who struggle with reading in Grades 3 – 6, and it also had a positive effect on children's affect including attitude toward reading and motivation to read.

Wolf and colleagues (for example, Wolf & Bowers, 1999; Wolf, Miller, & Donnelly, 2000) at Tufts University developed a more complex reading fluency intervention program called "Rave-O" (Retrieval, automaticity, vocabulary elaboration, orthography) in response to their "reconceptualisation of dyslexia", and subsequent development of the double deficit hypothesis (Wolf & Bowers, 1999). Rave-O aims to develop fluency and automaticity in severely impaired readers. Wolf and colleagues have provided a comprehensive description of the intervention including a theoretical framework (Wolf, Miller, & Donnelly, 2000) but have not yet reported an empirical study. However, Wolf, Miller, and Donnelly (2000) stated that preliminary data indicated participating students made significant gains in almost every aspect of reading. Components of the intervention include providing practice reading connected texts and recognising orthographic patterns, and activities that address lexical and sub-lexical reading fluency related skills. The Rave-O intervention is complemented by a phonological program. Rave-O also includes a component of strategy instruction linked to emotional and motivational components which aim to improve students' self-efficacy.

As indicated by the discussion above, reading fluency research is an emerging focus in LD in reading, and is particularly relevant for older readers experiencing LD. However, more analysis of the interaction of reading rate, accuracy and fluency, as well as of sight words vocabulary and recognition of orthographic patterns, is required to better substantiate this approach (see Torgesen et. al, 2001; Wolf & Katzir-Cohen, 2001).

Effective reading interventions for older students experiencing LD focus on remediation of key aspects of reading including word reading, reading fluency and reading comprehension. The research reviewed indicates that there is substantial evidence to support interventions focusing on word reading and reading comprehension as effective, particularly when instructional strategies or approaches including direct instruction and strategy instruction, advance organizers, control of task difficulty and self-questioning strategies are utilized. Reading fluency intervention research has been shown to be a promising area of intervention for reading remediation, although further work to provide greater clarity about specific approaches and interactions between factors, is required.

Mathematics Intervention Research. Consistent with the current emphasis on early intervention for students with LD in reading, mathematics interventions in Australian schools are also largely focused on students in the lower primary or infants grades (Doig, 2001; van Kraayenoord & Elkins, 2004; Milton, 2000), often within the framework of number sense and strategy development. Although there are currently fewer published research reports on mathematics instruction for students with LD in mathematics than in the past (Mastropieri, Scruggs, Davidson, & Rana, 2004) and even fewer focused on the middle-school years, the available literature does identify components of effective interventions relevant to older students who experience difficulties with basic mathematics. However, Baker, Gersten, and Lee (2002) noted that mathematics interventions have demonstrated only moderate effect sizes, relatively low compared to measures of literacy interventions.

For present purposes, the mathematics intervention research reviewed here is limited to work that largely focuses on the development of basic mathematics skills. Meta-analyses reporting results in effect size have been utilized to provide an overview of effective approaches by drawing together the results of many studies.

Pellegrino and Goldman (1987) concluded their research review by stating that the focus of mathematics interventions for students with LD should involve extended practice on basic facts particularly those for which the student still relied on counting procedures to retrieve, until these facts become declarative knowledge stored in long-term memory. Their conclusion, which went against the grain of the pre-dominant constructivist approaches of the time, was later validated by research findings, as shown below, but with the qualifying recommendation that the extended practice on basic facts requires meaningful context, and not simple rote learning. For example, Gersten and Chard (1999) acknowledged that a core component of mathematical disabilities is difficulty in the representation and retrieval of arithmetic facts, but they argued that drill and practice interventions need to also encompass a focus on developing number sense and mathematical reasoning.

Fuchs and Fuchs (2001) conceptualised prevention of mathematics LD at three levels – primary, secondary and tertiary. At each level instructional principles proven to be effective in mathematics for students with LD are identified. Primary and secondary level principles incorporate non-intrusive instructional methods that are delivered by a general educator (classroom teacher) in a whole class, classroom setting. Tertiary prevention is synonymous with intervention and the instructional features are strikingly different to those for the other two levels. The key difference is that the emphasis shifts from pedagogy and classroom instructional design to a clear focus on the individual student's learning needs.

At the tertiary level Fuchs and Fuchs (2001) identified three evidence-based principles, supported by research, to inform intervention for students with LD in mathematics. The first principle, individually referenced instructional decision making based on the strengths and weaknesses of the individual student, is associated with of an effect size of .70 (Fuchs & Fuchs, 1986). The second principle, intensive instruction, can produce impressive growth rates among students with LD in mathematics. Intensive instruction involves responsive interaction, instruction commensurate with the student's skill level, instructional cues, prompts and fading to support students to approximate correct responses, and detailed task-focused feedback. Intensive instruction can be delivered either one-on-one or in small groups.

The third principle of effective intervention identified by Fuchs and Fuchs (2001) is explicitly contextualised skills-based instruction. This principle reflects the recommendation of Pellegrino and Goldman (1987) by acknowledging the importance of skills instruction but moves away from isolated drill and practice routines to an emphasis on the explicit teaching of skills in authentic, "contextually rich" (p.93) teaching and learning experiences. These three instructional principles, which have been verified by a substantial body of intervention studies, can be combined in mathematics interventions that may result in improved student achievement with effect sizes ranging from .50 to over 1.50.

In a comprehensive synthesis of 194 selected studies published from 1971 to 1999 on the effects of interventions to improve the mathematics achievement of students with learning disabilities, Baker, Gersten, and Lee (2002) identified four findings stated as "consistent enough to be considered components of best practice" (p.70). These are (1) providing teachers and students with specific information on how each student is performing, (2) using peers as tutors or guides, (3) providing clear specific feedback to parents of low achievers on their children's successes in mathematics, and (4) providing direct or explicit instruction. Each of these is briefly explored below.

Providing performance data to teachers and students showed greater effect on student learning outcomes when supplemented by recommendations to them on what problems to work on (overall effect size.57). The positive role of computers in generating problems for students to work on and providing performance feedback to students, was also demonstrated in the analysis. The considerable success of peer assisted learning for students with mathematics LD (average effect size .62) is contingent on several conditions including using older tutors who had received extensive training, students working in pairs rather than larger groups, the opportunity for students to alternate between the role of tutor and tutee, and a tightly structured format for the tutoring session.

Although only two studies in Baker and colleagues' meta-analysis (2002) included providing parents with information about student success, the results for this approach showed moderately improved student achievement (effect size .42) when parents were informed about and encouraged to celebrate their child's progress. This finding, though not statistically significant, was notable not only because of its moderate efficacy but also because of the low-cost of implementation, and the fact that no additional teaching was involved.

Baker and colleagues' (Baker, Gersten & Lee, 2002) findings about explicit instruction were embedded within an investigation into the effects of instructional practices which were generalised into two categories – explicit teacher-led and contextualised teacher facilitated approaches, each comprising four studies. Content included mathematics operations, problem-solving, rational numbers and concept development. Aggregated effect size for explicit instruction was .58, indicating moderate improvement. The overall effect size of studies in contextualised instruction was .01, essentially zero. These results suggest that principles of direct or explicit instruction can be very useful in teaching mathematics concepts and procedures to students with LD but that contextualised approaches, where the teacher serves primarily as a facilitator, have no perceptible benefit for low-achieving students.

In a meta-analysis that sought to identify the domains of mathematics-related skills targeted in effective interventions for elementary students with mathematics learning disability, Kroesbergen and van Luit (2003) analysed 58 studies categorised as preparatory mathematics, basic skills or problem solving. Findings relevant to instruction, rather than research design, are previewed here.

Kroesbergen and van Luit's (2003) analysis showed that the majority of studies focused on basic skills but that there was no significant difference between the effect sizes of the three different domains. Across all domains the self-regulatory strategies of self-instruction, (1.45) were shown to be more effective than direct instruction (.91), mediated instruction (.34), peer tutoring (0.87), or computer-assisted instruction (0.51). However, for the learning of basic skills, direct instruction was most effective. Interventions in the domain of basic skills showed the highest effect size, leading to the conclusion that basic mathematics skills appears to be "a domain in which intervention is effective" (p.111).

Results of analysis of single variables included that small studies showed higher effect size than large studies, interventions with older students had more effect than interventions with younger students (age range 5 to 12 years), self instruction led to higher effect sizes than direct instruction; and that computer-assisted instruction studies had lower effect size than direct instruction studies with no effects found for peer tutoring. A trend was identified showing direct instruction to be more effective than mediated instruction (discovery learning approaches) but no significant differences were found. However, the authors do comment that recent changes in mathematics education (towards using discovery learning approaches) "do not lead to better performance for students with special needs" (Kroesbergen & van Luit (2003, p.112).

In looking at multiple variables to explain differences between the studies within each category Kroesenbergen and van Luit (2003) found that for preparatory arithmetic interventions most of the variance pertained to duration of the intervention and instructional time. In basic facts interventions direct instruction was shown to be more effective than mediated instruction or self-instruction, and interventions for older students were more effective. Analysis of problem-solving interventions showed that students with a specific learning disability are less responsive to intervention than those with a mild intellectual disability.

Throughout the mathematics intervention research reviewed, explicit instruction in basic mathematics has emerged as an important component of successful numeracy interventions. Examples of effective, explicit teaching include teacher demonstrations and student modeling (Miller, Butler, & Lee, 1998) and explicit instruction in teaching mathematics concepts and procedures (Baker et. al, 2002). As researchers agree that a core difficulty experienced by students with LD in mathematics is the ability to use retrieval-based processes (Geary, 2004; Gersten & Chard, 1999; Pellegrino & Goldman, 1987), the importance of direct skills instruction should not be overlooked in any intervention aiming to support students in their middle-school years' experiencing persistent LD in mathematics. Although beyond the scope of research reviewed here, highly explicit instructional approaches to teach problem solving have also been clearly demonstrated as effective, validated practices (Gersten, Chard, Baker, Jayanthi, Flojo, & Lee, 2006).

In review, it would seem that the conclusion of Pellegrino and Goldman (1987), that the focus of mathematics interventions for students with LD should involve extended practice on basic facts, still holds considerable currency, although contemporary researchers emphasise the importance of incorporating relevant context and strategies into basic skills instruction. Close attention to individual learning needs, intensive instruction, a focus on basic skills, providing feedback to teachers, students, and parents and using peers in a highly structured, reciprocal intervention are also identified as very effective mathematics intervention approaches for students with LD.

Teacher proficiency has been shown to be very influential in determining learning and vocational outcomes for students, and this is especially the case for students who experience persistent LD. Effective teaching in the classroom relies on teachers' understanding not only the content of the subject they are teaching but also the learning needs of their lower-achieving students. To meet these needs effective teachers rely on a repertoire of strategies and approaches that feature direct instruction and strategy instruction. Effective teachers lead instruction in their classroom and when utilising 'discovery learning' approaches they ensure that students with LD have first had adequate instruction in the basic knowledge and concepts of the topic.

The above review of intervention research substantiates the idea that interventions to support students with LD in reading and basic mathematics can achieve positive results. Direct instruction and strategy instruction are highlighted as core instructional features of effective interventions. Interventions in reading that focus on word reading and reading comprehension have validated potential to improve the academic performance of students with LD, as do mathematics intervention focusing on basic skills. In reading, interventions to develop reading fluency also show promise but are yet to be firmly substantiated. In mathematics interventions sound approaches include problem solving using self-instruction, the use of peers as tutors, computer-assisted instruction and the important role of feedback. However, interventions need to be based on rigorously evaluated research, rather than a practitioner's 'best guesses' about what might work well.

To be considered rigorous, intervention research needs to include a control condition, provide information about follow-up studies, and adequate information to enable replication (Swanson, 2000). Follow-up studies are important because maintenance and generalisation of knowledge, particularly strategy use, is potentially problematic, especially for students with LD (Westwood, 2003). Schools should be wary of supporting programs that do not have a significant body of sustained research to support claims of success (Louden et al., 2000) as interventions based on unsubstantiated ideas have the potential to take up vulnerable students' valuable instructional time with little, or no maintained gains in performance (Strain & Hoyson, 2000).

Conclusion

Research and remediation in the field of LD would undoubtedly be aided by greater clarity in definitions and timelier, more accurate identification of students experiencing LD. Despite these challenges, in Australia, the current approach of school-based identification of students with LD according to achievement levels does allow a relatively wide range of under-achieving students to access support services. However, many would question whether the level of support available and the approaches utilised are appropriate.

The learner characteristics displayed by students in the middle-school years who experience LD are clearly related to memory difficulties, and the role of working memory has been strongly implicated as a causal factor in LD. A common observation of the learning behaviour of older students with LD, notably their lack of automaticity in basic academic skills, such as reading and calculating, appears to be linked to memory deficits or inefficiencies.

Researchers in the field of LD in reading identified the important role of phonological processing in younger students, and the related deficits in word reading in older students. Similarly, in mathematics LD research, younger students have been shown to commonly experience delays in the development of number sense whilst older students, beyond the first few years of school, exhibit difficulties in basic computation, have difficulty recalling previously encountered knowledge, and use inaccurate and inefficient strategies. Such constraints in basic skills have considerable negative impact on students' ability to access and participate in higher-order, novel and interesting aspects of classroom teaching and learning.

The experience of having persistent LD impacts on students' self-concept, social interactions at school, and the development of positive attitude to learning and to themselves as learners. The powerful effects of learned helplessness invoke a cycle of failure that can be difficult to interrupt. A potent antidote to such negativity is for affected students to experience authentic success in learning tasks, and to attribute this success to effort and effective strategy use.

Effective teaching has a significant role in supporting students with LD to be successful in their learning and to achieve improved learning and living outcomes. Effective teaching requires teachers to use a range of instructional approaches which, of necessity, must include direct instruction of basic academic skills, and strategy instruction to promote more efficient learning. Intervention research and meta-analysis of such research has indicated clear directions in effective remediation of persistent reading and basic mathematics difficulties. However, no single approach may be successful for all students, and a variety of evidence-based instructional designs, intervention content, strategies and resources, as well as systemic support, need to be considered when designing interventions for middle-school students experiencing LD.

The literature review in this chapter has provided a broad overview of contemporary theory and research in the field of learning difficulties but, in order to develop plausible, authentic research questions, further information is required. One of the main themes which emerged from the literature review is that the cognitive processing underlying basic academic skills development has a very significant place in understanding LD, and in informing the development of effective, responsive interventions. Memory, information storage and retrieval, cognitive processing for different types of information, and the component processes of reading and basic mathematics are all topics in the field of psychology that are relevant to this investigation into learning difficulties. These issues are examined in the following chapter, with a view to developing appropriate, relevant research questions.

Chapter 2

Investigating Cognitive Processing and Learning Difficulties, and Developing Research Questions

The preceding chapter provided a broad coverage of literature related to students experiencing learning difficulties, LD in reading and basic mathematics, and effective teaching and learning for LD. One of the key issues identified, particularly in relation to framing an investigation into effective intervention for students experiencing LD, was the crucial role of cognitive processing in learning. Accordingly, an examination of models of cognitive processing, and an exploration of cognitive processes related to learning academic skills, are key areas of focus for further investigation, and they are addressed in this chapter. This additional information about cognitive processing factors enables formulation of research questions that are well informed, theoretically consistent, and relevant to the study population, Australian students in the middle-school years experiencing LD, and their teachers.

The chapter is divided into three sections. The first and longest section explores the information-processing framework and the cognitive processes implicated in basic academic skills and LD. The second section provides a summary of the literature review and presents a series of conclusions. In the third section, specific research questions and a research theme are proposed for investigation.

Information-processing Models of Cognition

The study of LD is not limited to the field of education. Learning difficulties research is also an important field in psychology and, increasingly, in the neurosciences. Theory and research from these perspectives provide relevant information for educators that is particularly instructive in relation to students experiencing LD. Developing knowledge, informed by cognitive psychology, about how human thinking and learning functions can lead educators to clearer understandings of the barriers to effective learning experienced by students with LD, and to identification of teaching strategies to facilitate student progress. Information-processing models of cognition relevant to learning basic academic skills are described in this section, which is divided into three parts. Firstly, information-processing concepts and selected models are described in relation to learning and LD. The functions and processes of working memory are then explored. This section concludes with an examination of the development of automaticity and factors that hinder its development in basic academic skills.

Information-processing Theory. In this section key thinking and learning functions and processes relevant to the development of basic academic skills are examined. The purpose of this information gathering is to provide background information from psychology that is relevant to an educational investigation into LD. The information-processing model, a predominant approach to understanding the processes of cognition, is explained, and relevant information about memory and types of knowledge is provided. As effective knowledge storage and retrieval are key processes for successful learning, these topics are also discussed in some detail. This part of the chapter concludes with a brief examination of modularity theory, a model of cognitive architecture that is particularly relevant to learning basic academic skills.

Information processing is a theoretical framework developed over the last sixty years to explain cognitive processes. It focuses on the study of the structure and function of mental processing within specific contexts, environments, or ecologies (Huitt, 2006). Cognitive processing models pertaining to this framework attempt to explore the processes by which humans encode, represent and retrieve knowledge, and the way that knowledge is organised and sequenced (Weiten, 2004). The information-processing framework is a theoretical model, often using ‘the mind as a computer’ metaphor, to describe how cognition takes place. It is currently a predominant conceptual framework for the study of cognitive development and learning (Eysenck & Keane, 1995; Lohman, 2005). This approach is quite distinct from the behaviourist perspective which focuses on a more unitary model of human and animal behavioural causes and effects, but not thinking and learning processes (Borich & Tombari, 1997).

As the mental processes and structures of learning cannot be readily observed (though technological advances are changing this), researchers into the features of information processing have developed models to explain them. The development of various models of cognition within the information-processing framework has enabled descriptions of cognitive activities that are theorised to occur between input of information and output of responses (McInerney & McInerney, 2002). Thus, by describing what ‘good thinkers’ do, cognitive psychologists have also been able to identify at least some of the obstacles that prevent students with LD from making satisfactory progress in academic learning.

Information-processing theories of cognition identify stages and component parts of complex thought processes. Swanson (1987) outlined three general components as i) structural components within which information can be processed at a particular stage; ii) strategy components which control the operations at various stages; and iii) an executive process by which learners' cognitive activities are overseen and monitored. In addition to these components, information-processing theory recognises that the flow of information occurs in a sequence of stages, whereby information is transformed in each stage, and the output information forms the input of the next stage. Understanding LD within an information-processing model requires knowledge about how these components and stages influence student performance, and the effect of teaching responsive cognitive and meta-cognitive strategies (Borich & Tombari, 1997).

An important premise of cognitive psychology is the idea that cognitive resources are limited, based on Kahneman's (1973) limited central capacity theory. The limited capacity assumption implies that there are constraints on how much information we can think about at one time, how long we can hold information, and how quickly we can process information (Kahneman, 1973; Shiffrin & Dumais, 1981). Accordingly, humans cannot think of two or more things simultaneously nor can they attend to two complex, non-automatic tasks at once (Shiffrin & Dumais, 1981). Limited capacity resource theory is an integral part of cognitive psychology because, when a system operates with limited resources, the distribution and efficient use of these resources is a key determinant of performance (Towse, 1994). From such a perspective, the amount of cognitive resources used is not the focal point, rather the focus is on efficient use of resources in cognitive processing (see Stanovich, 1990). To better understand the issues associated with efficient use of cognitive resources, an overview of relevant information-processing theories of development, within the topics of memory, types of knowledge, knowledge storage and retrieval, and modularity theory, are presented below.

Memory. In seeking to describe what happens when new information is encountered by a learner, information-processing models commonly refer to models of memory. The functions and processes of memory are briefly described here as they underlie much of the forthcoming discussion.

A prevailing model of memory, called stage theory, is based on the work of Atkinson and Shiffrin (1968). This model proposes that information is processed and stored in three stages, sensory memory, long-term memory and short-term memory (Huitt, 2006). Information processing begins with sensory perception (e.g., sound, sight, smell) which may be influenced by prior knowledge or expectations (Borich & Tombari, 1997). These sensory impulses are registered in immediate or sensory memory. When attentional resources are devoted to this information, memory codes are created in short-term memory.

Short-term memory holds up to seven pieces of unrehearsed information for about 20 to 30 seconds (Miller, 1956). Information then needs to be rehearsed or acted upon to pass into long-term memory, otherwise it is lost. Attention has a significant role in the selection of perceptions that will enter memory stores. A definition of attention is that it involves the active process of focusing awareness on a narrowed range of stimuli or events (Weiten, 2004). Focusing attention allows small amounts of new information to be stored temporarily in short-term memory, which has a limited duration and capacity.

Information is stored in long-term memory in a range of forms, for example as visual, semantic or verbal data, and can be held there for a lengthy period of time. There is evidence to suggest that long-term memories are permanent, but this has been questioned as long-term memories have also shown to be subject to distortion or decay (Payne & Blackwell, 1998). The way that memories are stored in long-term-memory, and the consequent retrieval mechanisms used to access the information are the subject of a range of theories proposed by cognitive psychologists.

Once the information-processing approach was applied to memory research the stage model of memory function described above, incorporating sensory registers, short-term memory and long-term memory, fell into disfavour. This occurred because the accounts of memory, particularly of short-term memory as a passive store, were oversimplified (Eysenck & Keane, 1995; Smyth, Levy, & Ellis, 1987). Consequently, Baddeley (1986, 1992) developed the more complex construct of working memory which has become increasingly influential (Hulme & McKenzie, 1992). The construct of working memory incorporates the ability to hold and manipulate information, and is postulated to have an important executive function in the processes of cognition. Working memory is explored in more detail later in this chapter.

Some cognitive psychologists see working memory as a re-conceptualised version of short-term memory. Others view the working-memory construct as a separate model or that short-term memory is an activated portion of long-term memory (Cantor & Engle, 1993). The debate about whether they are actually separate memory stores is yet to be resolved (Weiten, 2004).

Types of knowledge. A widely referred to information-processing model of memory and knowledge, focusing on storage and access, is Anderson's Adaptive Control of Thought (ACT) (Anderson, 1983, 1990) which was re-conceptualised as ACT-R (Andersen, 1993) to incorporate working memory. Within this model, knowledge is conceptualised as fitting three types of memory structures: declarative (verbal information such as facts, concepts, principles and theories); procedural or production memory (knowledge about how to do); and working memory which is the combination and interaction of the declarative and procedural knowledge in the context of task demands.

As described in ACT-R, all knowledge begins as declarative information. Procedural knowledge is then learned by making inferences (i.e., developing a 'production system') from already existing declarative knowledge. Expert thinkers (in this sense those who display efficient and accurate knowledge output) have a large base of knowledge which includes both procedural and declarative knowledge, with their procedural knowledge characterised by automaticity (Sternberg, 1985). Expert thinkers are able to develop automaticity because their procedural knowledge is efficient, and their declarative knowledge is organised and stored in domains that are connected and related (Borich & Tombari, 1997).

Knowledge is further categorised as being either episodic or semantic (Tulving, 1972). Episodic memory is made up of temporal recollections of personal experiences, allowing one to re-experience the past. The semantic memory system contains general knowledge that is not strongly connected to the time when information was learned. There is evidence to suggest that episodic and semantic facts operate somewhat differently and are stored in different parts of the brain (Tulving, 1984).

Knowledge storage and retrieval. The storage and retrieval of declarative and procedural knowledge in long-term memory is the subject of much research and theorising by cognitive psychologists. One such theory is Paivio's dual coding theory (1986, in Weiten, 2004) which proposes the creation of both a visual and verbal memory for the same knowledge item. Dual coding theory holds that knowledge is stored in complex networks of verbal representations and visual images, and that memory codes for verbal information are enhanced by the use of visual images (Tigner, 1999).

Anderson's ACT-R hypothesis incorporates the idea that knowledge is stored in networks of interconnected ideas called propositional networks (Anderson, 1983) or schema. A schema is a structure, or a cluster of related knowledge, for representing concepts, events or relationships stored in semantic memory (Atkinson, Atkinson, Smith, & Bem, 1993). Storing knowledge in schemata enables large amounts of information to be processed efficiently. Schemata contain hierarchically organised networks of inter-related knowledge about a domain-specific category (Rummelhart & Ortony, 1977; Schallert, 1982). Consistent with ACT-R, schema theory holds that one's existing knowledge influences the content and formation of new knowledge. Schemata affect both the encoding and retrieval of information and may also account for distortions of long-term memory (Atkinson, et al., 1993) when one tries to 'fit' new information into an existing schema.

Connectionist models of memory incorporate inter-connected networks of general knowledge. Such models attempt to reflect what is known about how the brain's neural networks process information (Weiten, 2004). When first theorised, connectionist or parallel distributed processing (PDP) models of memory and processing were claimed to be a revolutionary new way of understanding cognitive processing (Rumelhart & McClelland, 1986). Within this model, interconnected semantic networks are associations (connections) between concepts (nodes). Nodes are activated with attention or input, sending either excitatory or inhibitory simultaneous signals across an entire semantic network to link with other nodes (Weiten, 2004). Such models are appealing because links can be readily made between these networks and actual nervous systems made up of inter-connected neurons and receptors (Atkinson et. al, 1993). However, such links are theorised only and have not been substantiated.

Modularity theory. A contrasting information-processing theory about the storage and access of information is Fodor's (1983) modularity theory, wherein information is held in domain specific cognitive modules that are activated autonomously and at times, automatically (Eysenck & Keane, 1995). In modularity theory a distinction is made between perceptual processes and cognition, or higher-order processes. Accordingly, perceptual or lower-order processes are autonomous, that is, not dependent on other information, while cognitive or higher-order processes require information integrated from a range of modules (Fodor, 1983, 1985). Hence, in modularity theory, knowledge is stored in self-contained (or encapsulated) modules which do not interact with other modules when solving lower-order or perceptual tasks (Fodor, 1983, 1985).

Efficient processing, according to modularity theory, depends on the quality of knowledge representation (i.e., how thoroughly information is 'known') in autonomous, independent modules. The modularity proposition that knowledge is stored in these encapsulated modules is in direct contrast with the connectionist notions of schema theory and PDP. Information encapsulation is important in efficient, lower-order cognitive operations (including reading words and recalling mathematics facts) because it allows for speedy access to specific stored knowledge. Therefore, cognitive efficiency is a consequence of not having to make a decision (Stanovich, 1992), that is, not having to refer to other modules containing potentially distorting background knowledge and beliefs but rather by having fast, accurate access to domain specific stored information.

A key implication of modularity theory for learning basic academic skills is with regard to the 'quality of the knowledge representation' and 'information encapsulation'. Well known (memorised) basic knowledge, effectively stored in modules in long-term memory, and used regularly, is essential for the efficient and effective cognitive processing required to master basic academic skills. The important role of modularity theory in providing a framework for developmental theories of reading was explained and developed by Stanovich (1990) in a paper about cognitive processes and reading, which included the sub-heading 'Modularity is King: Information Encapsulation'.

In review, information-processing models attempt to explain the processes by which humans encode, represent and retrieve knowledge and the way that knowledge is organised and sequenced. From this perspective, learning difficulties in basic academic skills are viewed as inefficiencies in cognitive processes, predominately lower-order processes, generally due to inappropriate resource allocation and/or deficient cognitive processes. Successful learning requires that new knowledge is learned thoroughly, and effectively stored in memory for efficient retrieval. Different types of cognitive processing are utilised for different types of knowledge, and the time required for processing or retrieving information is a determinant of efficient, effective learning. The modularity model of cognitive architecture seems particularly pertinent when attempting to understand efficient cognitive processing of basic information, such as word reading or basic mathematics calculations.

The construct of working memory, relevant to many of the models of cognition mentioned, has been identified as a key cognitive resource in efficient processing. The functions and processes of working memory are discussed in the following section.

Working Memory and Learning Difficulties. In this part of the chapter working memory is explored, with a view to developing further understandings about efficient and deficient cognitive processes that impact on the academic performance of middle-school students experiencing LD. A model of working memory and its component parts is described, processing constraints within working memory are identified, and links between working-memory function and automaticity in basic academic skills is established.

All major information-processing models which focus on skill acquisition and learning include the component of working memory (Meyen, Vergason, & Whelan, 1996). Working-memory measures significantly correlate with intelligence measures and with performance on academic and language related tasks such as vocabulary, language acquisition, mathematics and problem solving (Swanson & Siegel, 2001). Performance on working-memory tasks can even predict reading proficiency (Ashbaker & Swanson, 1996). In this section the construct of working memory is described, specifically the model developed by Baddeley and colleagues (e.g., Baddeley, 1996; Baddeley & Hitch, 1974; Baddeley & Logie, 1999). The relationship between working-memory functions and processes and LD in basic academic skills is also explored.

Working memory has been described as a theoretical construct used in cognitive psychology to characterise the system or mechanism underlying the maintenance of task-relevant information during the performance of a cognitive task (Miyake & Shah, 1999). Other definitions in the literature similarly describe working memory as a temporary, simultaneous storage mechanism in memory for incoming information required in the performance of a complex task (Baddeley, 1992; Hulme & McKenzie, 1992; Siegel & Ryan, 1989; Swanson & Keogh, 1990).

Everyday examples of activities that involve working memory include holding an address in mind whilst listening to directions about how to get to the destination or remembering the price of an item whilst calculating the correct amount of change due. The essential characteristic is that working-memory functions by simultaneously storing and processing information (Ashbaker & Swanson, 1996). Other characteristics of working memory include its limited duration of 10-20 seconds and a limited capacity of 7-9 units of information (Hulme & McKenzie, 1992). This means that only a limited amount of information can be held temporarily in working memory and then it must be attended to, through rehearsal or connection to prior knowledge, or else it is lost and not transferred to long-term memory. Working memory improves throughout childhood, adolescence and into early adulthood and then declines in older adults (Wilson & Swanson, 2001).

Baddeley and Hitch's (1974) predominant model presents working memory as consisting of three subsystems: the central executive and its two slave systems; the phonological loop and the visuo-spatial sketchpad. Each component is responsible for different cognitive activities (Baddeley & Logie, 1999; Swanson & Sachse-Lee, 2001). The central executive is regarded as the most important component of working memory with regard to its general effect on cognition (Baddeley, 1996). Its function is to co-ordinate the transmission of information between parts of the cognitive system, including the slave systems and long-term memory. It is essentially responsible for attention and the control of behaviour. The central executive is of limited capacity and controls the manipulation and flow of information, including the small amount of information that may be held in the slave stores (Baddeley, 1992; Baddeley, 1996; Baddeley & Logie, 1999).

The two other components of working memory, the phonological loop and the visuo-spatial sketch pad are thought to process and maintain either verbal or visual information (Swanson & Sachse-Lee, 2001). The phonological loop is the most extensively explored component of the model (Baddeley, 1996). It comprises a phonological store and an active rehearsal process, effectively enabling one to both store and rehearse verbal or visual information, to prevent losing it. Students with LD in reading frequently have deficits in the phonological system, particularly in relation to verbal working memory (Swanson & Siegel, 2001). Similarly, the visual-spatial sketch pad is specialised in its processing and storing of visual and spatial information (Baddeley & Logie, 1999).

Baddeley's model of working memory has important implications for understanding cognition and LD because working-memory deficits are fundamental problems of students with LD (Swanson & Saez, 2003). Working memory is a valuable cognitive resource for learning but its limits in both capacity and duration mean that efficient processing within and between the components are required for effective learning (Baddeley & Logie, 1999). Inefficient processing in working memory is 'expensive' in terms of general cognitive resources. Thus, poor working-memory processing may explain, at least in part, why basic academic tasks are more effortful (i.e., require more cognitive resources) for students with LD when compared to their non-LD peers.

Perhaps one of the most informative findings in research into LD and working memory has been that, relative to non-LD students, students with LD have reduced capacity in their working memory and this is a key, causal factor in LD. However, these capacity limitations disrupt only certain cognitive operations and only when high demands are placed on processing (Swanson & Siegel, 2001). When performance demands tax working-memory capacity, deficits in central executive functions, particularly controlled attentional processing (e.g., monitoring limited resources, suppressing conflicting information and revising information) negatively impact on the performance of students with LD in academic tasks (Swanson & Saez, 2003). Thus, when a task demands multiple components, some of which require executive processing (e.g., reading for meaning, solving a mathematics problem), reduced working-memory capacity of a student with LD comes into play, as a constraint to efficient cognitive processing.

For middle-school students with LD in reading, deficits in the domain specific phonological system manifest as difficulties retrieving speech-based information (Swanson & Saez, 2003), a deficit that impacts on word recognition and comprehension. Problems in activities of the domain general central executive can also affect performance in word recognition and comprehension because the processes of checking, testing, evaluating and co-ordinating multiple pieces of information are deficient. There may also be problems in coordinating or switching between these two levels of processing (Swanson, 2000b).

Deficient processing in the central executive and in the domain specific phonological system is also related to poor performance in mathematics (Geary 2003; Wilson & Swanson, 2001). Inefficient accessing of phonological representations applies to students with LD in mathematics as well as reading, and sometimes the same verbal deficiencies contribute to computational and reading problems (Geary, 2004, Swanson & Siegel, 2001). Although deficits in the visual-spatial system can affect performance in mathematics, computation skill is better predicted by the phonological system than the visual-spatial system (Wilson & Swanson, 2001).

Although the working-memory deficits of students with LD are hard to change relative to performance changes in skilled readers (Swanson, 2000b), working-memory aids and compensatory mechanisms have the potential to help students with LD overcome obstacles to successful learning. As a working-memory aid, strategy instruction, when rigorously implemented, has the potential to benefit students with LD (Swanson & Saez, 2003). However, over-reliance on particular strategies can have a harmful effect on the performance of students with LD, when the strategies become an inefficient method of solving the task at hand.

In review, the development of the model of working memory has enhanced understandings of cognitive processes and learning within the information-processing framework. Working-memory functions by simultaneously holding and manipulating information, it is a limited resource that is utilised to process components of a task. Students experiencing LD have reduced working-memory capacity when a task has complex cognitive demands. This has a negative effect on the efficient functioning of the central executive (Swanson & Siegel, 2001).

When undertaking more complex cognitive tasks the limited capacity and duration of working memory means that some components of the task need to be processed automatically, relying on previously encountered, stored knowledge. The processes underlying such automaticity are described in the following section.

Automaticity and Learning Difficulties. Lack of automaticity in basic academic skills is a common, readily observable, characteristic of students with LD. In this section theories to explain the development of automaticity are explored, and reasons for the lack of automaticity in basic academic skills displayed by middle-school students with LD are identified.

Automaticity is the ability to undertake a task, or part of a task, without apparently applying attention or expending effort. Automaticity develops as the result of learning, repetition and effective practice (Bloom, 1986; Ellis & Hunt, 1989; Schneider & Fisk, 1983).

Automatic processes are characteristically mandatory or unstoppable with automaticity related to increased accuracy (Bloom, 1986; Shiffrin & Schneider, 1977). Another characteristic or 'rule' of automatic processing is that it should not reduce the capacity for doing another simultaneous task (Schiffrin & Dumais 1981). Thus automaticity enables us to do several things at once. Examples of automaticity in everyday activities which require a range of component tasks include driving a car, walking, and bicycle riding. In classroom and other learning environments students display automaticity when they fluently read texts, when they write their thoughts with scant attention to the mechanics of writing, or when they make a basic calculation as part of solving a mathematics problem.

A seminal paper by La Berge and Samuels (1974) focused on the role and processes of automaticity in information processing. Their model of automaticity in reading proposed that specific word-identification patterns (component skills) become automated in a hierarchical sequence, with the lowest level skills becoming automated first, and that learning to read involves increasing automaticity in processing word units. Good readers use this hierarchy when they encounter unknown words and emerging readers use it as a global process in the acquisition of reading. Using this hierarchical process requires attention or cognitive resources. La Berge and Samuels posit that if a stimulus response is automatic then it requires no attention and no processing time.

Since La Berge and Samuels' (1974) publication, more specific models of automatic information processing have been developed (see Perfetti, 1985; Samuels, 1987; Shiffrin, Dumais, & Schneider, 1981; Stanovich, 1990). The focus has shifted away from the notion that automatic processes use no cognitive resources, towards the idea that automaticity actually requires a complex, fast and efficient interaction of cognitive processes.

Shiffrin and Schneider (1977, also Schneider and Shiffrin, 1977) argued that information processing can be divided into two fundamental processing modes: controlled and automatic. Controlled processing, as the name implies, is controlled by the individual, it is relatively slow, requires active attention (cognitive resources) and generally permits only one sequence to be performed at a time (Schneider & Shiffrin, 1977). In contrast, automatic processing is fast, it is triggered by appropriate inputs, it does not require active attention (although it can temporarily utilise capacity), it is parallel in nature and is impervious to other inputs (Schneider & Shiffrin, 1977).

Accordingly, all learning begins as controlled processes which can become automatic. This development was described in the search and detection tasks used in Shiffrin and Schneider's (1977) research – automatic detection developed when stimuli were consistently mapped to the responses (i.e., where a particular stimulus always led to the same response). Shiffrin and Schneider's explanation for this process is that targets (for example letters or words) develop the ability to attract attention and initiate responses automatically, immediately and regardless of other inputs or memory load. This led Shiffrin and Schneider (1977) to conclude that controlled processes and automatic processes entail different kinds of processing.

In reality, performing almost any task requires both automatic and control processing, although word identification during reading can be considered a purely automatic process (Shiffrin & Dumais, 1981), and effortlessly recalling basic mathematics facts could also be considered a purely automatic process. Anderson (1990) proposed that it may be more correct to think of automaticity as a matter of degree rather than a well-defined category. However, he also acknowledged the utility of the dichotomy of controlled and automatic processing in understanding cognitive processes.

In a descriptive article about automaticity, Bloom (1986) outlined how outstanding talent development in many arenas depends on developing automaticity. He described four inherent qualities of automaticity. Firstly, if a skill has been developed to an automatic level, the process can be used with greater economy of effort. Secondly, processes completed under automatic processing can be done much more rapidly than those under conscious control. A third quality of automaticity identified was that it increases accuracy in carrying out a particular process. The fourth quality of automaticity Bloom identified, consistent with that identified by Shiffrin and Dumais (1981), was that other conscious brain functions may occur simultaneously with the automatic functions.

Wolf and colleagues (Wolf, Miller, & Donnelly, 2000) provided a contemporary definition of automaticity when they described it as "a continuum in which processes are considered automatic when they are fast, obligatory and autonomous and require only limited use of cognitive resources" (p. 1). Accordingly, automaticity is a process that is determined by efficient uses of available cognitive resources, rather than one which by-passes cognitive processing.

Models of automatic processing, as briefly described above, provide some insights into the possible effects of lack of automaticity in basic academic skills, a key characteristic of learning difficulties in the middle-school years. At this stage of their schooling many students with LD are visibly ‘slowed down’ by their lack of automaticity, and are less able to focus on higher-order skills or procedural requirements because the sub-skills of decoding and calculating are so effortful. Lack of knowledge of lower-order components and slow response latency are key cognitive obstacles that contribute to lack of automaticity. Inefficient allocation of limited cognitive resources to these lower-order processes is also thought to contribute to the lack of automaticity in basic academic skills displayed by students with LD. The most desirable outcome of increased automaticity of academic basic skills is that it enables improved participation in, and performance on, higher-order processes, such as comprehension and problem solving, or other aspects of the task.

Consistent with the idea that automaticity is a hierarchical process (La Berge & Samuels, 1974), lower-order tasks, which are not automatic, require cognitive resources or attention and this requirement needs to be met before resources can be directed to higher-order tasks. Low-order skills in reading include feature extraction, letter identification, pattern recognition, spelling pattern identification and lexical access (Sinatra & Royer, 1993). In mathematics, lower-order skills include counting and ordering, recognising numerals, knowing cardinal value, and combining and partitioning groups, which all result in knowing and recalling simple number facts (addition, subtraction) and times tables (multiplication & division). Younger learners use their cognitive resources to attend to lower-order skills, gradually developing automaticity. It seems that by mid-primary school average-achieving students have developed automaticity in low-order skills (Wolf, 1991), and become ‘experts’ in using automatic knowledge as a tool to access new knowledge and skills. In contrast, many students with LD in the middle-school years continue, by necessity, to be ‘novices’ in their approach to academic skills, allocating most of their cognitive resources to lower-order tasks such as decoding and calculating.

Component processing cognitive theories suggest that complex cognitive skills such as reading comprehension or mathematics problem solving can be broken into sub-skills that must be performed accurately and rapidly in order to accomplish the complex skill (Sinatra & Royer, 1993). The development of fast and relatively load-free component processing is important because these processes place few demands on working memory, thereby leaving most of the capacity available for higher-level activities (Sinatra & Royer, 1993). Unskilled learners give most of their attention to sub-skills or component skills, whereas skilled learners do not have to allocate attention to these tasks (Thompson & Nicholson, 1999).

Sinatra and Royer (1993) proposed that when "simple skills" such as reading words and performing basic mental calculations are difficult for students with LD, these simple skills block further academic progress. It seems then, that for students with LD who cannot automatically access basic academic skills, some component processes do not function efficiently and autonomously, resulting in effortful and resource demanding reading and calculating.

This view of automaticity is consistent with modularity theory (see Stanovich, 1990). Modularity theory explains lack of automaticity as resulting from lack of high quality knowledge representations, that is, the knowledge is not well enough 'known' to be stored specifically enough to allow immediate access (see Fodor, 1985; Perfetti, 1992). From this perspective, non-automatic performance is limited by lack of knowledge, rather than by scarcity of cognitive resources (Perfetti, 1985).

Time related deficits are also a key factor in lack of automaticity for students with LD, one which becomes increasingly obvious and important during the middle-school years. Automaticity in basic information retrieval is of prime importance because it allows for the accrual of small decreases in time in undertaking sub-tasks associated with a question which again frees up cognitive resources (Royer, Tronsky, & Chan, 1999). Even small decreases in the time taken to process information during basic problem-solving situations can be significant, especially in time-limited tasks or assessments. Thus, speed of information retrieval plays a significant role in developing automaticity in basic academic skills. Ostensibly, lack of automaticity is related, at least in part, to slow and inefficient information retrieval.

Time, or response latency, is also related to naming speed, which can be considered an index of the automaticity of lower-level cognitive processes (Wolf, 1991). The work of Wolf and colleagues (see Wolf, 2001) demonstrated that the time it takes for the brain to process written symbols impedes the development of reading. This relationship implicates both sub-processes in naming, and sub-processes in reading, in lack of automaticity in reading.

Accordingly, the time required to access and retrieve a name-code from memory (naming speed) and limitations in alphabetic decoding (phonological processing) both impact on reading rate (Wolf, 1991). The 'double deficit' hypothesis, explained in the preceding chapter, addresses this relationship between naming speed and reading.

In review, automaticity in complex tasks is a result of efficient use of limited cognitive resources. Automaticity develops after learning, repetition and effective practice. Once acquired, automaticity in a given task is generally 'unstoppable', that is, it apparently happens without conscious choice, and it enhances accuracy. Models of automaticity have been developed which show that it is acquired hierarchically for sub-components of a complex task and that the cognitive processing resulting in automaticity is distinct from processing for tasks that require attention, monitoring and problem solving.

The lack of automaticity in basic academic skills characteristically displayed by students in the middle-school years who are experiencing LD can be attributed to inefficient use of cognitive resources, particularly working memory. Limitations in domain knowledge related to the components of the task, and storage of previously encountered knowledge also affect automaticity, as do processing constraints that result in slow response latency. In the following part of this chapter information processing specifically related to basic academic skills is examined and constraints in the cognitive processes of reading and basic mathematics, which impact on the performance of students with LD, are identified.

Cognitive Processes of Word Reading and Basic Mathematics. The cognitive processes important to the development of basic academic skills relate to obtaining, storing and retrieving knowledge. It is relevant to note that, when performed proficiently, word reading and number fact calculation are considered to be lower order or perceptual tasks because no active attention and only minimal cognitive resources are required. As previously identified, such automatic processing is different to the controlled processing required for problem solving and novel tasks (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). Fodor's modularity theory (1983, 1985) described earlier, also distinguishes between different types of processing, positing that, once learned, perceptual or lower-order knowledge is stored in independent modules, and this allows the speedy, efficient retrieval of specific stored knowledge.

These perspectives on the development of automaticity are important because they indicate that the cognitive processes for word reading are different to those for comprehension. Similarly, the cognitive processes for basic mathematics calculations are different processes to those used for solving mathematics problems. However, such processes are inter-related and in reality classroom learning tasks rarely require only one type of cognitive processing. In this part of the chapter information-processing models of cognition in reading and then mathematics are explored in an attempt to identify which cognitive processes specifically related to academic skills are problematic for students experiencing LD.

Information-processing models of cognition in reading. One of the earlier information-processing theories proposed to explain cognitive processing during reading was the 'bottleneck hypothesis', first developed by Perfetti (1977). The hypothesis suggested that automatic word recognition facilitates comprehension, or conversely that poor word recognition creates a 'bottleneck' in reading processes. Initially, follow-up research did not support the hypothesis (Fleisher, Jenkins, & Pany, in Nicholson & Tan, 1999), yet the idea retained some currency with reading researchers (Stanovich, 1990) and was later validated in a replication study conducted by Tan and Nicholson (1997). This study showed a causal relationship between rapid decoding and reading comprehension to support the bottleneck hypothesis. More recently, a strong correlation between fluent reading and comprehension has been established (see Chard, Vaughn, & Tyler, 2002) indicating that training poor readers in lower-order processes such as word recognition, facilitates improvements in higher-order processes such as comprehension. Kintsch (1998) summarised this perspective by stating that speedy decoding is important because better word recognition frees up resources for higher-level processing.

Perfetti's work on the bottleneck hypothesis was re-developed in light of new theories and research within the modularity framework. Accordingly, Perfetti (1985, 1992) proposed the Verbal Efficiency Theory (VET) to describe cognitive processes during reading. Verbal efficiency requires the development of an "autonomous lexicon" (Perfetti, 1992) which provides fast, accurate access to linguistic knowledge and limited use of available cognitive resources (Stanovich, 1990). VET predicts a positive correlation between verbal efficiency and comprehension, a notion consistent with the earlier 'bottleneck hypothesis'.

According to VET, verbally inefficient readers have difficulty accessing and manipulating text representations in memory (Perfetti, 1985), in other words, orthographical and phonological representations of words are not precise enough to be accessed without reference to background knowledge. Consistent with this theory, poor readers have deficient cognitive processes in word recognition, particularly with regard to representation and access, and this impacts on their reading comprehension. Thus, the efficient cognitive processes identified by Perfetti (1985, 1992) as necessary for skilled reading are very much consistent with those identified within modularity theory.

In Perfetti's (1985) Verbal Efficiency Theory (VET), efficient word recognition is viewed as an autonomous and independent processing system (Nicholson & Tan, 1999) that does not necessarily rely on contextual cues. Accordingly, word recognition facilitated by knowledge stored in autonomous modules, is cognitively more efficient (by virtue of being less resource demanding and more error-free) than word recognition which requires context or prior knowledge input.

Interactive models of reading also 'fit' within the construct of modularity (Stanovich, 1990). For example, Stanovich's (1980) Interactive-Compensatory Model proposes that younger or less skilled readers make more use of context than skilled readers, and this is a cognitively inefficient way to read. Using context to predict words is cognitively demanding, but it does aid reading fluency when 'bottom up' recognition from words and print is slow and error prone (Smyth, Morris, Levy, & Jenkins, 1987). Thus, students who cannot decode words fluently use context cues to help decode, but this is cognitively more taxing and reduces the availability of cognitive resources required for higher-level operations, including comprehension processes.

The idea of word recognition as an "acquired modularity" (Stanovich, 1990) provides an important link between the phonological core deficit hypothesis and modularity theory (Stanovich, 1990). Consequently, students who have a core deficit in phonological processing have not acquired sufficiently modularised (or 'stand-alone') orthographic and phonological knowledge representations to enable context-free word reading. So, in order to decode words, they need to rely on resource-demanding context cues.

Siegel (2003) described five cognitive processes identified in the literature that are significant in the development of reading proficiency. The processes involve phonology, syntax (also called grammatical sensitivity), working memory, semantics and orthography. Siegel proposed that three of these processes are "significantly disrupted in children who are reading disabled" (p.178): phonology, syntax and working memory. Interestingly, the research and reviews Siegel conducted showed that for students who are "reading disabled" semantic and orthographic processes are not disrupted to the same extent as the other three processes, but an over-reliance on semantics and orthography, combined with the under utilization of phonological processing, results in reduced performance. Thus, an over-reliance on certain cognitive processes renders them inefficient, and this inefficiency is further compounded by under-utilisation of efficient processes.

Slow naming speed is closely linked, possibly by causality, to deficits in orthographic knowledge (Bowers, 2001). The complex cognitive processes involved in these operations are thought to be the result of impairment in central executive processing systems rather than due to slow sensory processing and motor execution (Fawcett & Nicholson, 2001). Slow naming speed contributes to an "automatization deficit" (ibid, p.36) but the mechanisms underlying these deficits are not yet clear. Slow naming speed is thought to impact on lower-level requirements for fluent word recognition processes that, in turn, affect reading comprehension (Wolf, Miller, & Donnelly, 2000). Similar to phonological deficits, naming speed deficits persist over time from kindergarten through to adulthood (Lovett, Steinbach, & Fritjers, 2000).

Information-processing models of cognition in mathematics. Information-processing abilities, as well as mathematical abilities, have an important role in successful mathematics learning (Munro, 2003a). These abilities in mathematics include being able to read and write numerals, being able to read and write symbolic number sentences, the ability to recognize and comprehend order among numbers and the ability to perform mental computations. Information processing in mathematics is mediated by factors including the efficiency of processing, familiarity with the information, its comparative complexity, the number of processing steps required and the effort needed to process the information (Munro, 2003b).

There are distinct patterns and consistencies with regard to cognitive operations for students with LD in mathematics. Students with LD in mathematics do develop understandings of arithmetic concepts but have difficulty using number concepts efficiently and have difficulty converting and applying their conceptual knowledge of a topic into arithmetic procedures (Geary, 2003). Many students experiencing LD in mathematics have difficulty recalling basic number facts automatically, sometimes even when they can display well developed conceptual knowledge (Munro, 2003b).

Similarly, Pellegrino and Goldman (1987) suggest that students with LD in mathematics do not necessarily experience conceptual deficits but rather, deficits in declarative knowledge related to basic facts and procedural knowledge about how to use the basic facts. These deficits impede performance in other tasks requiring this knowledge. Thus, it can be difficult for students with LD in mathematics to achieve efficiency in procedures because of more basic difficulties in fact retrieval due to lack of knowledge, rather than poor conceptual understandings.

Geary (1993, 2004) identified three sub-types of mathematical disability – procedural, semantic memory and visuo-spatial. Each of the sub-types is defined in terms of cognitive related processes. The procedural sub-type is characterised by the use of less mature, more time-consuming counting strategies and is described as a developmental delay, i.e., performance is similar to that of younger, academically average children, and often improves across age and grade (Geary, 2003). Procedural deficits relate to working-memory deficits and to poor conceptual knowledge, for example, immature counting knowledge and difficulties sequencing the order of operations and monitoring the problem-solving process.

A deficit in storing or accessing arithmetic facts in or from long-term memory is the defining feature of Geary's semantic memory subtype of mathematics disability (Geary, 2003). When attempting to retrieve basic facts, students with a semantic memory mathematics disability subtype commit many more errors than younger students, and their error and response time patterns are different, suggesting a developmental difference rather than a delay. This means that with regard to the semantic memory subtype of mathematics disability, a student's cognitive and performance features are dissimilar to that of their normally-achieving peers, not just immature, and these features do not change substantively across age or grade. Also, a second form of retrieval deficit, namely, disruptions in the retrieval process due to difficulties inhibiting the retrieval of irrelevant associations, may be present, especially in students with co-morbid Attention Deficit Hyperactivity Disorder. Inefficient inhibition results in activation of irrelevant information, which functionally lowers capacity (Geary, 2003). The third sub-type identified by Geary (1993), visuo-spatial mathematics disability, is characterised by difficulties in spatially representing numerical and other forms of mathematical information and relationships, and appears to be related to a neurological dysfunction.

In review, LD in reading and mathematics are related by way of a range of information-processing factors, particularly constraints and inefficiencies in working-memory processes. These limitations commonly result in a lack of automaticity in basic academic skills. Skills such as proficient word reading and accurate basic mathematical calculations are considered to be lower-order, perceptual skills once they have been learnt. However, it is important to acknowledge that all learning is problem solving for learners at some stage and that even lower-order tasks, such as memorising lists, have a meta-cognitive component under certain conditions (Doyle, 1983).

Students experiencing LD commonly approach lower-order tasks as resource-draining problems to be solved, rather than routine tasks to be performed with the minimal use of cognitive resources. For students with LD in reading, word recognition is a resource-consuming task that impedes comprehension. This is because efficient access to linguistic knowledge, specifically orthographical and phonological representations of words, is affected by insufficiently specific representations in long-term memory. This results in over-reliance on inefficient cognitive processes, such as using semantic cues to decode a word. Slow naming speed also impacts on fluent word reading which, in turn, negatively impacts on comprehension.

In mathematics, key cognitive deficits of students with LD include limitations applying conceptual knowledge of number to everyday arithmetic, and difficulties in fact retrieval related to poor knowledge representations in long-term memory. These constraints result in the use of effortful, resource-draining procedures to solve simple calculations that non-LD students can perform automatically.

The information-processing framework has considerable utility when applied to cognition and learning. The literature reviewed in this section has focused on the cognitive processes of learning as viewed through the information-processing framework. From this perspective learning results from the flow of information which occurs in stages and the information is transformed in each stage. The cognitive resources used to transform information from perception to storage in memory are limited, and efficient use of these cognitive resources results in efficient information processing and effective development of new knowledge.

Understandings from information-processing perspectives have led to useful advances in knowledge about teaching and learning, including the understanding that different types of knowledge are processed in different ways. Students experiencing LD commonly process and store information inefficiently, and this leads to performance deficits across a range of academic domains.

Literature Review Summary and Conclusions

The first chapter and the current chapter up to this point have presented an overview of contemporary literature relating to learning LD, social-emotional factors influencing learning and participation for students with LD, effective teaching and intervention approaches for basic academic skills, and an overview of the information-processing framework as it relates to LD. The aim of the literature review was to build a knowledge base to inform the development of research questions. The focus for the investigation has been on basic academic skills, specifically reading and mathematics. The review is briefly summarised below and conclusions are presented. These conclusions inform the development of research questions in the next section.

During the middle-school years, students with LD are vulnerable to school failure experiences as the instructional focus shifts from acquiring basic reading and mathematics skills towards using those skills to attain content knowledge and subject specific procedural knowledge. With limitations in the basic ‘tools’ of reading and mathematics, students with LD in the middle-school years are prone to falling further behind their non-LD peers in academic performance, and become at risk of emerging from school into the adult world of work with skills and knowledge levels much below that of their potential.

There are definitional issues relevant to LD in Australia and in the international community. In Australia, students who do not have an indentified neurological impairment but are significantly under-achieving in academic skills, when compared to their same-age peers, are considered as students experiencing LD. Estimates of prevalence vary but there is agreement that, in Australia, between five and ten percent of students experience LD in academic skills such as reading and mathematics.

Middle-school students experiencing LD in reading have difficulty reading words they have encountered many times before, and lack skills to decode novel or complex words. Deficits in phonology, related to language representation in memory, and processing constraints that result in reduced naming speed have been identified as key, underlying factors in reading LD. Mathematics LD in older students may be co-morbid with reading LD and is characterised by delayed development of number sense, memory difficulties and over-reliance on inefficient strategies. Once a targeted skill has been improved, students experiencing LD require constant rehearsal and review to make sure that the skill is maintained over time.

In the middle-school years the self-perceptions of students with LD about their learning aptitude can have a negative effect on learning and participation. For some students, this is confounded by limitations in social competence, and anxiety about learning which impacts on learner characteristics such as motivation and persistence. Learned helplessness, whereby students believe that their performance on learning tasks is attributable to factors outside their control, is a debilitating affective factor that negatively reinforces a cycle of failure and reduced participation.

Encouragingly, consistent research findings have highlighted instructional approaches that are effective in supporting students in the middle-school years experiencing LD. Most notably, direct instruction and strategy instruction have been validated as effective instructional approaches whilst discovery-learning type approaches are increasingly thought to be less effective, especially when teaching students with LD new or complex information. Making instructional adjustments, such as altering the level of task difficulty so it is appropriate to student's proficiency, is a key approach for effective teaching and learning for students experiencing LD.

Intervention research in reading and mathematics also provides relevant information for improving the learning outcomes of students experiencing persistent LD. For middle-school students with LD, reading interventions that focus on word reading, reading fluency and reading comprehension are effective, particularly when instructional strategies encompass direct instruction, strategy instruction, advance organisers, control of task difficulty and self-questioning strategies.

In mathematics interventions there is strong evidence to support a focus on basic mathematics facts and operations, incorporating extending practice in a relevant and motivating context, attention to individual learning needs, using peers in structured, reciprocal teaching roles, and providing performance-based feedback to participating students, and their teachers and parents.

More detailed insights into the specific difficulties experienced by students with LD are afforded when the cognitive processes involved in reading and basic mathematics are considered. The information-processing framework is the predominant approach for understanding cognition and learning. From this perspective, inefficiencies in the cognitive processes of knowledge acquisition, processing, storage and retrieval are thought to underlie LD. In particular, LD can be attributed to constraints in working-memory processes, particularly the functioning of the central executive and the phonological loop.

Automatic processing of routine tasks involved in reading and basic mathematics reflects efficient processing in working memory and other cognitive resources. Conversely, lack of automaticity in basic academic skills consumes limited cognitive resources and results in effortful, error-prone performance which impedes success in higher-order learning tasks, such as reading comprehension and mathematical problem solving.

Learning difficulties in reading for older students is thought to result from limited phonological and orthographical representations in memory, as well as central executive impairments that result in slow naming speed. Therefore, students come to rely on inefficient strategies for word recognition by approaching the task in a way that over utilises cognitive resources rather than relying on automatic processes to read words, as their average-achieving peers do.

Similarly, students with LD in mathematics are thought to have poor knowledge representation in long-term memory which results in limitations in the effective use of conceptual knowledge and difficulties recalling previously encountered knowledge. Consequently, students experiencing LD in mathematics also tend to over-rely on inefficient strategies, and attempt to utilise approaches to learning that sap their limited cognitive resources and impede engagement with novel or complex aspects of the task at hand.

As an investigation into LD is a broad topic, it is necessary to acknowledge areas that have not been investigated in this review. The focus on basic academic skills in this literature review largely precludes a closer examination of comprehension, problem solving and other higher-order cognitive processes such as strategy use and self-regulation. These factors have a significant role to play in learning development for students with LD. The skills of phonological processing, prominent in the literature for early reading programs, are not widely included in this review because the bulk of that literature refers to young, emergent readers. More broadly, the vital role of proficiency in language concepts for the development of social skills, cognitive abilities and academic outcomes (see Hay, Elias, Fielding-Barnsley, Homel & Freiburg, 2007) has not been explored in this report, because most research literature pertains to younger students, but nonetheless this important developmental factor requires acknowledgement.

This literature review has focused on the basic academic skills deficits experienced by students with LD during their middle-school years. The aim was to provide information useful for developing research questions, the answers to which may, potentially, have positive implications for enhancing school-based teaching and learning for students with LD in contemporary Australian classrooms. Social-emotional perspectives, effective teaching for improving the learning outcomes of students with LD, and aspects of cognition relevant to teaching and learning basic academic skills, have also been considered. The information-processing framework provided a theoretical structure for examining thinking and learning processes and gaining more detailed understandings of the phenomena of LD for students in the middle-school years.

In conclusion, there are four key points from the literature review to be considered in developing the research questions and the theme. These are:

- the cognitive characteristics of the learner, specifically students in the middle-school years experiencing persistent learning difficulties
- the role of cognitive processes implicit in learning basic academic skills
- the constraints and inefficiencies in learning commonly exhibited by middle-school students with LD, and teaching approaches to support improved learning outcomes for these students, and

- the solid base of evidence from research reports and meta-analyses that identifies direct instruction and strategy instruction as effective instructional approaches for supporting students with LD.

Each of these key points is briefly reviewed in turn.

In the case of the first key point important considerations are that students in the middle-school years experiencing LD are a heterogeneous group but they commonly experience impaired performance in basic academic skills. This impaired performance negatively impacts on participation in learning activities and access to curricula across all key learning areas, with potentially life-long consequences. In the past thirty years and to date, the issue of learning difficulties in the middle-school years has attracted less attention in research and policy than LD for younger students.

Despite the fact that these students experiencing LD are a heterogeneous group in terms of demographics, specific difficulties they experiences and their underlying causes, many students experiencing LD display common learner characteristics that impede appropriate development in academic skills. These characteristics include memory difficulties, impaired ability to use limited cognitive resources efficiently, poor work habits such as lack of persistence, and learned helplessness. These older students and their teachers stand to benefit from further research into the school-based remediation of LD. Therefore, LD in the middle-school years, particularly intervention research in basic academic skills, is a worthy, justifiable focus for further research.

The second key point is the importance of considering the role of cognitive processes and cognitive processing in understanding and remediating LD. Inefficient or deficient information-processing operations, particularly within working memory, are a significant, causal factor in LD. An understanding of the nature of these constraints can usefully inform the development of effective interventions and appropriate adjustments to teaching and learning.

Cognitive resources, particularly the processes of working memory are limited for all learners, and efficient use of these cognitive resources is important for successful learning and performance. Key constraints in working memory experienced by students with LD include a reduced capacity when task demands are complex, and inefficient allocation of resources. Specifically, students with LD commonly experience deficiencies and inefficiencies in the coordination and allocation of resources from working memory's central executive and in accessing representations of language-based information in the phonological loop.

These constraints manifest in a lack of automaticity in basic academic skills. While non-LD students rely on automatic processing of lower-order information, students with LD expend cognitive resources on the controlled processing of lower-order information, limiting the cognitive resources available to participate in higher-order or novel aspects of a learning task. Supporting students to overcome or 'work around' such constraints is a vital aspect to consider when providing appropriate adjustments to classroom teaching and learning, and when designing effective interventions. Accordingly, improving automaticity in basic academic skills is a valid intervention focus when seeking to improve learning outcomes for students with LD in the middle-school years.

The third key point to consider in developing the specific focus for this study was to clearly identify difficulties that pertain to the core basic skills, word reading and basic mathematics, and also to identify evidence-based remedial approaches. In looking at these factors, related affective factors, such as the importance of experiencing success in academic endeavours, also need to be considered.

In reading, key difficulties experienced by middle-school students with LD include constraints in phonological processing and in storing and accessing previously encountered knowledge, culminating, for older readers, in word reading and comprehension difficulties. For middle-school students experiencing LD in reading, improving reading at the word level is an essential focus for intervention. This requires practice to develop word recognition, recall and knowledge of effective strategies. Strategy instruction in comprehension is also important.

In mathematics, key difficulties experienced by middle-school students with LD relate to recall and application of basic number facts and to inefficiencies in storing and accessing previously encountered knowledge. For students in the middle-school years with LD in mathematics, extended practice on basic facts within a context that promotes the development of effective strategy use, is an essential focus for intervention. This requires practice to develop knowledge, effective information storage and efficient recall.

Social-emotional factors impact on learning participation and achievement for older students with LD. These factors need to be considered when seeking to improve these students' learning outcomes. Difficulties in the affective domain experienced by students with LD can be ameliorated, at least in part, by improving basic academic skills.

Finally, a vital point for consideration in implementing an academic skills intervention aimed at improving learning outcomes for middle-school students experiencing LD, is the strong evidence-base to support direct instruction, strategy instruction, adjusting the level of task difficulty and utilising peer interactions, as effective intervention approaches. Effective intervention for students experiencing LD needs to include regular practice and review, as well as follow-up assessment to evaluate maintenance and generalisation of the targeted skills.

These conclusions provide clear directions for the research questions offered in the following section.

Research Questions and Theme

Taking into consideration the information presented in the literature review and the conclusions stated, three research questions were formulated. The questions were stimulated by, but not explicitly answered in, the reviewed literature, therefore they warrant empirical investigation. These questions are:

1) Will the participant students' automaticity in basic academic skills improve after taking part in the *QuickSmart* intervention, and will their automaticity in basic academic skills be closer to that of the comparison group at post-test?

2) Will there be a significant difference, from pre-test to post-test, in student achievement levels on standardised tests?

3) Will participant students show maintenance of post-intervention automaticity rates when tested again one year later?

The above research questions focus on measuring and verifying some of the factors that mediate the cognition and learning of students with LD. The investigation of these questions, through intervention research, requires extended teacher and student interaction, and this affords a unique opportunity to observe the learning progress of the participants. Qualitative information available from these teaching and learning interactions include learning strategies and approaches used by the students and teacher, the pattern of student progress, variation in students' performance growth over time and students' expressed developments in their perceptions of themselves as learners.

Accordingly, a secondary focus for the investigation was developed. This secondary focus is presented as a research theme that investigates individual participant students' learning growth and development throughout the intervention. Three focus questions were developed to guide the investigation of this research theme:

a) What learner characteristics did the participants display, particularly in terms of behaviours that might inhibit, or facilitate, successful learning?

b) For each participant, what was their pattern of progress and how long was needed to show consistent improvement?

c) What were the participants' opinions about taking part in the intervention?

As these questions are supplementary to the main investigation, no specific research question are posed; rather the theme is addressed in a separate chapter to the research questions, and the findings of both investigations are considered together, in the final chapter. This secondary focus on individual participant students, supports the study focus on students with LD because it utilises 'real' students, in 'real' school settings, to provide information and clarity around the phenomena of learning difficulties as experienced by students in the middle-school years.

In developing the research design several considerations were identified with regard to the practicality of the study, and the demands and assumptions implicit in the research questions and research theme. Among these considerations was the need to ensure that the intervention and instrumentation used to investigate the questions were rigorous and ecologically valid in a contemporary Australian school context, the setting for the research. Thus, careful consideration needed to be given to the research methods selected. The following discussion in Chapter 3 considers design aspects of the study in detail.

Chapter 3

Experimental Design

Several focus areas emerged from the review of the literature in Chapters 1 and 2. These were formulated into three research questions and a theme for investigation. Accordingly, the investigation focuses on whether an improvement in automaticity in basic academic skills has a facilitating effect in improving broader, curriculum-based, learning outcomes, and examines other topics relevant to the phenomena of learning difficulties in the middle-school years. The theme aims to supplement the main investigation with more fine-grained examination of individual participants' progress throughout the intervention.

The purpose of this chapter is to provide a detailed description of the development of the research design and the methods used to investigate the research questions and theme. The chapter contains discussion under the following six sub-headings: Research Context, Planning for Research, Research Design, Participants and Instrumentation, Evaluation of the Design, and Data Analysis Plan.

Research Context

The investigation was planned as an intervention study to be implemented in local schools using the researcher as the teacher in the intervention lessons. Conducting intervention research in schools requires a number of particular considerations, especially that the content of the intervention is linked to curricula and perceived as worthwhile by the participant students, their parents and teachers. Further, the long duration of the intervention meant that the researcher had the opportunity to work closely with participants and their teachers in an on-going manner so establishing and maintaining good professional relationships with those involved was an important requirement.

The investigation was designed primarily as a quasi-experiment supplemented by a less formal study utilising profiles of the learning growth and development of a selection of participant students. The context of the research, as considered in the planning stage of the investigation, is now discussed in two sections, the first focusing on the setting, and the second detailing the mixed methods research framework selected to guide the development of the research.

Overview and Setting. The research was to focus primarily on whether students with LD in their middle years of schooling can make gains with regard to automaticity of basic academic skills and whether these gains facilitate improvements in general standardised tests. The secondary focus of the research more closely examines the learning progress of individual participants.

In overview, the research was to be conducted with students from a state primary school and a Catholic high school, both located in a regional town in northern NSW, Australia. The participants were twelve Year 5 students and ten Year 7 students, all of whom experienced LD. The researcher was a qualified primary school and special education teacher, and post-graduate special education student, who regularly consulted with supervisors from the University of New England, class teachers and the school principals to ensure the investigation was authentic and appropriate in both research and pedagogical contexts.

The significance of this research lay in the fact that there were very few published contemporary Australian research-based studies investigating the development of basic academic skills and improved learning outcomes for middle-school students with LD. Further potential significance of this research was that it highlighted relationships that may exist between increased automaticity in basic academic skills and improved generalised learning outcomes for the group of middle-school students with LD included in the study. In this way the study attempted to link changes in learning performance with theorised shifts in cognitive processing, as suggested in the research literature.

The research presented here is an educational intervention study which incorporated information from the field of cognitive psychology to frame development of the intervention and to inform later discussion of the results. Also, the investigation of the theme potentially added information about the heterogeneous nature of the population that constitutes middle-school students with LD. However, the key significance of the proposed research was that it focused on an area — LD and basic academic skills for students in the middle-school years — where relatively scant contemporary Australian research was available.

At this point the importance of rigorously evaluating intervention research must also be noted, particularly as the student population for this work is among the most vulnerable in our education system (Dobson, 2001; Reynolds, Temple, Robertson, & Mann, 2001). Interventions based on unsubstantiated ideas have the potential to take up valuable instructional time for these students with little, or no maintained gains in performance (Strain & Hoyson, 2000). From the outset, this study aimed to deliver an intervention based on sound theoretical underpinnings and utilising an appropriate, relevant and well-planned research framework.

Research Framework – Mixed Methods Research. Conceptually, educational research has been traditionally divided by the 'paradigm wars', a divisive debate about whether a quantitative or qualitative orientation for research in the social sciences is most appropriate (Teddlie & Tashakkori, 2003). Mixed methods research, a class of research in which quantitative and qualitative techniques, methods or approaches are combined in a single study, has been described as a 'third paradigm' in educational research, one that recognises that both quantitative and qualitative research are important and useful (Johnson & Onwuegbuzie, 2004). The mixed methods research approach has been described as follows:

A mixed methods approach is one in which the researcher tends to base knowledge claims on pragmatic grounds. It employs strategies of enquiry that involve collecting data either simultaneously or sequentially to best understand research problems. The data collection involves gathering both numeric information (e.g., on instruments) as well as text information (e.g., on interviews) so that the final database represents both qualitative and quantitative information (Creswell, 2003, pp. 19-20).

The mixed methods research presented here is underpinned by the philosophy of pragmatism, which presents a practical and applied research philosophy (Maxcy, 2003). Pragmatic researchers reject the thesis of incompatible research paradigms, and, in doing so, consider the research question to be more important than the method (Teddlie & Tashakkori, 2003). The design of the research presented here is consistent with this perspective. The goal of mixed methods research is not to replace either the qualitative or quantitative approach but rather to draw from the strengths and miniminse weaknesses of each approach (Johnson & Christensen, 2000). Combining qualitative and quantitative methods in one study allow researchers to capitalise on the strengths of the two approaches, and to compensate for the weaknesses of each approach (Punch, 1998).

Data analysis in mixed methods research requires researchers to use both qualitative and quantitative techniques to understand the phenomena better, essentially providing the opportunity to "get more out of the data" (Onwuegbuzie & Teddlie, 2003, p. 353). In this instance, a mixed method study was selected to enable the presentation of rigorous results about participants' performance changes, accompanied by authentic information about the learning progress of selected individual participant students.

Mixed methods research as been conceptualised as a function of two dimensions: time orientation (concurrent verses sequential) and paradigm emphasis (do qualitative and quantitative investigations have equal status or does one have dominant status?) (Johnson & Christensen, 2004). In this thesis, the quantitative research paradigm is dominant with a concurrent qualitative theme. Results from the quantitative research questions of the main study and the qualitative questions from the theme are considered separately in Chapters 5 and 6 (respectively), and the findings are then considered together, in Chapter 7, with the purpose of providing an expanded 'picture' of the phenomena of LD in the middle-school years.

In review, the justification for the selection of a mixed method design as a framework for this research was contained in the idea that in reality, ascertaining ways to support older students with LD to achieve improved learning outcomes is not likely to be amenable solely to a quantitative investigation or solely to a qualitative investigation. This is due to the complexity of the associated issues and the heterogeneity of the population of students with LD. The research context fits comfortably within the mixed methods framework encompassing a pragmatic perspective that clearly relates to the needs of students with LD, identified in the literature review, which determined the research questions.

Planning for Research

At the outset of the investigation process, consideration was given to the demands of implementing a quasi-experiment and developing informative profiles of selected students' performance change. It was also important to be aware, from the beginning of the research process, of restrictions that may limit the scope and implementation of the research. In this section an overview of the planning for research implementation is provided, design features are identified, and limitations of the research design are identified and discussed.

Design Factors to Consider. The proposed research required the use of an appropriate intervention to facilitate the development of automaticity in basic academic skills. The intervention used was called *QuickSmart*. It was co-developed in the planning stage of the research, utilising content and strategies indicated in the literature, as potentially able to facilitate the development of automaticity in basic academic skills in reading and mathematics. Two programs were utilised, *QuickSmart* Reading and *QuickSmart* Mathematics, with very similar instructional design applied to the different domains. These programs are described in detail in the following chapter.

A design feature of the *QuickSmart* programs is the incorporation of the Cognitive Aptitude Assessment Software (CAAS), used to measure response latency and accuracy in basic academic skills. The CAAS is described in detail later in this chapter. However, in designing the investigation reported here, it was important to be mindful that the research study reported here is not an evaluation of the *QuickSmart* program or the CAAS, rather, an investigation into the feasibility of improving reading or basic mathematics fluency for middle-school students experiencing persistent LD, and potential effects of this on performance on standardised tests.

A decision was made in the planning phase to select students to participate in either the *QuickSmart* reading intervention or the *QuickSmart* mathematics intervention, not both. Whilst some students may have benefited from intervention in both domains, it was considered not feasible to have participant students withdrawn from their regular classes for the extended time required for participation in both interventions.

In order to compare the progress of the participants, the research design used in this study also incorporated measures from a group of average-achieving (non-LD), same-age peers, to act as a benchmark measure. This design feature falls short of an experimental control group but it was the best option available in the circumstances, as explained below. In recent years there has been an increasing focus, both in the educational research literature and in government policies, on the implementation of randomised controlled research as the preferred ‘standard’ to be used for verifying educational improvements (e.g., Gersten, Fuchs, Compton, Coyne, Greenwood, & Innocenti, 2005).

Whilst many educational researchers and practitioners see the potential benefits from such an approach, the requirement that ‘evidence-based’ research utilises a randomised control group, at times, poses a significant challenge to researchers as they seek to validate effective practices in special education (van Kraayenoord, 2006). Later in this chapter the case is made that the use of a comparison group, in this study, to some extent mediated the threats to internal validity inherent in the quasi-experiment design.

Some practical matters also needed to be attended to before the investigation could be implemented, including obtaining ethics approval from the University of New England, meeting with personnel from the NSW Department of Education and Training to explain the project and obtain their approval to approach a nominated school, and then meeting with school principals and class teachers to explain the project and map out a time line for implementation. Both university and school personnel recognised the importance of adequate communication with the parents of participating students, so to this end it was established that the researcher would be available by appointment to meet with parents any time during the research program. Also, written reports to parents were provided, by the researcher, mid-way through and at the end of the interventions.

A final factor of the research design to be considered was in relation to grouping the collected data. Data relevant to the research design were collected across a number of fields including comparison and participant, Year 5 and Year 7 students, Indigenous and non-Indigenous, male and female. However, the sample size available for the study was relatively small, such that to consider all of the groups separately would have yielded results with very limited generalisability. For this reason, a decision was made to not investigate effects for year group, gender or Indigenous or non-Indigenous, rather to consolidate the grouping of results to show data for participant and comparison students in each of the interventions.

Design Constraints. Both the quantitative and qualitative methods used in the research had inherent limitations. In a quasi-experiment, variables such as maturation and the effects of history can potentially compromise the validity of the design (Isaac & Michael, 1980), and undermine the significance of the findings. In a qualitative investigation which relies largely on descriptive data, the credibility of the findings needs to be considered carefully, and the researcher needs to be mindful of these limitations throughout the research process.

A further limitation on research design was imposed by ethical considerations with regard to restricting the amount of testing that could be administered to the participant and comparison students, including consideration of taking up valuable instructional time. As it was, the research design required considerable pre- and post-testing on both formal and informal measures, such that the inclusion of additional assessments, which could add to the validity and reliability of the study, was perceived as potentially detrimental to the participants, and therefore was not built-in to the research. These restrictions reflect the reality of working in an educational setting, where, unlike in a clinical setting, the research program needs to be ecologically valid, in the sense that it is consistent with the curricula, policies and priorities of the educational system within which it operates. Additional testing and data collection, although potentially informative for the research, was not collected as it may have negatively impacted on the ecological validity of the study.

In review, a tenet of mixed methods research is that researchers should mindfully create designs that effectively answer their research questions (Johnson & Onweuegbuzie, 2004). In attempting to achieve a design that addressed the research questions and the research theme, especially in a small-scale educational study, it was almost inevitable that the research design would have some constraints. In this instance, limitations in the design of the study, including the inability to provide a randomised control group, were identified and noted. However, it was anticipated that the careful planning of the design as described in the next section, would provide results that were nonetheless informative, and that these results could be a platform for further research.

Research Design

This section outlines the research design developed to investigate the three research questions and the three secondary questions that constitute the research theme. The design needed to take into consideration several factors. It needed to reflect the mixed-method framework and the theoretical perspectives selected, as outlined above. Further, the design needed to closely address the content of the research questions and the research theme, such that it maintained fidelity to the intent of the investigation. The research is designed to address the three research questions and an exploration of the factors relevant to the research theme. These are described in detail below.

Design for Investigating the Research Questions. The three research questions in this study focus on cognitive processing, and improvements in student learning outcomes that can potentially be mediated by increased automaticity in basic academic skills. This line of inquiry fits comfortably within the information-processing framework.

The research typology used to address research questions 1, 2 and 3 is a quasi-experiment. The origins of such an approach can be directly linked to the traditional, scientific investigations of social phenomena based on the natural sciences (Cohen & Manion, 1989). The methodology enabling quantitative research requires variables to be measured numerically (Punch, 1998). Unlike a true experiment, a quasi-experiment assumes that not all relevant variables can be controlled and consequently limitations exist that may compromise the validity of the research design (Isaac & Michael, 1980). The design of the quasi-experiments used to investigate each of the three research questions is represented in Figure 3.1.

Research Question 1	P	T1	X	T2		
	C	T1	0	T2		
Research Question 2	P	T1	X	T2		
Research Question 3	P	T1	X	T2	0	T3

Legend:

P = Participant Group   C = Comparison Group

T1 = Pre-test   T2 = Post-test   T3 = Maintenance

X = Treatment   0 = No Treatment

Figure 3.1 Experimental design used to investigate the research questions.

For research question 1, which investigates improved automaticity in basic academic skills, the independent variable was conceptualised as participation in an appropriate intervention and the dependent variable was conceptualised as improved automaticity in basic academic skills. Thus the study required an empirical focus on measuring participant and comparison students' automaticity in basic academic skills. Automaticity was assumed to be measurable by response latency and accuracy rate on a range of reading or basic mathematics items. These measures, detailed in the following section, provided accurate information about the extent of automaticity in basic academic skills for both participant and comparison students, before and after the intervention.

The data collected, for this study, were response latency and accuracy rates on three CAAS reading tests (for the *QuickSmart* reading participant and comparison students) and response latency and accuracy rates on three CAAS mathematics tests (for the *QuickSmart* mathematics participant and comparison students). These data were collected both before and after the *QuickSmart* intervention programs were delivered.

For research question 2, which investigates performance gains on standardised tests after participation in the *QuickSmart* intervention programs, the independent variable was conceptualised as improved automaticity of basic academic skills, and the dependent variable was conceptualised as performance on standardised tests. This required measurement of participant students' performance on standardised tests of reading (for the *QuickSmart* reading participant students) and mathematics (for the *QuickSmart* mathematics participant students) before and after the *QuickSmart* intervention programs, in order to gauge the effect of increased automaticity in basic academic skills on participants' levels of academic achievement in the standardised tests, viewed as broader measures of learning attainment. The data collected for this study consisted of raw scores, percentile ranks scores and scale scores, for each participant students' test performances, before and after the intervention programs.

For research question 3, which investigates maintenance of automaticity gains one year after the intervention concluded, the independent variable is participation in the *QuickSmart* intervention one year prior to the measure being taken, and the dependent variable was maintained automaticity in basic academic skills. The data collected for this study were response latency and accuracy rates on three CAAS reading tests (for the *QuickSmart* reading participant students), and response latency and accuracy rates on three CAAS mathematics tests (for the *QuickSmart* mathematics participant students). These data were collected one year after participation in the *QuickSmart* intervention programs ceased.

The design for these three studies proceeded in four phases. Firstly, a pre-testing phase where data were collected, as outlined above, from both participant and comparison students. In the second phase, the *QuickSmart* intervention was implemented, with the participants only. The third phase of this study involved post-testing, a replication of the pre-testing protocol with participant and comparison students. In the fourth phase, implemented one year after the intervention programs concluded, response latency and accuracy data were collected from available participants.

Design for Investigating the Research Theme. The research theme focuses on individual participant students, their progress throughout the intervention, and their approaches to learning. Three areas were identified for exploration. These are: (i) the ‘learner characteristics’ demonstrated by the participant students, particularly in terms of behaviours that might inhibit successful learning, (ii) the pattern of progress for each participant student and how long was needed to show consistent improvement, and (iii), the participant students’ opinions about taking part in the intervention. The findings yielded from this exploration were anticipated to be informative for developing more detailed understandings of the phenomena of LD, based on the individual experiences of ‘real’ students in a contemporary school setting.

A necessary component of mixed methods research is the use of a visual model of the approach (Creswell, 2003). A notational system developed by Morse (1991, in Teddlie & Tashakkori, 2003) is the standard currently used in the mixed methods research area. Key components of the notation include: (i) the abbreviations QUAN for quantitative and QUAL for qualitative; (ii) use of the plus (+) sign to indicate that data are collected simultaneously; (iii) use of the arrow (→) to show that data were collected sequentially; and, (iv) use of uppercase to denote more priority given to that orientation (Teddlie & Tashakkori, 2003).

This standard notation system is utilised below, in Figure 3.2, to portray the research design from a mixed methods perspective (this information compliments and expands on the depiction of the solely quantitative design displayed, above, in Figure 3.1).

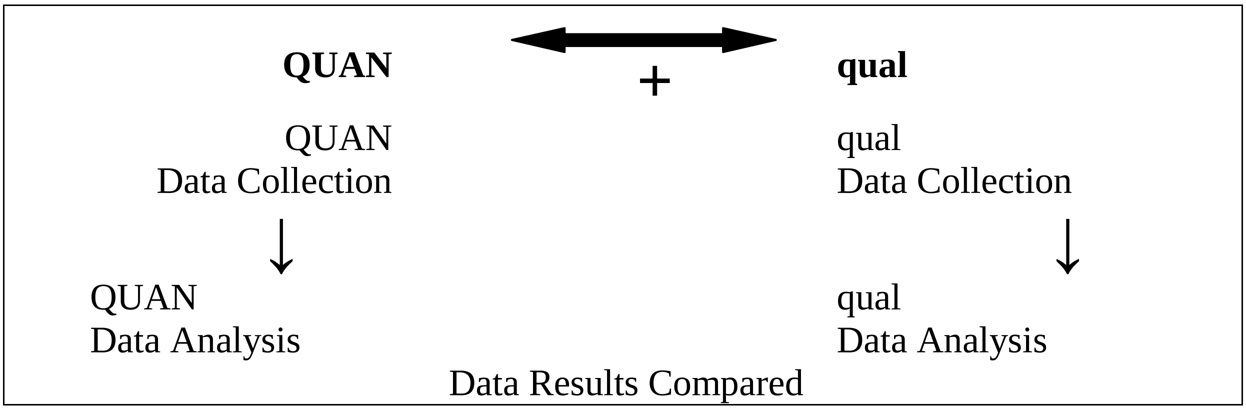

Figure 3.2 Model of concurrent triangulation design (after Creswell, 2003, p. 214).

More specifically, the research approach utilised in this study fits largely within the type of mixed methods design called Concurrent Triangulation Design (Creswell, Plano, Clark, Gutmann, & Hanson, 2003). This ‘traditional’ mixed methods design uses separate quantitative and qualitative methods (in this case with priority given to quantitative methods) to collect data simultaneously, with the results integrated in the interpretation phase of the research report (Creswell, 2003). In the study reported here, the qualitative and quantitative data collection phases of the study occurred simultaneously, but the quantitative research is the main contributor to answering the research questions.

However, there are some minor variations of the design portrayed in this figure, most notably with regard to the research theme. Both quantitative and qualitative data are used to address the questions relevant to the theme and the quantitative maintenance data. These data were collected one year after the main investigation ceased.

The design to investigate the research theme relies on progressive response latency data collected during the intervention, but not used in the three main studies, as well as referring to the pre-, post- and maintenance data reported in relation to the research questions. Specifically, the data used for the research theme consists of measurements from CAAS taken throughout the intervention, student responses to an exit interview and information taken from field notes made by the researcher throughout the intervention programs. The findings are presented in the form of six profiles of participant students. Each profile describes the participant and their progress during the intervention.

In review, the research design reflected a mixed methods approach, predominately relying on quantitative data gathered from the three quasi-experiments of the main investigation, and student progress data supplemented by qualitative data from student interviews, and field notes, to investigate the research theme. Details about participant and comparison student selection and the instruments used to measure progress are provided in the following section.

Participants and Instrumentation

This section explains practical and organisational aspects of the investigation. It includes descriptions of the participant and comparison students involved in the study, an overview of the measurement instruments and data gathering techniques used in the quantitative experiments, and an outline of the qualitative data collected. The reliability of the measurement instruments is also addressed.

Selection of Participant and Comparison Students. In the studies to investigate the first two research questions, a total of 38 students took part, 24 Year 5 students and 14 Year 7 students. From this group of 38 students, 22 students were identified as students with LD. These students became the participant students (i.e., they participated in the *QuickSmart* intervention programs). The other 16 students were nominated as not having LD and did not participate in the intervention but were included in testing protocols as comparison students.

For the Year 5 students, participant selection was based on teacher nomination, test results as related by the teacher (informal class tests and prior state-wide testing) and results from part of the pre-testing protocol, specifically the CAAS response latency and accuracy data. Using the results of these assessments and consultation with the class teacher, the 12 lowest performing, consistently attending students were selected to participate in the intervention programs and other, average-achieving students were selected to be comparison students.

Year 7 participants from the Catholic secondary school were selected by the English and Mathematics head teachers. The criteria they used for selecting the sample of students were: (i) they were experiencing LD in either numeracy or literacy; (ii) they had performed in the lowest two bands on the state-wide Year 7 screening tests; and (iii) they had a regular school attendance pattern. Year 7 comparison students were nominated by the teachers as average-achieving students. Originally, 16 Year 7 students, being 12 participant students and 4 comparison students, were selected. However, two of the selected participant students withdrew from the program in the first two weeks, leaving ten Year 7 participants.

Thus, 22 students, 11 boys and 11 girls, identified as experiencing LD were selected to participate in either a reading intervention program or a basic mathematics intervention program. Of the 22 students selected to participate in the interventions, nine identified as Indigenous. The students were nominated by their teachers to participate in either the *QuickSmart* Reading or the *QuickSmart* Mathematics program, then further allocated into the pairs that would undertake the intervention lessons together. Five pairs of students participated in the reading intervention program and six pairs in the basic mathematics intervention program. An overview of the configuration of the cohort is included as Appendix B.

In the study to investigate the third research question, which required participants only, selection was based on student availability. Seventeen of the original 22 participants were still enrolled in the same school as the previous year, and were available for re-testing, so these students were selected to participate in the maintenance phase testing.

Participant selection for the student profiles featured in the exploration of the theme in Chapter 6 was based on decisions about gaining information that would best help the researcher address the research questions (Cresswell, 2003). Qualitative research studies typically use smaller samples selected through 'purposive sampling' (Kemper, Stringfield & Teddlie, 2003), in contrast to random sampling techniques typically used in quantitative studies. This type of sampling is relevant when the point of the research is to explore the thinking or behaviour of people in specific roles (Cooksey, 2007), in this case, the learning behaviours of middle-school students experiencing LD. Accordingly, six students were selected to be 'profiled' to explore the research theme. Participant selection was based on the intention to provide a representative, informative sample of original participants, and on membership of the group of seventeen participants for whom maintenance data were available. More details of how this selection was made are provided in Chapter 6.

The Year 5 participant students received three, thirty-minute lessons per week for 22 weeks, across three school terms. The Year 7 participant students received three, thirty-minute lessons per week for 18 weeks across two school terms. On advice from the high school Principal, the intervention with the Year 7 group commenced slightly later than that of the Year 5 group, due to the recommendation that there be a delay in commencing the Year 7 program. There were several valid reasons for this advice including that the Year 7 group had just commenced high school and needed time to settle into new school routines.

Once the researcher and the class teachers had completed the participant selection process, permission for the students to take part in the investigation needed to be obtained from their parents. The researcher and the class teacher drafted a permission letter which was issued under the school letterhead. Attached to the permission letter was information about the research and intervention programs. Once parent permission had been obtained and the consultation processes between stakeholders had taken place, pre-intervention testing was commenced. Detailed descriptions of the assessment instruments are provided in the following section.

Instrumentation. Throughout each of the four phases of the research, changes in key variables needed to be carefully measured using relevant and reliable measures. Details of the measurement instruments used to investigate the research questions are provided in this section.

Research questions 1 and 3, as well as some of the questions related to the research theme, all relied on data collected from the CAAS (Cognitive Aptitude Assessment Software). The CAAS software package, which records response latency and accuracy on a range of basic academic skills in reading and mathematics, was used to measure automaticity in basic academic skills in this study. The CAAS was developed by researchers at the Laboratory for the Assessment and Training of Academic Skills (LATAS) at the University of Massachusetts, Amherst (see http://www.umass.edu/latas/research.html).

The CAAS is a battery of computer-presented tasks, with record keeping capabilities, that measures a range of basic academic skills including word reading at different levels, sentence reading and basic mathematics (e.g., addition, subtraction and multiplication tasks). Students respond to the computer-based tasks by answering into a microphone attached to the computer as soon as a stimulus appears on the computer screen.

When a stimulus is presented on the computer screen the student responds into a microphone. The system records the vocalisation latency at this time, and then the scorer pushes one of two mouse buttons to record the response as correct or incorrect. Thus the examinee is given immediate feedback about the accuracy of their response. Correct responses are signaled by a high-pitched trilling sound and incorrect responses are signaled by a low-pitched tone. At the end of a test the CAAS software computes a mean and a standard deviation for response latencies and automatically cleans the data by eliminating impossibly fast responses of under 200ms, and data for responses 2 standard deviations or more above the mean performance. The software then re-calculates accuracy and latency performance for the test (Cisero, Royer, Marchant, & Jackson, 1997). The student's assessment results are then automatically summarised and made available in either a graph or report form that is easily interpretable by both students and teachers.

The CAAS reading assessment and the CAAS mathematics assessment both have a range of tests. A test contains 15-to-20 items in mathematics and 30-to-40 items in reading. These items are randomly selected from a bank of between 160 to 250 items stored for each test. In this study, pre-test and post-test protocols required at least three CAAS tests to be administered. CAAS assessments administered at the end of most *QuickSmart* lessons utilised only one test related to the content of the lesson, for example word reading or simple addition tests.

For the *QuickSmart* reading program, the participating students and comparison peers completed the following CAAS tests: Elementary Word (Years 2 to 4 in difficulty level, with regular and irregular orthographic patterns), Middle Word (Years 5 to 8 in difficulty level, with regular and irregular orthographic patterns), and a sentence reading and understanding task that assessed the application of semantic knowledge in sentence processing, using a variation of the 'cloze' procedure. The three reading tests reflect a range of component skills necessary for fluent reading.

For the *QuickSmart* mathematics intervention the three tests of CAAS used in the research for both the participating students and their comparison peers were addition (single plus single digit and single plus double digit addition, presented as 4 + 8 or 4 + 23), subtraction (single and double digit numerals less than 20, presented as 12 – 9) and multiplication facts (to times 12). These basic calculation tasks are foundational skills for learning in many strands of mathematics.

Research question 2 investigated whether the intervention participants showed improved performance on standardised tests. To this end, standardised tests were administered to participants before and after the intervention. It was important that the standardised tests selected to use in this investigation were rigorous, independent of the instructional program, and normed on Australian student population. After consultation with colleagues and an investigation into published tests that might be suitable, the Progressive Achievement Tests in Reading: Comprehension (PAT-R Comprehension) (ACER, 2001a) and the Progressive Achievement Tests in Mathematics (PAT Maths Revised) (ACER, 1998) were selected as appropriate instruments. Appropriate levels of these tests were administered to participant students before and after the *QuickSmart* intervention.

The PAT-R Comprehension (ACER, 2001a) was designed to assist teachers in their assessment of students' reading comprehension skills. It contains multiple choice questions intended to measure literal and inferential comprehension of prose material. It requires up to 40 minutes of testing time plus time for administration. Tables of norms for PAT-R Comprehension are included in the PAT-R Teachers' Manual (ACER, 2001b) and they convert raw scores on the tests to scale scores (on the 'patc' scale), percentile rank and stanine.

The Progressive Achievement Tests in Mathematics (PATMaths Revised) (ACER, 1997a) are used in Australian schools to provide a broad estimate of students' mathematical achievement. In the research reported here Year 5 participant students sat Test 1 and Year 7 participant students sat Test 2 (test 2A at the beginning of the intervention and 2B at the end of the intervention). The tests were administered in a group setting. The tests are timed tests and require 45 minutes of testing time plus time for administration. All the test items are in multiple-choice formats with each test including items from the topics of Number, Space, Measurement, Chance and Data.

Tables of norms for the mathematics test are included in the PATMaths Revised Norming Manual (ACER, 1998) which can be used to convert raw scores on the tests to either percentile rank scores or stanine scores, in order to compare students' attainment to the performance of national reference groups of students. The PATMaths Revised Teachers' Manual (1997b) provides a PATMaths Scale scores, used to relate the attainment of students and the difficulty of items to a single scale of achievement.

For the investigation of the theme, CAAS data of three reading or mathematics tests were supplemented by personal and demographic information, relevant educational and personal history, field notes and transcription of student responses to the exit surveys.

Indicators of Reliability of Measurement. In this section the reliability of the assessment measures used is evaluated. Reliability of measurement refers to the consistency with which a test or instrument produces results. It is a central concept in measurement that focuses on consistency over time and consistency within the instrument (Punch, 1998; Sprinthall, Schmutte, & Sirois, 1991). Reliability can be considered "a special instance of correlation" (Crowl, 1993, p. 292) whereby performance or achievement on a particular measure in one instance should be highly correlated with that attained in a repeated administration of the measure, at a later time, in order to prove stability of the instrument over time.

Another quality that measurement instruments should demonstrate is internal consistency, which requires the items within the test to be consistent with each other. In determining reliability over time or consistency within the test, a correlation co-efficient is calculated and reported, where +1.00 indicates a perfect positive correlation and -1.00 indicates a perfect negative correlation. The closer the reliability co-efficient is to +1.00 the more reliable the test

(Punch, 1998; Sprinthall, Schmutte, & Sirois, 1991). Academic achievement tests and aptitude tests with reliability co-efficients of +.80 and higher, represent a level of consistency of measurement that is realistic in terms of predicting future behaviour (Crowl, 1993).

The study undertaken to investigate questions 1 and 3 relied on the CAAS to measure automaticity with basic academic skills, conceptualised as response latency and accuracy on a range of basic reading and basic mathematics tasks. The software manufacturers report that, in their evaluations, the tasks that comprise the CAAS assessments were found to be highly reliable. For example, they report reliability indices of the response time measures ranging from .88 to .97 and overall CAAS task reliabilities that exceeded .80 (Cisero, Royer, Marchant, & Jackson, 1997; Royer & Sinatra, 1994). Data gathered by the CAAS can also claim a high level of reliability because of the system's ability to precisely measure and record speed and accuracy and because the measurement records cannot be altered in any way. Further, the long term nature of the intervention means that response variations – such as unusually good or poor performance on CAAS, do not significantly affect the overall outcome of the research (Cisero, Royer, Marchant, & Jackson, 1997; Royer & Sinatra, 1994).

Learning effects from repeated testing on CAAS are minimal. Each task in the system consists of multiple items that are randomly (without replacement) sampled on a given administration. For example, the elementary word task contains about 250 items, only 40 of which are sampled on a given occasion. This means that every test a student receives is different, thereby minimising learning effects associated with repeated testing.

The study undertaken to investigate research question 2 relied on the PAT-R Comprehension (ACER, 2001a) and the PATMaths Revised (ACER, 1997a) and the as measurement instruments. These tests were used to measure participating students' reading comprehension skills and vocabulary knowledge or participating students' mathematical achievement, before and after the intervention, against Australian standardised grade norms.

With regard to internal consistency of the PAT tests, that is, the extent to which the items are consistent with each other (Punch, 1998), this was measured by the test authors using split half reliability co-efficients. In this method the test is split into two halves, each of which is scored separately and the scores are then correlated to indicate the reliability of the complete test. A high and positive correlation indicates there is a strong relationship between the two halves of the test, and therefore that the test has internal consistency (Sprinthall, Schmutte, & Sirios, 1991).

The PAT-R Teacher's Manual (ACER, 2001b) reports split half reliability and validity coefficients in excess of .80. The PATMaths Revised Norming Manual (ACER, 1998) also reports split half reliability and validity coefficients above .80. These statistics are a positive indicator of the internal consistency of the PAT tests and support the researcher's view that the measures used for question 2 are a genuine measure of changes in student attainment levels.

The reliability of the qualitative data, field notes and exit interviews, used as part of the investigation into the theme, is more difficult to establish. Although it is harder to reduce error variance in social and behavioural research than in quantitative measurement, error variance is present whenever measurement is used (Punch, 1998). In qualitative methodologies reliability can include fidelity to real life, context and situation specificity, authenticity and honesty (Cohen, Manion, & Morrison, 2007). In other words, qualitative research reliability can be regarded as a 'fit' between the data recorded and what actually occurs in the natural setting. Video documentation of the exit interviews and regular monitoring of filed notes by the research supervisor contribute to the integrity of the qualitative data utilised in the theme investigation.

In review, the research proposed utilised 38 students, 22 of whom were nominated as experiencing LD who participated in the intervention programs. The remaining 16 students were included as comparison students. Selection of participant students for the maintenance testing was based on student availability, with most of the original participant group being available. Selection of participant students to be profiled in the theme investigation was based on relevance of the information yielded, as well as performance at pre-tests in an attempt to ensure a fair and reasonable coverage of participants.

Arguments have been presented above to support the researcher's conviction that both of the key instruments of measurement used to investigate the research questions, and sources of information for the theme, were reliable and competent measures of the properties they purport to measure. The use of exit interviews and field notes to support the student learning profiles presented in the theme do have some constraints in reliability but, as outlined above, steps were taken to reduce the likelihood that these constraints would impact on the reliability of the information included in the theme investigation.

Evaluation of the Design

The purpose of evaluating the research design is to ensure that the interpretation of the results, specifically, the interpretation of the possible effects of the independent variable, is perceived as reliable, appropriate and informative. This evaluation of the research is considered here using two criteria: control of extraneous variables and experimental validity.

Control of Extraneous Variables. Researchers need to be aware that variables, other than the dependent variable can potentially influence the independent variable and that this can limit the ability to generalize the results beyond the confines of the study (Jonhson & Christensen, 2004). Planning considerations for the control of potentially confounding variables in the research presented here are outlined below.

Research question 1 had the independent variable as participation in an appropriate intervention and the dependent variable as improved automaticity in basic academic skills. Therefore, factors that could have impacted on changes in participants' automaticity in basic academic skills needed to be identified and, if possible, controlled. The use of the researcher as the main tutor in delivering all the lessons of the *QuickSmart* intervention programs ensured that all students had the same kind of instructional input and that participant responsiveness to the tutor remained constant throughout the research.

Further, close communication with the students' teachers meant that the researcher was kept informed of any potential confounding factors related to the students such as participation in additional tutoring or remedial programs. To the best of the knowledge of the researcher, none of the participants received extra tutoring or significant additional assistance with literacy or numeracy programs during the intervention. Another extraneous variable that was held constant was regular student attendance, as students with poor attendance patterns were not selected to participate in the intervention.

In research question 2, the independent variable was improved automaticity of basic academic skills and the dependent variable was performance on standardised tests. Potentially confounding variables in this study were substantially controlled by the use of age-normed, standardised tests which included a scripted sequence for administering the test. This sequence was described in the test manuals and rigidly adhered to for both the pre- and post-test procedures. Further, communication with the class teachers revealed that the students were not familiar with the tests administered, they did not have coaching at school about test-taking strategies and they had not participated in additional supplementary programs aimed at developing students' higher-order skills such as comprehension or mathematics problem solving.

Several measures to control for extraneous variables within the third research question were identified. For this research question the dependent variable, maintained automaticity in basic academic skills one year after the intervention concluded, could potentially be compromised by other factors, especially participation in another educational intervention in the interim period. At the time maintenance data were collected it was established that none of the participating students had since been involved with programs, in school or outside of school, which focused on the development of basic academic skills. To ensure consistency the same instrument, CAAS, and the same tests were used to measure automaticity in basic academic skills at post-test and maintenance test. Further, the tests were administered by the same researcher.

Experimental Validity. Validity cannot be assessed directly but rather, it depends on subjective judgments and objective evidence (Singleton & Straits, 1988). The validity of a quantitative study is assessed on two main indexes. Internal validity refers specifically to the research design of the study and whether it is a true reflection of what it purports to study. The second index of validity is external validity which examines how far the study's findings can be generalised or transferred to other settings (Cohen, Manion, & Morrison, 2007; Punch, 1998). Typically, quasi-experiments are limited in their internal validity but offer the potential for high external validity (Sprinthall, Schmutte, & Sirois, 1991). This inherent threat to the validity of the results of the research questions investigated here is countered, at least to some extent, by the inclusion of a qualitative investigation, as presented in Chapter 6. In the following section the internal and external validity of each of the research questions and the theme are considered.

An experiment is said to have strong internal validity when one can make strong inferences about cause and effect, inferring confidently that the independent variable, rather than extraneous variables, have caused the measured effect. Threats to internal validity represent "a distinctive class of extraneous variables" (Singleton & Straits, 1988, p. 188). Quasi-experimental research design is acknowledged as potentially subject to less internal validity than true experiment designs (Crowl, 1993; Punch, 1998). The most commonly cited threats to the internal validity of quasi-experimental research are history, maturation and attrition.

The threat of history to internal validity centres on events or changes that may happen in the duration of the intervention which could impact on the dependent variable. The quantitative research reported in this study could have been impacted upon by events such as a student being provided with prescription glasses which lead to an improvement in reading attainment. Throughout the intervention the researcher was mindful to note such events, should they occur, and also monitored such possibilities in the regular communication with the teacher, parents and participant. The researcher was satisfied that no overt or significant events that could impact on the dependent variable in any of the quantitative studies occurred during the intervention.

The threat of maturation to the internal validity of a study refers to physical or mental changes that may occur within individuals over time (Johnson & Christensen, 2004). Such changes are a particular threat when the intervention occurs over a longer period of time. With regard to the experiment relevant to question 1 the measurements taken from the comparison group were a substantial control for this variable. These measurements provide information about the changes in automaticity rates for a group of same-age peers who do not experience learning difficulties, over the same length of time as the changes measured for the participant group, enabling a comparison of growth rates. Essentially, maturation effects were removed, because the same amount of time passed for both groups.

Testing effects are another potential threat to internal validity. This refers to the effects of having taken a pre-test on an individual's later performance on a post-test (Sprintall, Schmutte, & Sirios, 1991). As mentioned in the previous section, testing effects in the CAAS data were minimised because the approximately twenty test items of each test are randomly selected from a large bank of test items, such that each occasion of testing on CAAS is comprised of different test items (i.e., different words or sums each time a test is undertaken).

Another threat to internal validity is experimental mortality, which may occur when subjects leave the experiment when it is still in progress. In this research that did occur in the first few weeks of intervention when two Year 7 students in the *QuickSmart* reading program did withdraw.

Statistical regression, a phenomenon whereby extreme scores on a test tend to be closer to the average on a re-test, also needs to be considered as a threat to internal validity (Isaac & Michael, 1980). This was controlled for in the early stages of the research when a number of considerations were used to select participants including testing on two instruments (CAAS & PAT tests), information from the school about past test performance, and considerable input from the teacher regarding which students were consistently low-performing. Although these considerations cannot be guaranteed to cancel the effects of statistical regression, using several criteria for inclusion in the treatment group goes some way towards ameliorating the possibility of statistical regression impacting on the dependent variables (Sprinthall, Schmutte, & Sirios, 1991).

One threat to internal and external validity that may not have been comprehensively controlled for, in this study, is referred to as ‘the Hawthorn effect’, whereby participants may respond positively to the intervention because of positive, affective factors from the extra attention they receive by participating in the experiment. Such effects raise questions with regard to whether they impact on the final measure of the dependent variable, and also on the generalisability of the findings from the experimental setting to the natural setting (Singleton & Straits, 1988). With regard to the threat to internal validity, the use of a control group is the simplest way to avoid the Hawthorne effect. As previously explained, this was not a viable option for this experiment, so in regard to this point the research results reported here do need to be interpreted with some caution.

However, some factors do ameliorate the potential impact of the Hawthorne effect in the studies reported here. Firstly, it is quite plausible that the long-term nature of the intervention reduces the positive impact of participants’ excitement about being involved in the experiment. Participation in the intervention for 18-22 weeks meant that participants had to make considerable effort with their learning over a long period and, characteristically, for young students the excitement of being involved in something different would have ‘worn off’ rather quickly as the lessons became a part of their weekly routine.

Secondly, as Fawcett (2002) indicated, in countering the impact of the Hawthorn effect, evidence of the improvement in skill should be very specific to the skill in question, rather than just a generalised improvement. The CAAS is a very specific instrument for measuring response time and accuracy and as such has greater validity than other alternatives such as reading fluency measures or number of correct responses in a timed mathematics test. In practical terms it is unlikely that a middle-school' student with persistent LD would be able to improve on precise measures of response latency and accuracy just because of the 'warm glow' of being involved in an intervention. The PAT tests are generalised measures so the reviewers of the research need to make judgments about the magnitude of improvements reported compared to magnitude of improvements that could plausibly be attributed to the Hawthorn Effect.

The internal validity of qualitative research can be judged on the following four categories: descriptive validity (the rigor of descriptions of settings and events of the research); interpretative validity (the validity of statements made or perspectives of the participants); explanatory (or theoretical) validity and generalisability (Maxwell & Loomis, 2003). The detailed information provided in this report about the research planning, setting, theoretical context, participant selection and the *QuickSmart* intervention programs (in the following chapter), as well as the participant student profiles, all potentially support the internal validity of the qualitative research reported. A note of caution is justified with regard to inferring the findings from the learner profiles presented in Chapter 6, as the participant selection was not random and the number of profiles presented is small. Another factor to note is with regard to the interpretative validity of the exit surveys which could have been subject to influence from a range of factors (e.g., desire to please the researcher, or a hurried response).

External validity is the extent to which the findings of the research questions can be generalised to and across persons, populations and settings, and it relies on 'thick descriptions' of the participants and the context (Punch, 1998). To promote external validity the research design has incorporated quite detailed descriptions of the planned research processes, as provided in this chapter, and a comprehensive description of the research implementation, in the following chapter.

Ecological validity is a facet of external validity which refers to the extent to which findings can be generalised to other settings, and for many researchers in education this is one of the key rationales of their approach (Cohen, Manion, & Morrison, 2007), as is the case in this research. A stated aim of the research reported here is to provide useful information, for researchers and teachers, to support achievement of improved learning outcomes for middle-school students experiencing LD in regular school and classrooms. To do this, the methods, materials and setting need to approximate the naturalistic setting, the ‘real life’ situation under investigation. Accordingly, the research reported here is set in regular, contemporary school settings, uses sound, replicable, educational approaches, curriculum relevant materials and readily made or accessed resources. The participant students include boys and girls, non-Indigenous and Indigenous students, from primary school and high school settings, all of which suggest that the study has features which promote external validity. The ecological validity of the study, in relation to middle-school students experiencing LD, is enhanced by the inclusion of the student profiles presented in Chapter 6, as they consist of detailed descriptions of the individual students and their learning behaviours or characteristics.

In review, the design of the study has been evaluated using two key criteria – control of extraneous variables and experimental validity. Close communication with the participant students’ class teacher, parents, and the students themselves, assisted the researcher in identifying any unrelated effects that could potentially impact on results. Threats to validity were identified prior to the research implementation and this meant that effects, such as the Hawthorn effect, were anticipated and controlled for, as far as feasible. For intervention research in education, ecological validity, relative to a contemporary school setting is an important underlying principle and, in this study, it was promoted by the research implementation being based in a regular school (rather than a clinic), and by using careful selection procedures to identify the participant students as authentic students who experience LD.

While it must be acknowledged that extraneous variables cannot be completely controlled for, and threats to the validity of the studies cannot be entirely eliminated, considerable effort was expended in the design and implementation of the study, to support the assertion that this research was sound, rigourous and well-justified. This is vitally important, as the population on which the study is based, middle-school students experiencing persistent LD, are particularly at risk of school failure and they deserve and require intervention support and teaching and learning strategies based on thorough, accurate, transparently reported research. This aim is further advanced in the following section which details the pre-determined approaches for analysing the data collected during the study.

Data Analysis Plan

In keeping with the mixed methods design, which holds that quantitative and qualitative data are compatible, multiple data sources were utilised in this research, requiring a range of data analysis approaches. In the following section the data analyses plans for the three research questions and the research theme are detailed.

Research Questions. Research question 1 investigates whether the participant students demonstrated improved automaticity of basic academic skills after participating in the *QuickSmart* intervention programs. The question also calls for reference to data of automaticity rates for comparison students. The instrument used to measure this variable was CAAS, which reports each participant's automaticity performance on a range of basic skills tests, as response latency in milliseconds and accuracy as a percentage. Automaticity was measured before the intervention (pre) and after the intervention (post) for the participants, and the comparison group of non-LD peers.

A between-within subjects Analysis of Variance (ANOVA) design was used for analysis (Tabachnik & Fidell, 2007). Specifically, a two-way Repeated Measures ANOVA (RM-ANOVA) was applied to test differences between means of three sets of pre and post CAAS tests. The PASW-18 statistical software package was used for these analyses. Differences in response latency and accuracy, within and between groups (participant and comparison), before and after the intervention, are analysed using the PASW-18 general linear model protocol for repeated measures.

The within-subjects repeated measures design is appropriate because the means tested are derived from the same subjects measured on different occasions (Tabachnik & Fidell, 2007). Repeated measures designs are frequently employed in behavioural research designs featuring a time-based pre-test-post-test (Cooksey, 2007). The purpose of RM-ANOVA is to test the equality of means for any significant differences on a single dependent variable (response latency, then, in a separate analysis, accuracy) under several conditions (three different CAAS tests), at two different times (pre-intervention and post-intervention). This design permits explicit control for individual differences and is particularly relevant where large individual differences on the dependent measure are expected to exist (Cooksey, 2007), as predicted for participant and comparison students across various CAAS tests.

Although using ANOVA for these data contravened some of the assumptions of the statistical procedure (as detailed in Chapter 5), the resulting analysis was used only to confirm or reject the degree of significance, rather than suggest changes due to the *QuickSmart* program. Further, it is important to be mindful that the data utilised are constrained – response latency is constrained by zero speed which represents the floor, and accuracy data, particularly at the end of an effective intervention, approaches the ceiling of 100%. According to Paris (2005), parametric tests may not be appropriate to analyse constrained data. However, given that it is a standard procedure, the decision was taken to conduct parametric tests but to ensure the data were transformed to approximate normal distribution.

Research Question 2 required data regarding whether the 22 students who participated in the *QuickSmart* intervention, with its focus on improving automaticity in basic academic skills, also demonstrated improved performance on standardised tests, which measure performance of more generalised reading or mathematics knowledge, skills and understandings. The available data for this research question were limited to participant students' standardised test performance at pre- and post-intervention.

Analysis of the resulting scale scores was undertaken using paired samples *t*-tests. Although these significance tests help clarify the nature of group differences, they do not assess how much of a relationship there is between the independent variable and the dependent variable (Tabachnik & Fidell, 2007). For this reason, effect size calculations, which do quantify the relationship between the two variables (Coe, 2002), were also reported. The type of effect size used is Cohen's *d*, which calculates the difference of two population means, divided by the pooled standard deviation.

Research Question 3 investigates whether participants in the *QuickSmart* intervention programs maintain the post-intervention gains made in automaticity approximately twelve months later. Maintenance CAAS data were collected from seven of the ten original *QuickSmart* Reading participants and ten of the twelve original *QuickSmart* Mathematics participants. Post-intervention and follow-up means, as well as tests of significance, were used to analyse the data.

Additional descriptive data are also included in the report, or as appendices, for each of the research questions. This information often includes reference to individual student data (raw data), as it provides an additional context to clarify the results reported, and is relevant to the individual student profiles presented to address the theme.

Research Theme. The research theme aims to explore selected participant student's growth and development in learning throughout the intervention. Data used to explore the theme included pre- and post-test CAAS measures and standardised test results, as well as progressive CAAS test measures administered throughout the intervention, demographic information about the students, observations and other jottings made by the researcher throughout the intervention, and exit surveys.

The findings are presented as six learner profiles, each comprised of three parts: a prose description of the participant, graphs to show development of automaticity using the CAAS tests undertaken throughout the intervention programs, and student responses to the exit survey. The findings from the theme are then considered together in an analysis based on the three theme questions. Findings from the theme will also be further reviewed in conjunction with results of the quantitative investigations, in the discussion of in the results in Chapter 7.

In review, the plan for the data anaylsis was developed to reflect the intentions of the research questions and the theme, in an attempt to provide results that are valid, practically informative and readily open to replication. Descriptive and parametric analyses are used in the research questions, and the research theme is addressed using descriptive data and prose reports.

Summary

This chapter has described the experimental design of the research and addressed issues relevant to its reliability and validity. The research was designed as a quasi-experiment within a pragmatic, mixed-methods framework. The theoretical context of the research encompasses aspects of information-processing framework as it relates to effective learning of basic academic skills. On a practical level, the context of the research was to investigate LD in reading or mathematics as experienced by middle-school' students enrolled in regular school settings. The research reported is based around three research questions investigated using quantitative data and a research theme presented as qualitative, in-depth profiles of six participants.

The comprehensive descriptions of the context of the research, the participant selection process and the instrumentation were provided to enable evaluation of the research and facilitate replication. The description of the research design indicated that careful consideration was given to support control of extraneous variables in the design phase and throughout the research implementation. A key strategy for being aware of potential extraneous variables was close communication with the participant students and their teachers.

In terms of the validity of the research, the effects of maturation, history, testing effects and statistical regression have, to the extent feasible, been moderated by various facets of the research design. Whilst the ‘Hawthorn Effect’ has been acknowledged as having potential to impact on validity, the length of the intervention and the specificity of the changes measured to some extent ameliorate the potential impact of this extraneous variable. Threats to external validity were largely contained by the provision of detailed descriptions of the context and the content of the investigation. These descriptions are complimented by the provision of detailed information about the intervention provided in the following chapter. Maintaining the ecological validity of the research was a high priority as the findings were intended to inform teaching and learning practice in regular school settings for students experiencing persistent LD and their teachers.

Quantitative data from two assessment instruments were collected before and after the intervention. Participant students’ automaticity was measured using CAAS tests at pre- and post-test and twelve months later, and their performance on standardised tests of reading or mathematics was also measured before and after the intervention. Comparison students, who did not participate in the intervention, were tested for automaticity rates twice, firstly at the time the intervention began and again after the intervention concluded. Thus, data were available for automaticity rates of participant and comparison students, and for performance on standardised tests for participant students only. Data were also collected to inform the exploration of the theme, with the aim of providing authentic, individual, ‘up-close’ descriptions of students experiencing LD and their progress throughout the intervention.

The overall strength of the research design is perceived to rest on its authentic connection to the conclusions from the literature review, its location within an appropriate theoretical and research framework, the established reliability of the measurement instruments used, and the substantial amount of information supplied, here and in the following chapter, to enable replication. Further, the research design potentially succeeds in the quest to balance the requirements of a rigorous research structure with the sometimes competing demands of implementing a relevant, motivating and educationally sound intervention in a real school setting. The information pertaining to how this was achieved is described in the following chapter which details implementation of the *QuickSmart* intervention.

Chapter 4

The *Quicksmart* Intervention

The intervention program used to develop participant students' facility in basic academic skills was an important element in the design of this study. The *QuickSmart* intervention brings together research conducted at the Laboratory for the Assessment and Training of Academic Skills (LATAS) at the University of Massachusetts (e.g., Royer & Tronsky,1998) and related work from the National Centre for Science, ICT, and Mathematics Education for Rural and Regional Australia (SiMERR) at the University of New England (UNE) in Armidale, Australia. Researchers from LATAS developed procedures for obtaining reliable assessments of pupil performance using CAAS, and researchers from UNE developed the *QuickSmart* intervention programs, situating CAAS within a contemporary, curriculum-relevant teaching approach that incorporates a focus on systematic instruction with the consistent monitoring of participant student performance.

This chapter provides a description of the *QuickSmart* intervention procedures, integral to the design of this research. This detailed description of the *QuickSmart* reading and the *QuickSmart* mathematics interventions includes materials, instructional approach and lesson outlines. General procedures are described, and then procedures for the *QuickSmart* reading intervention and the *QuickSmart* mathematics intervention are presented in turn.

General Procedures

The research implementation consisted of four phases. These were an initial assessment, implementation of the *QuickSmart* intervention, the final assessment phase and the delayed maintenance data collection. The implementation phase is described in this section. It is timely to again note that the efficacy of the *QuickSmart* intervention itself was not the subject of the research reported here, rather the intervention was used as an instrument to explore whether the automaticity in basic academic skills of students with LD could be improved, and if this improved automaticity facilitated improved performance on standardised tests. Nonetheless, as it is a key element in the research, a detailed description of the *QuickSmart* intervention is appropriate.

QuickSmart is a theory-based instructional intervention designed to improve students' information retrieval times to levels that free working-memory capacity from an excessive focus on routine tasks. The intervention was developed in response to the proposition that, in general, poor readers take more time to decode words, and have more difficulty constructing meaning from text because their cognitive resources, specifically working-memory capacity, are allocated almost entirely to low-level components of the reading process (e.g., Fodor, 1983; Perfetti, 1985, 1992; Royer & Sinatra, 1994; Stanovich, 1986, 1990). Similarly, students with difficulties in mathematics tend to use time-consuming, inefficient, or error-prone strategies to solve simple calculations. Conversely, minimal use of cognitive capacity for low-level arithmetic operations means that the cognitive resources can be devoted to high-level problem-solving activities (Geary, 1994).

For the Year 5 participants, the *QuickSmart* intervention programs were designed to consist of three, thirty-minute lessons per week for 22 weeks, across three school terms. The Year 7 participant students received a maximum of three, thirty minute lessons per week for 18 weeks across two school terms. Participant students were selected for either the *QuickSmart* reading program or the *QuickSmart* mathematics program. All students participating in the intervention were withdrawn from their classes, in pairs, for three half-hour *QuickSmart* lessons each week, with the same instructor. This researcher/instructor was regularly supported and observed by the research supervisor. Where possible the pairings of students matched individuals with similar levels of attainment in either reading or basic mathematics.

The intervention programs focused on using practice to develop knowledge and fluent skills in the core components of reading or basic mathematics. The practice activities were brief, varied and required performance in written and oral modes, with some recording of results. Over the course of the intervention students were engaged in focused practice for an estimated 20 hours.

Assessment and instruction formed a continuous cycle in the *QuickSmart* intervention approach. Teacher observations and information gained from questioning students about their strategy use were used as the basis for instructional decision-making and individualisation. Assessment information was also derived from many of the activities in the lessons such as flashcards, repeated reading and speed sheets. Most lessons concluded with an assessment on one sub-test of the CAAS, to provide the students and the instructor with formative information about accuracy and speed of recall of basic academic facts. Students aimed to increase their accuracy and decrease response times as a means of demonstrating increasing automaticity.

This close link between assessment and instruction enabled an important feature of the *QuickSmart* program – participant students experiencing success in every lesson. This required careful matching of instructional activities with the students' levels of attainment. Repeated practice on the same content (in a range of activities) provided the participant students with the opportunity for repetition of familiar content, needed in order to achieve mastery and success.

Another general feature of the program was that much of the assessment information obtained during *QuickSmart* lessons was both accessible and understandable to the participating students. Assessment information obtained from the CAAS was plotted onto individual graphs in order to provide students with a motivating visual representation of their progress. Students were able to monitor and evaluate their own learning through recording information, such as how many flashcards they read accurately or how many correct questions per minute they answered.

An important aspect in the implementation of the *QuickSmart* intervention programs was that the instructor was actively involved in the lessons by participating in the games, modelling strategies, performing 'think-alouds', selecting tasks at an appropriate level and readily prompting students, so they achieve success. Feedback from the teacher/researcher was directed toward a specific learning behaviour, rather than general, non-specific feedback.

As the intervention program began, each student received a work folder. The students were encouraged to personalise their folder in whatever way they wished, for example with drawings and stickers. The folder, divided into sections, contained information about the *QuickSmart* program that was relevant to the student. This included a timetable of lessons, lists of focus words or number facts, reading passages or mathematics worksheets, a 'Help' section for strategy cue cards, and an assessment and graphing section in which speed and accuracy rates, as well as flashcard scores and other relevant assessment data, were recorded. Students left these folders in the instructional setting so that they did not need to bring anything to *QuickSmart* lessons. A variety of pens, pencils, highlighters, and writing materials were provided for students.

Sets of flashcards were used for regular practice activities. Each different group of focus facts or focus words required at least sixty of flashcards. In mathematics lessons, students also used speed sheets prepared to practice the focus facts. As well, students completed carefully selected, relevant worksheets photocopied from copyright-free teacher resource publications.

For the reading lessons, two or three passages of connected text, containing most or all of the focus words, were used for each unit of work. Some of these passages were specifically written to incorporate all the words from the word list. At other times focus words were selected from appropriate reading passages about a particular topic. Also, in the reading lessons, appealing fiction and non-fiction books were available to the students. Simple games were also used as an activity in the lessons. For the mathematics lessons, focus facts were presented as sets of related number facts requiring both addition and subtraction or multiplication and division. Students progressed through sets of facts of increasing difficulty.

The intervention lessons in both reading and mathematics followed a structured sequence based around a ‘focus set’ of number facts or words. Teaching and learning strategies included explicit strategy instruction, modelling, discussion, questioning, and guided and independent practice. A mnemonic, **PATH**, was used to guide instruction during the intervention. **PATH** encapsulates the *QuickSmart* programs’ instructional focus on **P**ractice, **A**ttention to understanding, **T**ime, and **H**ow to (strategies). The way that this mnemonic was implemented into the teaching and learning procedures of the intervention lessons is illustrated in the following section.

Quicksmart Reading Intervention Procedures

The *QuickSmart* reading program focused on improving students’ automaticity of word recognition and fluency in reading connected texts. Instruction was organised into units of work taking approximately three-to-four weeks (i.e., 9-12 lessons). Each unit was centered on a set of approximately thirty focus words. The sets of words increased in difficulty, beginning with a set of high usage three and four letter words and progressing to more complex and demanding sets.

The sets of focus words were either high frequency common words, words linked to a curriculum learning area (e.g., English or Human Society and Its Environment), or key vocabulary related to a theme of interest to the students (e.g., natural disasters). The focus words were incorporated in passages of connected text relevant to the topic. These were used in the repeated reading activities. Figure 4.1 outlines the procedures of *QuickSmart* reading lessons.

QUICKSMART *READING LESSON PROCEDURES*

1. **Knowledge and Understanding Check** (5 minutes)
*Review focus words
*Students show developing understandings of the focus words

2. **Games** (5 minutes).
*Games including Word Memory, *QuickSmart* Bingo & Three in a Row

3. **Flashcards** (5 minutes)
*How many flashcards can be read in 1 Minute?
*Can students 'beat their own record'?
*Record results

4. **Repeated Reading - Passages** (5 minutes)
*Repeated reading practice activities
*Record number of correct words per minute or amount of text read, & accuracy

5. **Independent reading (5 minutes).**
*Independent reading of student selected, appropriate level texts
*Students can choose to time themselves using egg-timer or stop-watch

6. **Assessment (5 minutes).**
*One sub-test of the CAAS
*Student and tutor view CAAS results (table &/or graph)
*Discuss results and set some goals for next time

NOTE: Last two activities can occur simultaneously.

Figure 4.1 Procedures in *QuickSmart* reading lessons.

Incidental strategy instruction was a feature of most *QuickSmart* reading lessons. Decoding strategies modeled included breaking words into chunks (with particular attention to onset and rime where appropriate), sounding out phonemes, recognising orthographic patterns, particularly prefixes and suffixes, and combining letter sounds with what makes sense in the context.

Although the focus of the *QuickSmart* reading intervention was word reading and reading fluency, occasionally throughout the teaching phase of the intervention a lesson followed a different format which focused on comprehension, specifically teaching about and practice using the 3H comprehension question-answering strategy (Graham & Wong, 1993), which also incorporates elements of reciprocal teaching. An outline of this strategy is provided in Appendix C. The 3H strategy focuses on developing meta-cognitive skills for comprehension, couched in the simple language of a mnemonic-type strategy. Each pair of *QuickSmart* reading students participated in four or five such lessons during the eighteen or twenty weeks of the intervention. Throughout the intervention, word reading and reading fluency were the focus of the *QuickSmart* lessons but as these components of reading interact to support comprehension, it was thought important to acknowledge the importance of reading for meaning during the intervention.

Quicksmart **Mathematics Intervention Procedures**

QuickSmart mathematics lessons aimed to improve students' understanding and speedy recall of basic mathematics (addition, subtraction, multiplication and division facts). Instruction in the *QuickSmart* mathematics program was also delivered in units of work of three or four weeks' duration. In mathematics lessons the focus was on a specific set of mathematics facts. The focus facts were sets of around 30 related number facts ranging in difficulty from combinations of numbers that equal 10, to the 12 times tables.

The focus facts for each unit also contained, in the flashcards and speed-sheets, some related facts such as 3 + 7 = 10, 30 + 70 = 100 and 2 x 12 = 24, ½ x 24 = 12, to facilitate students' observations and understandings about relationships and reciprocity between numbers in the basic operations. The actual unit sequence for each student pair was matched to their individual learning needs. Most of the students began with an easy set of addition/subtraction facts. The same focus facts set was used in the lessons' games and activities and practiced using flashcards.

In the intervention lessons, incidental strategy instruction was delivered, focusing on mental computation strategies. The aim was to move students on from relying on slow and error prone strategies, especially count-by-one strategies, to using more sophisticated and efficient strategies, which foster automatic recall. The main strategies emphasised were counting on (or back) from the largest number, relating the sum to a known sum, skip counting, rounding up or down to enable adding or subtracting tens, and using knowledge of doubles.

QUICKSMART *MATHEMATICS LESSON PROCEDURES*
1. **Knowledge and Understanding Check** (5 minutes) *Preview focus number facts * Discussion to develop students' understanding of the focus facts **2. Games** (5 minutes). **Games including Three in a Row, Totally Dicey, Number Fact Memory* **3. Flashcards** (5 minutes) *How many flashcards can be calculated in 1 Minute? *Can students 'beat their own record'? *Record results **4. Speed Sheets** (5 minutes) *Timed practice of focus facts 'sums' with written responses *Revise responses, include some error analysis *Record time and accuracy **5. Independent Practice (5 minutes).** *Independent practice on relevant, appropriate level worksheets *Students can time themselves using egg-timer or stop-watch **6. Assessment (5 minutes).** *One sub-test of the CAAS *Student and tutor view CAAS results (table &/or graph) *Discuss results and set some goals for next time NOTE: Last two activities can occur simultaneously

Figure 4.2 Procedures in *QuickSmart* mathematics lessons.

In review, the procedures used to implement the *QuickSmart* intervention programs in both reading and mathematics followed a somewhat similar routine, based on the rationale that improved automaticity would be most likely to result from intensive practice of 'known' information, that is, familiar content practiced with high accuracy using a range of motivating activities. In keeping with the design of the research and to ensure that the research questions could be investigated, data were collected before and after the intervention and again twelve months later for remaining participants. Also, performance data for participant students was collected during the intervention to monitor the effectiveness of the intervention and to track individual progress. This was to inform the exploration of the theme.

Summary

The research described in this report required that the selected students, who experience persistent LD, participate in an intervention program that focuses on developing automaticity in basic academic skills. This approach, theoretically located within the information-processing perspective, was based on the common observation that lack of facility with 'the basics' not only impacted on the performance of students with LD in literacy and numeracy, but also had a harmful effect on participation and success in a wide range of curriculum-based learning activities.

Poor performance in basic academic skills, in effect, very often precludes students from making adequate progress, even if they possess good general knowledge and positive motivation. Although other areas have been identified as delayed or impaired in students with LD (e.g., executive functioning, motivation, self-efficacy, effective strategy use) this key component for successful learning, facility in basic academic skills, seemed an obvious choice as the focus for a school-based, educational intervention.

At the time when the research process for this study was being developed, the *QuickSmart* intervention approach had recently been designed. The appealing aspects of the *QuickSmart* intervention approach, in terms of this research study, were that it was theoretically consistent with the findings from the literature review, it utilised evidence-based strategies, it was applicable to both reading and mathematics, it was curriculum-relevant, and it could be readily implemented in contemporary school settings. Few, if any, Australian-developed intervention programs were considered comparable.

The *QuickSmart* intervention approach, delivered as the *QuickSmart* reading program or the *QuickSmart* mathematics program, used a range of fast-paced, motivational activities, delivered in a set sequence, to support students to develop improved automaticity in basic academic skills. It relied on explicit instruction, deliberate practice, formative assessment and task-focused feedback to build students' proficiency in accurately and efficiently 'knowing' basic academic skills. The CAAS was an integral component of the intervention approach.

The relatively long-term intervention aimed to provide the time and practice opportunities required to enable middle-school' students experiencing LD to acquire mastery of basic academic skills. The following chapter presents the results of the study to test whether

QuickSmart participant students improved automaticity in basic academic skills, the impact of any improvement on standardised test results, and whether gains in automaticity were maintained one year later.

Chapter 5

Results – Research Questions

This chapter reports the results of testing in relation to the research questions raised at the end of Chapter 2. Results for each of the three research questions are considered in turn. The chapter concludes with a summary discussion of the findings of the research questions.

Research Question 1

Repeated Measures Analysis of Variance (RM ANOVA) and descriptive data were used to address the first research question. Question 1 was concerned with changes in participant students' and comparison students' automaticity of basic academic skills, and asked:

> Will the participant students' automaticity in basic academic skills improve after taking part in the *QuickSmart* intervention, and will their automaticity in basic academic skills be closer to that of the comparison group at post-test?

Participant students were identified as students experiencing persistent learning difficulties who had taken part in a *QuickSmart* intervention program, and comparison students as average-achieving peers from the same class group who did not take part in a *QuickSmart* intervention program. Thus, this study required evaluation of participant students' and comparison students' response latency and accuracy on three CAAS reading or basic mathematics tests, before and after participation in the *QuickSmart* intervention.

The method selected for investigating the research question was a between (groups) – within (test or test occasion) RM ANOVA, and the test was carried out using the PASW-18 software package. Four separate RM ANOVA analyses were required, each focusing on a distinct dependent variable: reading response latency, reading accuracy, mathematics response latency and mathematics accuracy. Descriptive data were used to provide further information.

As the assumptions relevant to the four RM ANOVA analyses are the same, these assumptions are now considered briefly before the results are presented (rather than re-stating assumptions for each analysis). In addition to validity assumptions common to all statistical procedures, RM ANOVA assumptions include that: i) the distribution of response variables is normal; ii) the variances of the populations from which different samples are drawn are equal; and iii) the assumption that sphericity is not violated.

To check for normal distribution of the data, an examination of the skewness of raw pre-intervention data in each of the three CAAS reading tests and the three CAAS mathematics tests was undertaken. This indicated that the response latency measures for these data were positively skewed, while the CAAS reading accuracy data were negatively skewed. These violations of normality are not the result of a faulty research design, but are an inevitable by-product of analysing constrained data sets (see Paris, 2005). Thus, latency data are almost always positively skewed (Tabachnick & Fidell, 2007), and accuracy data, which may be normally distributed at the beginning of an intervention, become negatively skewed at the end of an (effective) intervention, as the scores start to approach 100%. Therefore, to approximate normal distribution, data transformations were applied (Tabachnick & Fidell, 2007).

Positively skewed raw response latency data, measured in seconds, were transformed using the formula [$\log_{10}(x + 1)$]. Negatively skewed raw accuracy data, expressed as a percentage, were first reflected to become positively skewed, using the formula ($101 - x$). These reflected data were then subjected to logarithmic transformation using the same formula as for latency data, [$\log_{10}(x + 1)$]. The log-transformed data were then reflected back (Tabachnick & Fidell, 2007) into their original scales, to allow for clarity in interpretation of results. The frequency distributions of the log-transformed accuracy data were then examined, and found to be generally within acceptable limits. In the results presented below, the directionality of the log-transformed data is consistent with that of the raw data, that is, improvement in response latency is indicated by a reduction in scores, while improvement in accuracy is indicated by an increase in scores.

In relation to the population variance assumption, it must be noted that the investigation design did not allow for random selection of participant and comparison students. However, an examination of the p value of Levene's tests indicated that the variances of the two populations were approximately equal for each of the tests conducted.

The final assumption for RM ANOVA considered here is that of sphericity. The sphericity assumption is often violated in practice but it can be effectively circumvented by analysing the

ANOVA test using multivariate ANOVA methods (Cooksey, 2007; Tabachnick & Fidell, 2007). The sphericity assumption in this case is that, in the population sampled, all the variances of the differences between means in pre-post measures across the three CAAS tests are equal. This is unlikely to be true. Inspection of the output for Mauchly's Test of Sphericity indicated that, in most tests the assumption had, in fact, been violated, and it was for this reason that the more conservative multivariate tests, which do not carry the sphericity assumption, were used to report a valid *F* ratio.

Results from the RM ANOVA and descriptive data relevant to research question 1 are reported below, firstly for the reading intervention and then the mathematics intervention. Within each account analyses are reported separately for response latency and accuracy.

Reading. A RM-ANOVA was conducted to compare the effects of Time (Time 1, pre-intervention and Time 2, post-intervention) and Group (participant students or comparison students) on response latency in three different CAAS reading tests – Elementary Word, Middle Word and Sentence. The same analysis was performed on accuracy data for the three CAAS tests. The between-group tests compare response latency and accuracy, averaged across Time. Results are reported in separate analyses for reading response latency and reading accuracy.

Reading response latency. Table 5.1 reports significant differences within groups. There were four significant effects for reading response latency, being Test, Test*Group, Time, and Time*Group, although not all of the significant effects are relevant to the research questions.

Table 5.1
Multivariate Tests for Log-Transformed Reading Response Latency

Effect: Wilks' Lambda	Value	*F*	Hypothesis df	Error df	Sig. ^	Partial Eta Squared
Test	.023	313.16	2.0	15.0	≤.001*	.98
Test*Group	.67	3.72	2.0	15.0	.049*	.33
Time	.32	33.23	1.0	16.0	≤.001*	.67
Time*Group	.49	16.36	1.0	16.0	.001*	.50
Test*Time	.71	3.04	2.0	15.0	.078	.29
Test*Time*Group	.844	1.39	2.0	15.0	.279	.15

^Significance, * Alpha level < .05

The significant main effect of Test indicated that one or more of the three mean CAAS test response latencies was significantly different, as such, indicating that there were differences between the results for each of the CAAS tests. This finding is not relevant to the research question. The significant main effect of Time shows a difference between response latency at pre test compared to post test, for the combined groups, and although this has some bearing on the research question it is not specific enough to be informative. Although there was a significant interaction for Test*Group, confirming significant differences between groups' response latency on the pre- and post-tests, this is not relevant to this research question, as it combines both pre- and post-test data as one factor. Similarly, the results regarding significant main effects of Test*Time (differences between tests) is not relevant to this research question because it combines the results for participant students and comparison students.

Of most relevance to the research question are results for the Time*Group interaction. This analysis detects whether there was a difference, from pre-test to post-test, between each of the groups, participant students and comparison students. Table 5.2 reports significant differences between groups, indicating that the performance change for participant students was not the same as that of comparison students.

Table 5.2
Test of Between-Group Effects for Log-Transformed Reading Response Latency

Source	**Sum of Squares**	**df**	**Mean Square**	***F***	**Sig^**	**Partial Eta Squared**
Group	.493	1	.493	8.67	.010*	.351

^Significance, * Alpha level < .05

Figure 5.1 displays the Time*Group interaction and clearly shows that participant students made gains in response latency scores. It is evident that the gains of participant students were greater than those of comparison students, and that the gap between participant students' and comparison students' response latency was much reduced after the intervention.

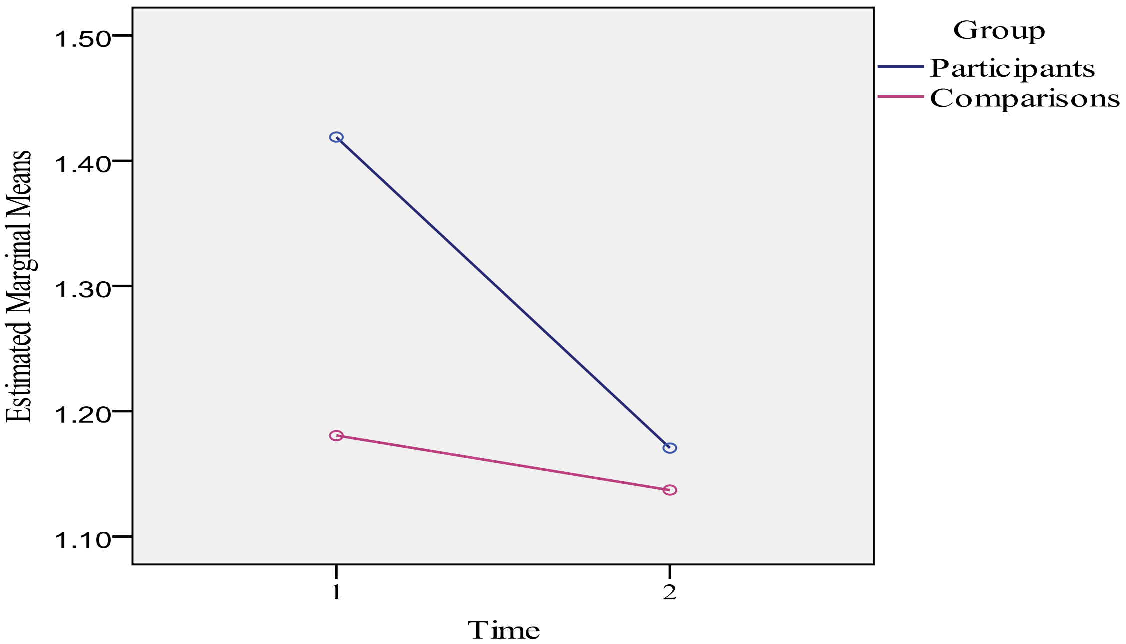

Figure 5.1 Graph of estimated marginal means for log-transformed reading response latency scores at pre-test (Time 1) and post-test (Time 2).

An examination of the means in Table 5.3 provides more specific information about the pre- and post-intervention accuracy scores of participant students, and comparison students, on each of the CAAS reading tests. These figures show that in each test the participants' mean response latency was reduced from pre-test to post-test, and that in each of the tests the difference in mean response latency between the participant group and the comparison group, evident at pre-test, was greatly reduced at post-test. Further, in each of the three CAAS tests participant students made greater gains than comparison students. Interestingly, the interaction was greatest in the most challenging test, Sentence, in which the comparison students showed a modest increase in response latency while participant students showed a dramatic decrease, such that, at post-test, participant students' response latency was faster than that of comparison students. Participant students (and comparison students) made the greatest gain in scores for Middle Word. Plots of estimated marginal means for log-transformed reading response latency, in each of the CAAS reading tests, are displayed in Appendix D.

Table 5.3

Log-Transformed Response Latency Means and Standard Deviation for Participant Students and Comparison Students on Three CAAS Reading Tests

Test per group	**Pre-Intervention Mean (*SD*)**	**Post-Intervention Mean *(SD)***	**Gain**	**% Gain**
Elementary Word Participants (*n* = 10)	1.07 (.14)	.89 (.04)	0.18	16.82
Elementary Word Comparisons (*n* = 8)	.92 (.08)	.88 (.06)	0.04	4.34
Middle Word Participants (*n* = 10)	1.47 (.20)	1.13 (.23)	0.34	23.12
Middle Word Comparisons (*n* = 8)	1.08 (.22)	.96 (.12)	0.12	11.11
Sentence Participants (*n* = 10)	1.71 (.16)	1.49 (.15)	0.22	12.86
Sentence Comparisons (*n* = 8)	1.54 (.11)	1.56 (.11)	-0.02	-1.29

The results reported to this point involve log-transformed data. By also considering raw data, a ‘real life’ context for examining changes in performance, as appropriate to mixed methods educational research, can be incorporated. Also, raw data, being actual response times and accuracy rates for each of the three tests, are particularly relevant to the individual student profiles presented in Chapter 6, and to later discussion of what the students’ performance changes potentially mean in terms of classroom learning and participation. To this end, tables of raw scores for individual participant students and comparison students, and group raw score means and standard deviations, are provided in Appendices E, F, and G. Inspection of these tables show that individual participant students consistently made gains in response latency from pre-test to post-test (i.e. reduced response latency). Individual comparison students were not as consistent in their response latency gains with their gains generally of lesser magnitude than those of participant students.

The key findings of the analyses presented above, in relation to reading response latency, are firstly, that, after participating in the *QuickSmart* reading intervention program, participant students made significant improvements on pre-test scores for response latency, as measured on three CAAS tests. Secondly, at post-test on each of the three tests, the response latency scores of the participant students, previously identified as students experiencing learning difficulties, were much closer to the scores of the average-achieving comparison students, than they were at pre-test. Next, results for the other important aspect of automaticity in reading, accuracy, are reported.

Reading accuracy. Table 5.4 reports significant differences between conditions for reading accuracy. Significant results were obtained for Test, indicating a difference between one or more of the test results, a finding not relevant to the research question. As expected, there was also a significant effect for Time, indicating that combined results for the groups at pre-test were different to those at post-test. As discussed in the previous section, some multivariate results of the RM ANOVA are either not relevant to the research question or not specific enough, so they are not examined. The results reported here will focus on results of between group conditions.

Table 5.4
Multivariate Tests for Reading Accuracy

Effect: Wilks' Lambda	**Value**	***F***	**Hypothesis df**	**Error df**	**Sig. ^**	**Partial Eta Squared**
Test	.21	28.11	2.0	15.0	≤.001*	.79
Test*Group	.82	1.64	2.0	15.0	.23	.18
Time	.54	13.77	1.0	16.0	.002*	.46
Time*Group	.91	1.51	1.0	16.0	.237	.09
Test*Time	.84	1.34	2.0	15.0	.29	.15
Test*Time*Group	.69	3.44	2.0	15.0	.059	.31

^Significance, *Alpha level < .05

Table 5.5 presents results for the between-group reading accuracy, indicating a marginally significant effect for Group.

Table 5.5
Test of Between-Group Effects for Log-Transformed Reading Accuracy

Source	**Sum of Squares**	**df**	**Mean Square**	***F***	**Sig^**	**Partial Eta Squared**
Group	2.98	1	2.98	4.087	.06	.203

^Significance Alpha level < .05

Figure 5.2 depicts estimated marginal means for Time*Group reading accuracy. It indicates that participant students' made greater gains in accuracy and that the gains of the participant students' were greater than those of the comparison students. This meant that the gap between participant students' and comparison students' accuracy was reduced after the intervention.

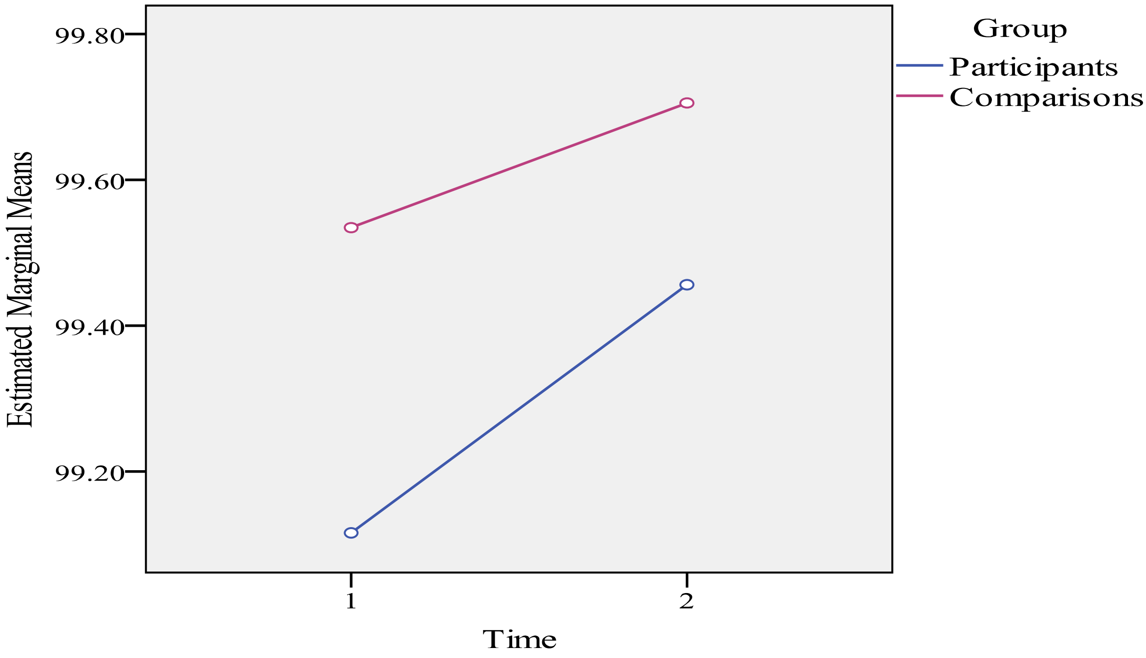

Figure 5.2 Graph of estimated marginal means for log-transformed reading accuracy scores at pre-test (Time 1) and post-test (Time 2).

Means and standard deviations for log-transformed pre- and post-intervention accuracy scores, for each group, in each test, are presented in Table 5.6. Inspection of these data indicate that participants made gains in accuracy on each of the three tests, and in the Middle Word and Sentence tests, participant students made greater gains than comparison students. The performance gap between participant students and comparison students, evident at pre-test, was much reduced at post-test in each of the tests. Participant students made considerable gains in accuracy in the Middle Word test. Comparison students made largest gains in accuracy on the Elementary Word test, with all comparison students achieving the maximum score at post-test. Plots of estimated marginal means for reading accuracy scores, for each group, in each of the three CAAS reading tests, are displayed in Appendix H.

Table 5.6

Log-Transformed Accuracy Means and Standard Deviations for Participants and Comparisons on Three CAAS Reading Tests

Test per group	**Pre-Intervention Mean (*SD*)**	**Post-Intervention Mean (*SD*)**	**Gain**	**% Gain**
Elementary Word Participants (*n* = 10)	99.56 (.42)	99.74 (.43)	.18	.18
Elementary Word Comparisons (*n* = 8)	99.65 (.28)	100.0 (0)	.35	.35
Middle Word Participants (*n* = 10)	98.39 (.32)	99.02 (.71)	.63	.64
Middle Word Comparisons (*n* = 8)	99.17 (.58)	99.34 (.58)	.17	.17
Sentence Participants (*n* = 10)	99.39 (.67)	99.61 (.51)	.22	.22
Sentence Comparisons (*n* = 8)	99.78 (.41)	99.77 (.42)	-.01	-.01

To provide additional detail useful for later interpretation of the above results, individual participant student's and comparison student's raw accuracy rate on the three CAAS tests, as well as group raw data means and standard deviations, are also displayed Appendices E, F, and G (referred to, above). Visual inspection of these data indicates some variability in accuracy gains for both individual participant students and individual comparison students.

The results for accuracy, particularly the log-transformed data, show very small margins for improvement. This is because accuracy rates were relatively high at start levels, especially in the easier CAAS tests. For example, in the Elementary Word test, comprised of simple words (Years 2 to 4 in difficulty level, with regular and irregular orthographic patterns), many of the participant students were able to recall or decode words at pre-test, even if the process of doing so was inefficient (slow and error-prone). At post-test participant students' accuracy rates were considerably improved (see the raw data in Appendices E, F & G) but visual inspection of the log-transformed data suggests only slight improvement. With regard to improved automaticity in basic academic skills, maintained or improved accuracy in the presence of considerably increased response latency is a desirable outcome, one which implies that previously ‘known’ information can now be recalled efficiently, that is, speedily with high accuracy.

The key findings of this investigation into participant students’ and comparison students’ accuracy in reading, as measured on three CAAS tests, are firstly, that participant students did make gains in accuracy, and secondly, that at post, test, the performance gap between participants and comparisons was much reduced. In the following section results for research question 1, in relation to changes in automaticity in mathematics, are reported.

Mathematics. Results regarding automaticity rates for participant students and comparison students involved in the *QuickSmart* mathematics intervention are now reported. Results are reported separately for response latency and accuracy. The analysis used for this investigation shares the same design as that reported above for reading. A RM-ANOVA was conducted to compare the effects of Time and Group on response latency across three different CAAS mathematics tests, Addition, Subtraction and Multiplication. This analysis was also applied to accuracy data for the same three CAAS tests.

Mathematics response latency. Table 5.7 reports significant differences between conditions. There were two significant effects. Firstly, there was a significant main effect for Time, as expected. This indicates that, for the combined groups, there was a performance change from pre-test to post-test. Secondly, there was a significant interaction effect for Time*Group. Results are reported below for this between groups interaction, as it is most relevant to the research question.

Table 5.7
Multivariate Tests for Mathematics Response Latency

Effect: Wilks’ Lambda	**Value**	***F***	**Hypothesis df**	**Error df**	**Significance^**	**ETA Squared**
Test	.85	1.5	2.0	17.0	.25	.15
Test*Group	.94	.57	2.0	17.0	.58	.06
Time	.23	60.55	1.0	18.0	≤.001*	.77
Time*Group	.59	12.46	1.0	18.0	.002*	.41
Test*Time	.81	2.03	2.0	17.0	.16	.19
Test*Time*Group	.77	2.47	2.0	17.0	.11	.23

^Significance, *Alpha level < .05

Table 5.8 reports significant differences between groups (participant students and comparison students, indicating that overall there is a statistically significant difference between these two groups' performance.

Table 5.8
Test of Between-Group Effects for Log-Transformed Mathematics Response Latency

Source	Sum of Squares	df	Mean Square	*F*	Sig^	Partial Eta Squared
Group	.596	1	.596	.4915	.040*	.215

^Significance, *Alpha level < .05

Figure 5.3 shows estimated marginal means for mathematics response latency. It depicts that participant students made greater gains in response latency than comparison students, and that the gap between participant students' and comparison students' response latency was much reduced after the *QuickSmart* mathematics intervention.

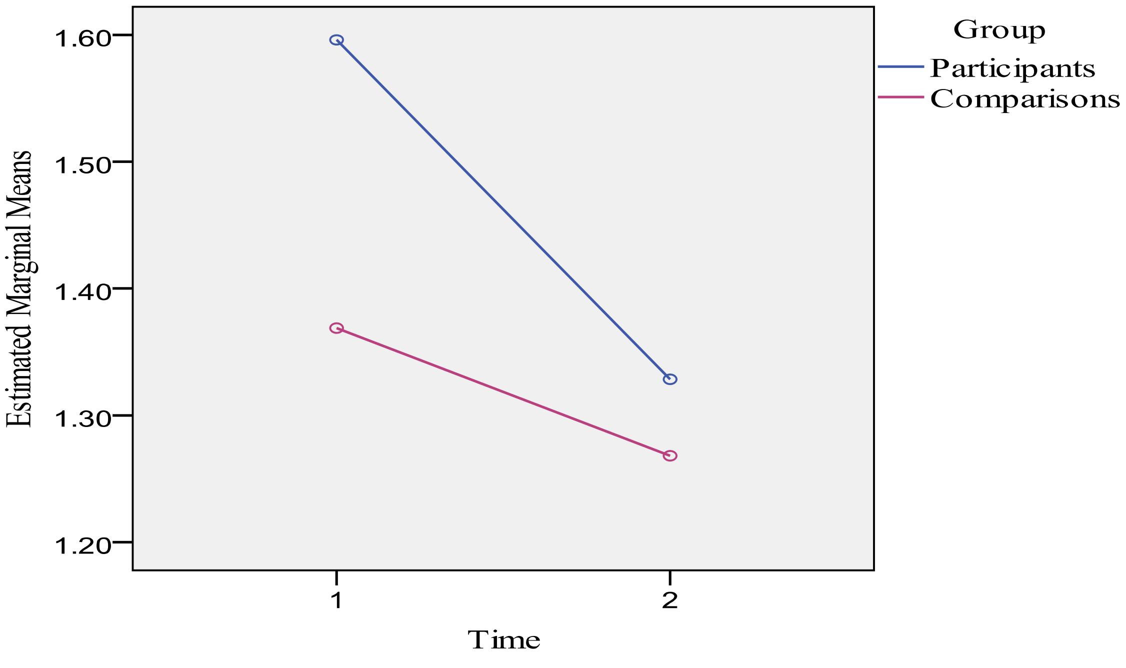

Figure 5.3 Estimated marginal means for log-transformed mathematics response latency scores at pre-test (Time 1) and post-test (Time 2).

Further detail is provided in Table 5.9 which presents means and standard deviations for pre- and post-test response latency in mathematics, for each of the two groups, and three CAAS tests. This information shows that participant students made gains in each of the three tests, participant students' gains were greater than those of comparison students, and in each of the tests the performance difference between groups was much reduced at post-test. Participant students made greatest gains in the Subtraction test. Plots of estimated marginal means for log-transformed mathematics response latency, in each of the CAAS mathematics tests, are displayed in Appendix I.

Table 5.9
Log-Transformed Response Latency Means and Standard Deviation for Participants and Comparisons on Three CAAS Mathematics Tests

Test per group	**Pre-Intervention Mean (*SD*)**	**Post-Intervention Mean (*SD*)**	**Gain**	**% Gain**
Addition Participants (*n* = 12)	1.56 (.15)	1.35 (.11)	0.20	12.82
Addition Comparisons (*n* = 8)	1.32 (.16)	1.23 (.15)	0.09	6.81
Subtraction Participants (*n* = 12)	1.61 (.24)	1.28 (.12)	0.33	20.49
Subtraction Comparisons (*n* = 8)	1.35 (.19)	1.27 (.15)	0.08	5.92
Multiplication Participants (*n* = 12)	1.61 (.22)	1.35 (.20)	0.27	16.77
Multiplication Comparisons (*n* = 8)	1.43 (.2)	1.30 (.17)	0.13	9.09

The results reported for this analysis, to this point, involve transformed data. To gauge the impact of performance changes on everyday learning tasks it is informative to consider raw data, that is, response latency in seconds. This information is particularly relevant to the individual student profiles presented in Chapter 6 and the discussion of results. For this reason, tables of raw scores for individual participants and comparisons, and group raw score means and standard deviations, are provided in Appendices J, K and L. Inspection of response latency data indicates that individual participant students consistently made gains in response latency from pre-test to post-test while comparison students were not as consistent in their response latency gains. The response latency gains made by participant students were more than double those made by comparison students.

With regard to mathematics response latency, the two key findings of this investigation are that, participant students made significant gains on each of three CAAS tests, and their performance on the tests after the intervention was much closer to that of the comparison students than it was prior to the intervention. Group changes in mathematics accuracy are considered next.

Mathematics accuracy. Significant differences between conditions for mathematics accuracy are reported in Table 5.10. There was a significant main effect for Test, showing that one or more of the three mean CAAS test accuracy scores is significantly different from the others. There was also a significant main effect for Time, indicating accuracy improved from pre-test to post-test for the combined group, a result not specific enough to address the research question. Results detailed below focus on between-group comparisons to address the research question.

Table 5.10
Multivariate Tests for Mathematics Accuracy

Effect: Wilks' Lambda	Value	*F*	Hypothesis df	Error df	Significance ^	ETA Squared
Test	.51	8.03	2.0	17.0	.004*	.49
Test*Group	.87	1.3	2.0	17.0	.3	.13
Time	.607	11.65	1.0	18.0	.003*	.39
Time*Group	.911	1.76	1.0	18.0	.202	.09
Test*Time	.84	4.56	2.0	17.0	.239	.15
Test*Time*Group	.97	.25	2.0	17.0	.778	.03

^Significance, *Alpha level < .05

The RM-ANOVA between-subjects test, specifically a comparison of differences between the groups' accuracy, indicated a statistically significant between-subjects effect for Group, as shown in Table 5.11.

Table 5.11
Test of Between-Group Effects for Log-Transformed Mathematics Accuracy

Source	Sum of Squares	df	Mean Square	*F*	Sig^	Partial Eta Squared
Group	4.49	1	4.49	6.03	.02*	.251

^Significance, *Alpha level < .05

Figure 5.4 displays the Time*Group interaction, and shows that participant students made gains in accuracy scores, that the gains of participant students were greater than those of comparison students, and that the gap between participant students' and comparison students' accuracy was much reduced after the intervention, even though this was not significant in the analysis.

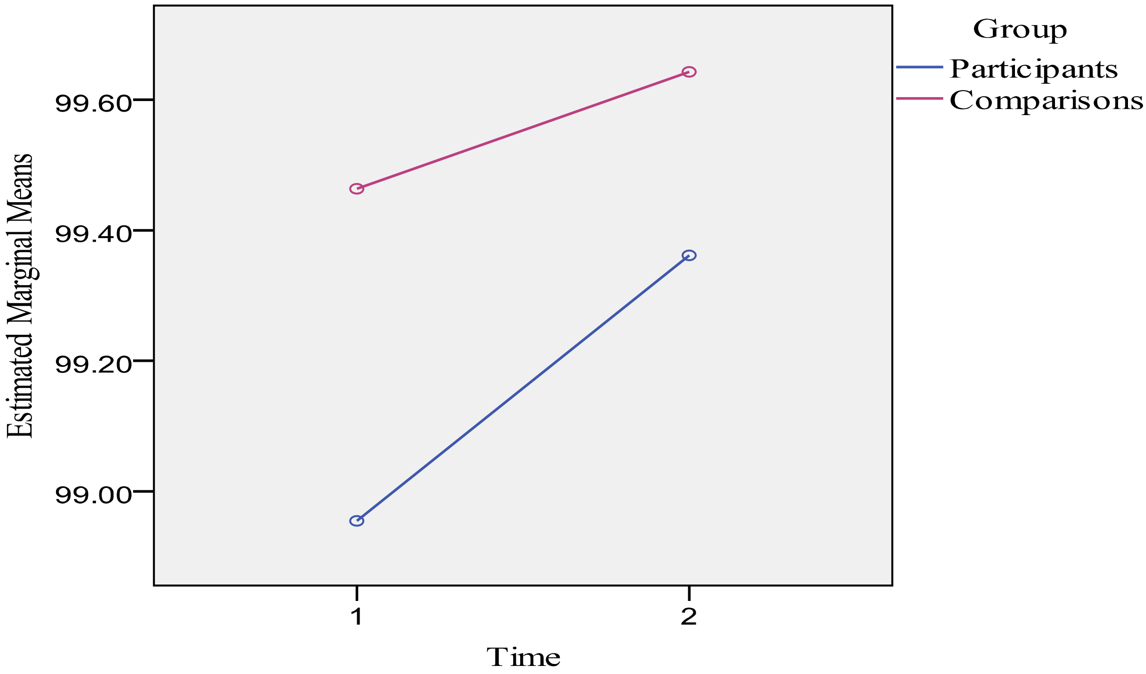

Figure 5.4 Estimated marginal means for log-transformed for mathematics accuracy scores at pre-test (Time 1) and post-test (Time 2).

Further relevant detail is displayed in Table 5.12 which shows means and standard deviations for mathematics accuracy, for each group, on each test. Visual inspection of these data show that participant students made gains in each of the three tests, their gains were of greater magnitude than those of comparison students in each of the tests, and the gap between participant students and comparison students, evident at pre-test, was much reduced at post-test on each of the tests. Participant students made the greatest gain in the Subtraction test. Plots of estimated marginal means for log-transformed mathematics accuracy, in each of the CAAS mathematics tests, are displayed in Appendix M. The accuracy gains in mathematics are smaller than the gains in response latency, for reasons similar to those explained, above, for reading. In the CAAS mathematics tests some knowledge of the items was required for testing to be successful. Accuracy gains in the log-transformed data appear to be minimal but inspection of the raw data (as provided in previously referred to Appendices J, K & L) showed that most participant students made considerable gains in accuracy, the result of more efficient access to stored knowledge.

Table 5.12
Log-Transformed Accuracy Means and Standard Deviation for Participants and Comparisons on Three CAAS Mathematics Tests

Test per group	**Pre-Intervention Mean (*SD*)**	**Post-Intervention Mean (*SD*)**	**Gain**	**% Gain**
Addition Participants (*n* = 12)	99.34 (.63)	99.48 (57)	.14	.14
Addition Comparisons (*n* = 8)	99.57 (.46)	99.63 (.51)	.06	.06
Subtraction Participants (*n* = 12)	98.96 (.56)	99.50 (.54)	.54	.55
Subtraction Comparisons (*n* = 8)	99.57 (.47)	99.77 (.42)	.2	.2
Multiplication Participants (*n* = 12)	98.56 (.35)	99.09 (.53)	.53	.54
Multiplication Comparisons (*n* = 8)	99.25 (.65)	99.51 (.54)	.26	.26

Tables showing raw accuracy rates for individual participants and comparisons, and group raw score means and standard deviations, are provided in Appendices J, K and L. These data show that participant students' accuracy rate gains in Addition were inconsistent but some of the individual accuracy gains in Subtraction and Multiplication, the more difficult tests, were impressive. The mean accuracy rate gains of participant students were more than double those made by comparison students in each of the three tests.

In response to the research question, the key findings of this investigation into mathematics accuracy are that the participants did make considerable gains from pre-test to post-test and that, at post-test, their performance was much closer to that of their average-achieving peers, the comparison group, than it was at pre-test. In the following section, the results of the four parts of the investigation into the research question 1 are reviewed.

Summary. The above reports of the RM-ANOVA results were presented consecutively for reading response latency, reading accuracy, mathematics response latency and mathematics accuracy. A brief summary of results for reading and mathematics is presented below, followed by a review of the results, considered together, in relation to the stated research question.

The results reported above demonstrate that participant students made gains in log-transformed scores for reading response latency after participating in the *QuickSmart* reading intervention and this was evident in each of the three CAAS tests. Although there was a difference between groups prior to the intervention, after the intervention this difference was much reduced, and in each test, gains made by participant students were greater than gains made by comparison students.

Results regarding changes to participant students' and comparison students' log-transformed reading accuracy scores indicate that participant students did improve accuracy rates after the intervention, and this was evident in each of the three CAAS tests. Also, reading accuracy rates for participant students and comparison students were similar after the intervention. In two of the three CAAS reading tests, the accuracy gains of participant students were greater than those of comparison students.

The accuracy scores in both reading and mathematics were constrained because they started at relatively high levels. This was particularly evident in the log-transformed scores which appear to indicate only minimal gains. Inspection of gains in raw accuracy scores provides a more informative context for gauging the effect of the intervention on accuracy. In both reading and mathematics, percentage gains were greater in response latency than in accuracy. This is because there was more room for improvement in response latency than accuracy, as students had encountered the content many times previously (basic words, sentences and numerical operations), such that they 'knew' some of the content but were inefficient (slow and error-prone) in retrieving this knowledge. After the *QuickSmart* interventions participant students increased their knowledge and were able to access it more efficiently.

Raw data for individual students who participated in the *QuickSmart* reading intervention showed that most individual participant students made gains in response latency and accuracy in at least two of the three CAAS Tests. These gains were generally larger and more consistent than those of the comparison students.

Results for tests of the mathematics intervention indicated a similar pattern to those for the reading intervention. In scores for log-transformed mathematics response latency, participant students made considerable gains from pre-test to post-test, and reduced the performance gap between their group and the comparison group. Improved performance was evident in each of the three CAAS mathematics tests, and participant students made greater gains than the comparison students in each of the tests.

The analysis of mathematics accuracy log-transformed scores also indicated that participants improved at post-test, that participant students' gain was greater than that of comparison students, and that after the intervention, between groups' differences in accuracy were much reduced. This was a consistent pattern in all three CAAS tests.

Individual results, using raw data, for students who participated in the *QuickSmart* mathematics intervention, indicated that most participant students made gains in two or three of the CAAS tests and that most often these gains were of greater magnitude than the individual gains of the comparison students.

In this study, automaticity in basic academic skills was conceptualised as response latency and accuracy in reading words and sentences, and response latency and accuracy in basic mathematics calculations. To address the research question positively, participant students in the *QuickSmart* reading intervention and the *QuickSmart* mathematics intervention were required to make gains in response latency and accuracy. Further, at the conclusion of the intervention, the response latency and accuracy of the participant group and the comparison group should be closer. Statistical and descriptive results reported above provide evidence that participant students in both the *QuickSmart* reading intervention and the *QuickSmart* mathematics intervention did make gains in automaticity (that is, both response latency and accuracy). The performance gaps between the groups were much reduced at post-test, such that the participants' and comparisons' scores were generally similar.

Accordingly, the results reported in response to research question 1 support the claim that, at least for these groups of students in the middle-school years who experienced persistent LD, participating in an appropriate intervention did result in improved proficiency in basic academic skills and narrowed the performance gap between them and their average-achieving peers. This is a hopeful finding, with potential to reverse the common experience that students with LD fall further behind in academic skills as they get older.

Improved automaticity in basic academic skills, as evidenced by the above results, is an important outcome for students in the middle-school years experiencing LD. However, the impact of such improvement is enhanced when it facilitates improved learning outcomes on measures of more generalised knowledge and skills. This aspect of the study is investigated in the following section.

Research Question 2

This question was concerned with pre- and post-intervention performance of participant students on standardised tests, as a measure of generalised reading or mathematical proficiency, and asked:

> Will there be a significant difference, from pre-test to post-test, in student achievement levels on standardised tests?

Participant students were assessed, at pre- and post-intervention, on standardised tests to evaluate whether improvements in word reading or basic mathematics skills, gained during the *QuickSmart* reading or *QuickSmart* mathematics intervention programs, impacted on performance in other domains relevant to curricula and classroom learning, such as reading comprehension or mathematics problem solving. Increased scores on standardised tests are a stringent way to measure improvement in the performance of students with LD (Simmerman & Swanson, 2001).

Results are reported below, firstly for the participants in the *QuickSmart* reading intervention, then for participants in the *QuickSmart* mathematics intervention. Comparison students were not included in this investigation. Results are then considered together in a summary.

Reading. Statistical investigation was carried out using paired sample *t*-tests on PAT-R Comprehension (ACER, 2001a) group scale score means, for nine of the ten *QuickSmart* reading participants (one student refused to attempt the test at pre-test as he thought it was ‘too hard'). Inspection of frequency distributions for the pre-intervention reading scale scores indicated that the data were normally distributed.

Paired sample *t*-test results indicated a statistically significant difference from pre-intervention (M = 35.98, *SD* = 8.05) to post-intervention (M = 42.13, *SD* = 6.94); $t(8) = 2.34$, $p = 0.048$. Accordingly, the participant students' group made statistically significant gains in performance on standardised comprehension tests.

To evaluate how much of a relationship existed between the pre-test and the post-test scores, effect size was calculated using scale score means and standard deviations. Results indicate an effect size where Cohen's $d = 0.82$, that is, the mean scale score in the post-test group is 0.82 standard deviations above the mean scale score in the pre-test group. This effect size is considered to be large (Cohen, 1988).

To provide greater context for the group results and to complement the individual student profiles presented in Chapter 6, participant's individual results, expressed in pre- and post-test percentile rankings, are presented in Figure 5.5. Inspection of these data shows that eight of the nine individual *QuickSmart* reading participants increased their percentile rank from pre-test to post-test. In contrast to all other participants, one student showed deteriorated performance. This student possibly experienced more severe learning difficulties than others in the participant group as her performance in both the standardised test measures, and the CAAS response latency data (see Appendices E, F and G) was uniformly low relative to the other participant students. Individual participants' raw scores, scale scores, and percentiles are presented in Appendix N.

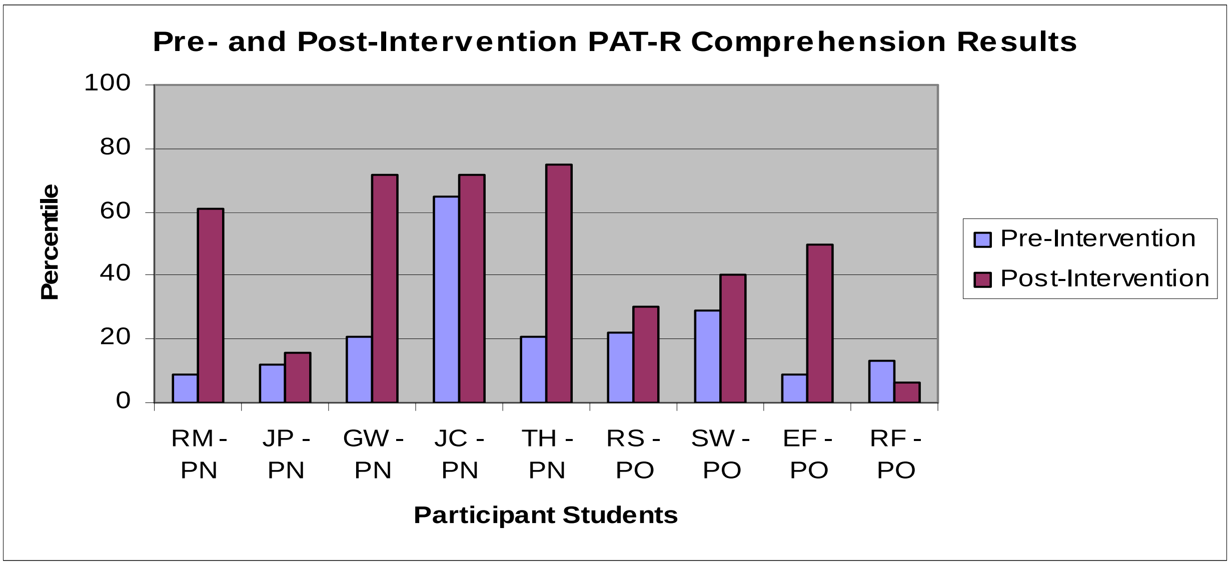

Figure 5.5 Graph of individual participant student's standardised reading comprehension test results.

The results for reading in relation to research question 2 suggest that, for this group of students who participated in the *QuickSmart* reading intervention, there were significant and substantial improvements in performance on the standardised comprehension test at post-test. This is an important finding as the intervention did not focus on reading comprehension. This finding suggests that, for this group of students, improved ability to read words and texts fluently after completing the *QuickSmart* reading intervention, positively impacted on students' comprehension performance on a standardised measure.

Mathematics. Participant students' performance in mathematics was measured on PAT Maths (ACER, 1997a). Analysis of results utilised paired sample *t*-tests to compare the pre- and post-test performance of the twelve participant students. The rationale for this was to evaluate whether the improvements in basic mathematics skills, particularly mental calculation, gained through participation in the *QuickSmart* mathematics intervention impacted on learning in other curriculum related domains of mathematics, as measured in the PAT Maths. Inspection of frequency distributions for the pre-intervention mathematics scale scores indicated that the data were normally distributed.

Paired sample *t*-test results indicated a statistically significant difference from pre-intervention ($M = 48.58$, $SD = 9.07$) to post-intervention ($M = 55.25$, $SD = 8.08$); $t(11) = 3.3894$, $p = 0.006$. Accordingly, the group made statistically significant gains in performance on the standardised mathematics test.

Effect size was calculated using scale score means and standard deviations for the pre- and post-tests. Results indicate an effect size where Cohen's $d = 0.78$, that is, the mean scale score in the post-test group is 0.78 standard deviations above the mean scale score in the pre-test group. This effect size is considered medium to large (Cohen, 1988).

To provide grater context for the group results and to complement the individual student profiles presented in Chapter 6, participant student's individual results, expressed in pre- and post-test percentile rankings, are presented in Figure 5.6. Visual inspection of these data shows that ten of the twelve participant students increased percentile rank from pre-test to post-test, one student maintained performance and one student's pre-test to post-test performance decreased. This was a surprising result for this student, who made quite satisfactory gains in response latency and accuracy (see previously cited, Appendices J, K, & L). Participants' raw scores, scale scores, and percentiles are presented in Appendix O.

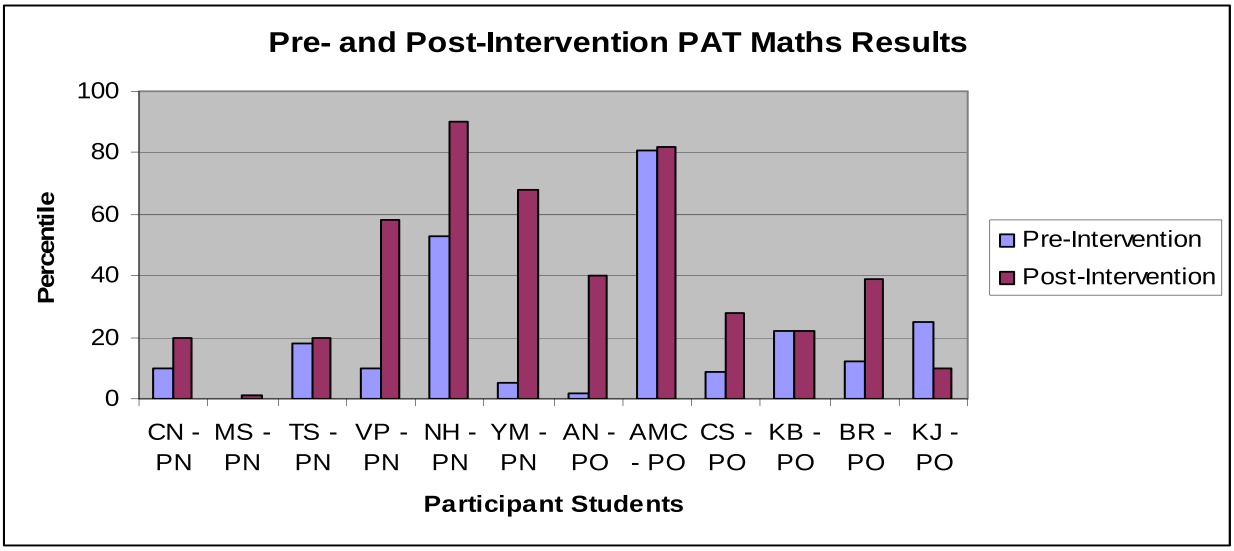

Figure 5.6 Graph of individual participant student's standardised mathematics test results.

These results for mathematics in relation to research question 2 suggest that the group of students who participated in the *QuickSmart* mathematics intervention, made significant and substantial improvements from pre-test to post-test in performance on the standardised mathematics test. This is also an important finding, as the test encompassed a wide range of mathematical knowledge and skills in contrast to the *QuickSmart* mathematics intervention which focused more narrowly on basic mathematics calculations and strategies. This finding suggests that for the participant students, improved ability to perform mental calculations of basic mathematics facts fluently and efficiently, after completion of the *QuickSmart* mathematics intervention positively impacted on standardised mathematics test performance.

Summary. The results of the investigation into standardised test performance of participants in both the *QuickSmart* reading and *QuickSmart* mathematics interventions showed statistically significant improvements from pre-test to post-test. Effect size calculations indicated that the magnitude of this performance change was large (reading) and medium to large (mathematics). Taken together, the results presented above clearly indicate that there were substantial, positive differences in student achievement levels on standardised tests from pre- to post-test. Descriptive results were also convergent with this finding and indicated that most individual participants made large gains in test performance. In response to the second research question the evidence reported supports the statement that participant students showed significant improvement in standardised test performance after participating in the *QuickSmart* interventions.

Although improved performance on standardised tests is important in a research context, it is also informative to consider what these results mean in the context of classroom teaching and learning. As the focus of the intervention was on basic academic skills, and the standardised tests evaluated a wider range of skills and knowledge, it is feasible to propose that improved facility in basic academic skills enabled improved participation in classroom literacy and numeracy lessons, and that this improved participation in classroom learning, in turn, contributed to improved standardised test performance. Accordingly, for students in the middle-school years experiencing LD, an appropriate intervention focused on basic academic skills seems to have great potential, as it supports their improved participation in classroom learning and their improved test scores.

The results to this point have reported information about changes in performance from pre-intervention, to post-intervention, over a time period of 22 weeks, across three school terms**.** Whilst results indicate that performance gains were made, the value of such gains is enhanced when they are sustained over an extended period of time. The results reported below investigate whether improvements in participant students' automaticity in basic academic skills were maintained twelve months after the intervention.

Research Question 3

Research question 3 focused on participant students' maintenance of automaticity in reading or mathematics after the *QuickSmart* interventions concluded, and asked:

> Will participant students show maintenance of post-intervention automaticity rates when tested again one year later?

Post-intervention maintenance of gains made during an intervention is essential to demonstrate the efficacy of the intervention and the robustness of changes in learner performance. In this investigation the participants are a sub-group of the original *QuickSmart* intervention cohort, who were still attending the same school one year later, and were available for re-testing on CAAS. The design for this study required that assessments on three CAAS tests be administered to participants in the *QuickSmart* interventions one year after the interventions concluded. These individual CAAS assessments took place at the students' schools in December of the year following the intervention year. Comparison students were not included in this investigation.

Consistent with the elementary data analysis for question 1, the data set for this investigation also showed that raw data were skewed and required transformation. To approximate normal distribution, data transformations were applied (Tabachnick & Fidell, 2007). Positively skewed raw response latency data, measured in seconds, were transformed using the formula $[\log_{10}(x + 1)]$. Negatively skewed raw accuracy data, expressed as a percentage, were first reflected to become positively skewed, using the formula $(101 - x)$. These reflected data were then subjected to logarithmic transformation using the same formula as for latency data, $[\log_{10}(x + 1)]$. The log-transformed data were then reflected back (Tabachnick & Fidell, 2007) into their original scales, to allow for clarity in interpretation of results. That is, the directionality of the log-transformed data was made consistent with that of the raw data (i.e., improvement in response latency is indicated by a decrease in scores, improvement in accuracy is indicated by an increase in scores). The frequency distributions of the log-transformed data were then examined, and found to be generally within acceptable limits.

Paired sample *t*-tests and the inspection of means were used to investigate this question, specifically to examine differences between post-intervention means and follow-up (one year later) means. Adequate maintenance of gains made in the intervention is indicated if the means are the same, or show improvement, from post-test to follow-up test. Results are reported firstly for the reading intervention group, and then for the mathematics intervention group.

Reading. Seven of the original ten *QuickSmart* reading participants were available for follow-up testing on three CAAS reading tests one year after the intervention concluded. Results are considered first for reading response latency and then for reading accuracy.

Response latency. Figure 5.7 shows log-transformed means for response latency, averaged across the three CAAS reading tests, and indicates that response latency was improved (i.e., reduced) at follow-up testing.

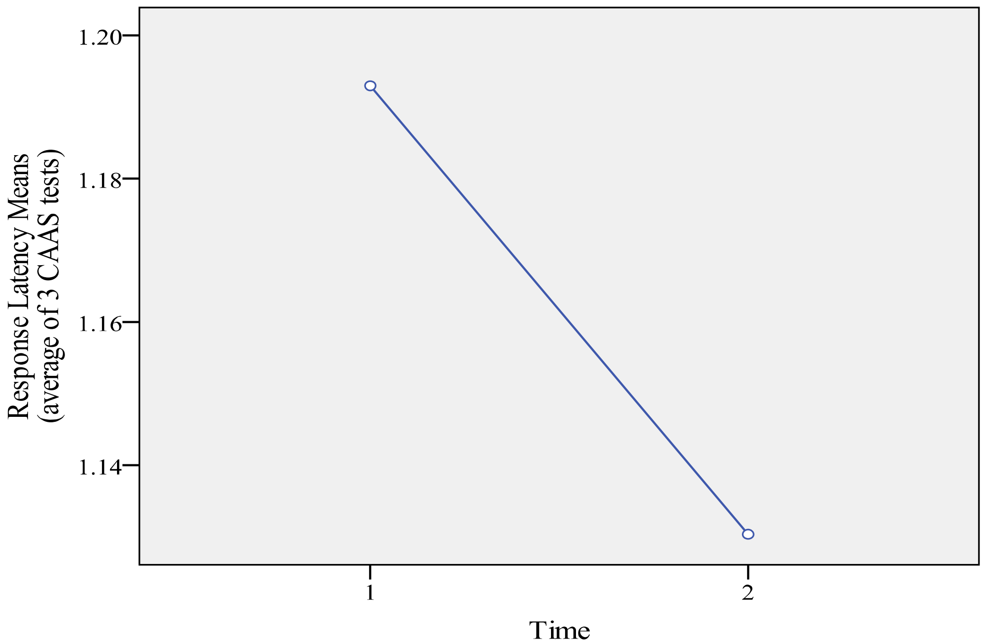

Figure 5.7 Average, log-transformed response latency mean of three CAAS reading tests at post-test (Time 1) and follow-up (Time 2).

Post-intervention and follow-up means, and tests of significance, for the participant group (n = 7) in each of the tests, are displayed below, in Table 5.13. This information demonstrates that mean response latency measures at post-intervention were maintained at follow-up in each of the tests. In the Elementary Word test and the Middle Word test response latency was slightly reduced, showing no significant difference from post-test to follow-up. In the Sentence test there was also a reduction in response latency score from post-test to follow-up test, resulting in a significant difference.

Table 5.13

Log-Transformed Response Latency Means, Standard Deviations and Significance Testing Results for Three CAAS Reading Tests

Test	Post-test Mean (*SD*)	Follow-up Mean (*SD*)	Paired Sample *t*-test^
Elementary Word Participants (n = 7)	.89 (.03)	.87 (.07)	$t(6) = 1.0$, $p = .35$
Middle Word Participants (n = 7)	1.21 (.23)	1.12 (.18)	$t(6) = .967$, $p = .37$
Sentence Participants (n = 7)	1.48 (.18)	1.4 (.16)	$t(6) = 3.9$, $p = .008$*

^Significance, *Alpha level < .05

To provide further detail, particularly relevant to individual student profiles presented in Chapter 6, participant's student's individual raw score changes from pre-test, to post-test, to follow-up test are displayed in Appendix P. Inspection of these data indicate that, at follow-up, most students' response latency scores were still better than their pre-test scores. When comparing post-test to follow-up test scores most of the individual students maintained or improved response latency on each of the three CAAS reading tests.

The results reported above regarding maintenance of response latency gains in reading indicate that the majority of participants in the *QuickSmart* reading program maintained post-intervention response latency rates when tested again one year later.

Accuracy. Figure 5.8 shows log-transformed means for reading accuracy, averaged across the three CAAS reading tests, and indicates that accuracy was improved (i.e., increased) at follow-up testing.

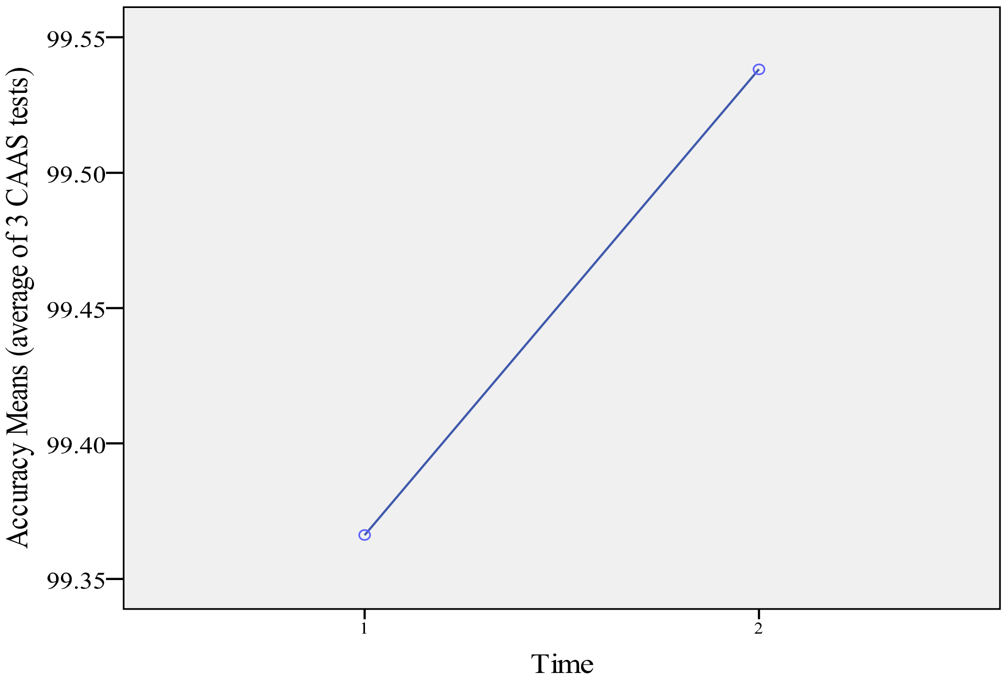

Figure 5.8 Average, log-transformed accuracy means of three CAAS reading tests at post-test (Time 1) and follow-up (Time 2).

Post-intervention and follow-up means, and tests of significance, for the participants (n = 7) in each of the tests, are displayed below, in Table 5.14. These data indicate no significant differences in means from post-test to follow-up, demonstrating that accuracy rates were maintained. In each of the tests accuracy scores were slightly improved.

Table 5.14
Log-Transformed Accuracy Means, Standard Deviations and Significance Testing Results for Three CAAS Reading Tests

Test	Post-test Mean (*SD*)	Follow-up Mean (*SD*)	Paired Sample *t*-test^
Elementary Word Participants (n = 7)	99.77 (.39)	99.92 (.21)	t(6) = 1.29, p = .24
Middle Word Participants (n = 7)	98.88 (.51)	99.16 (.65)	t(6) = 2.02, p = .09
Sentence Participants (n = 7)	99.44 (.53)	99.54 (.64)	t(6) = .36, p = .727

^Alpha level < .05

Individual participant's accuracy raw score changes from pre-test, to post-test, to follow-up test are displayed in Appendix Q. These data show that most students, at follow-up testing, were still achieving better accuracy scores than at pre-test, and that the majority made further progress from post-test to follow-up test. As explained earlier in this chapter, log-transformed accuracy data do not adequately depict the gains made, due to the constrained nature of the data (relatively high pre-test scores with a ceiling of 100% at post-test), and more informative context for changes in accuracy data is gained when raw data is inspected.

The investigation into maintenance of reading accuracy one year after the intervention concluded, showed that the group's reading accuracy improvements, gained during the *QuickSmart* reading intervention, were maintained.

The key finding of the research regarding reading automaticity and maintenance of gains is that participants in the *QuickSmart* reading program did maintain the gains in response latency and accuracy one year after the intervention concluded. An investigation into maintenance of automaticity for participants in the *QuickSmart* mathematics program is reported next.

Mathematics. Ten of the original twelve *QuickSmart* mathematics participants were available for follow-up testing on three CAAS mathematics tests one year after the intervention concluded. Results are considered first for response latency and then for accuracy.

Response latency. Figure 5.9 shows log-transformed means for response latency, being the average score of the three CAAS mathematics tests, at post-test and follow-up test. There was an increase in response latency but the small graduations of the score scale suggest this increase was slight.

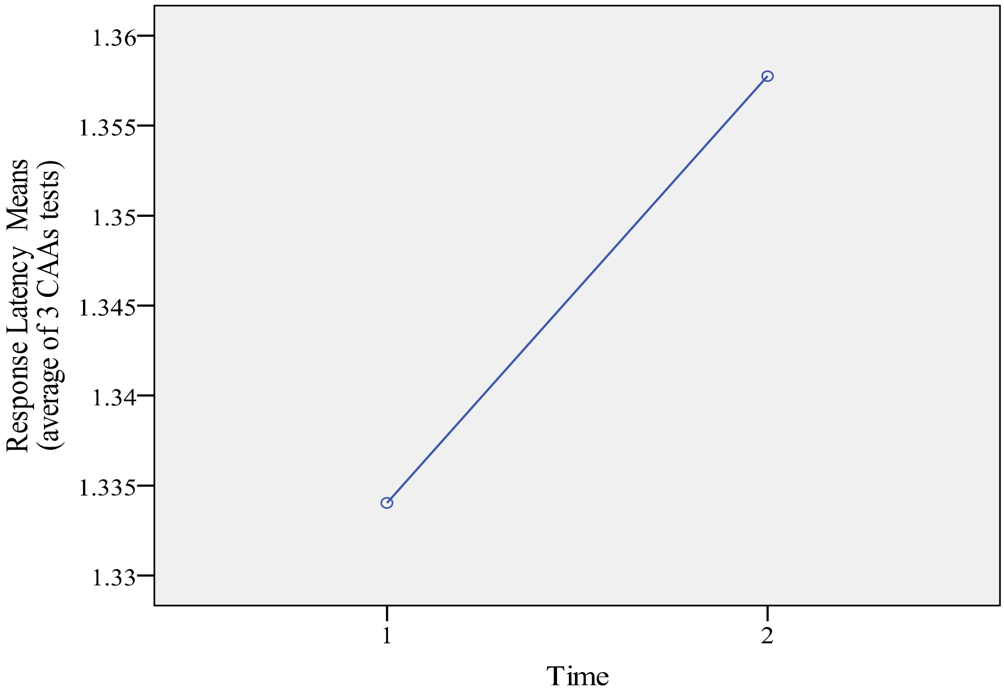

Figure 5.9 Average, log-transformed response latency means of three CAAS mathematics tests at post-test (Time 1) and follow-up (Time 2).

Post-test and follow-up means, standard deviations and tests of significance for the students who participated in the *QuickSmart* mathematics intervention are displayed below, in Table 5.15. This information demonstrates that increases in response latency from post-test to follow-up were marginal and non-significant.

Table 5.15
Log-Transformed Response Latency Means, Standard Deviations and Significance Testing Results for Three CAAS Mathematics Tests

Test	**Post-test Mean (*SD*)**	**Follow-up Mean (*SD*)**	**Paired Sample *t*-test^**
Addition Participants (*n* = 10)	1.37 (.12)	1.37 (.16)	$t(9) = .09, p = .9$
Subtraction Participants (*n* = 10)	1.29 (.13)	1.33 (.14)	$t(9) = 1.12, p = .29$
Division Participants (*n* = 10)	1.35 (.21)	1.37 (.15)	$t(9) = .45, p = .66$

^Alpha level < .05

Individual student's raw score changes from pre-test, to post-test to follow-up are displayed in Appendix Q. These data, more informative than the log-transformed data in terms of the actual gains made, show that in each of the tests, the great majority of the participants' follow-up test scores were considerably improved on their pre-test scores and similar to, or improved from their post-test scores.

Accuracy. Figure 5.10 shows log-transformed means for mathematics accuracy, averaged across the three CAAS mathematics tests. Accuracy was improved from post-test to follow-up test.

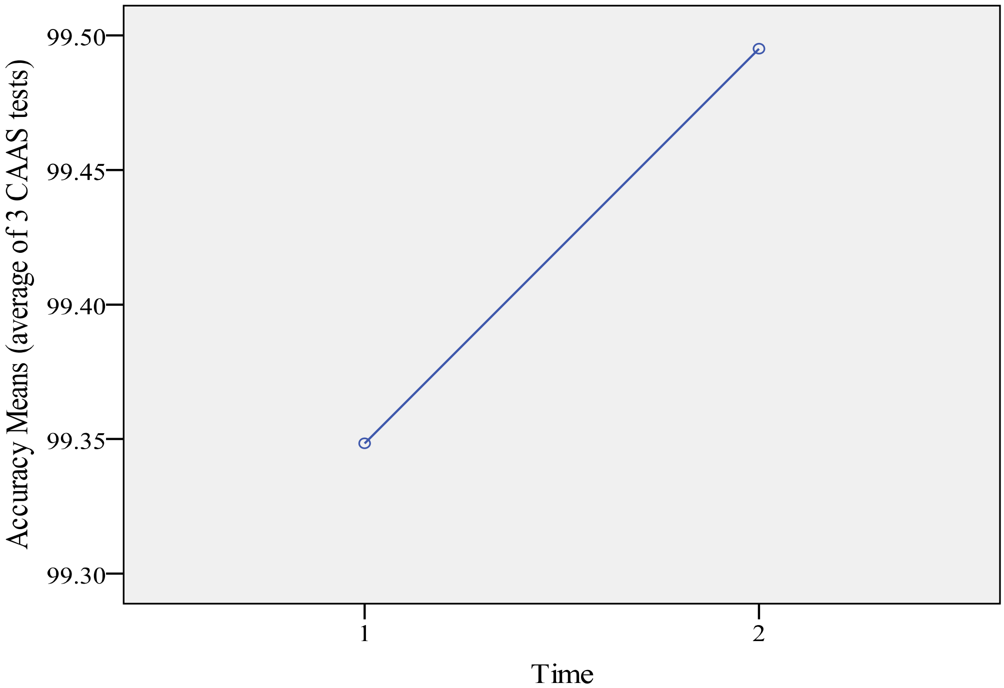

Figure 5.10 Average, log-transformed accuracy means of three CAAS mathematics tests at post-test (Time 1) and follow-up (Time 2).

Post-test and follow-up means, standard deviations and tests of significance of difference between these scores, are displayed below, in Table 5.16. In each of the tests there was an increase in accuracy and the follow-up test scores were not significantly different from the post-test scores, indicating students did maintain accuracy gains.

Table 5.16

Log-Transformed Accuracy Means, Standard Deviations and Significance Testing Results for Three CAAS Mathematics Tests

Test	**Post-test Mean (*SD*)**	**Follow-up Mean (*SD*)**	**Paired Sample *t*-test^**
Addition Participants (n = 10)	99.38 (.57)	99.62 (.49)	$t(9) = 1.15$, $p = .28$
Subtraction Participants (n = 10)	99.57 (.59)	99.58 (.57)	$t(9) = .057$, $p = .95$
Division Participants (n = 10)	99.09 (.58)	99.28 (.55)	$t(9) = 1.40$, $p = .194$

^Alpha level < .05

Individual participant students' accuracy raw score changes from pre-test to post-test to follow-up test are displayed in Appendix XVI. The majority of students demonstrated maintained or improved accuracy in each of the tests.

The investigation into mathematics accuracy one year after the intervention concluded indicated that the group's mathematics accuracy improvements gained during the *QuickSmart* intervention, were maintained. Results regarding mathematics automaticity and maintenance of gains clearly indicate that participants in the *QuickSmart* mathematics program did maintain gains in response latency and accuracy one year after the intervention concluded.

Summary. The results of the investigation, using log-transformed data, into maintenance of gains made during the *QuickSmart* programs one year after the intervention concluded that the participants' groups, in both the reading and mathematics interventions, did maintain, or improve both response latency and accuracy when re-tested. This was established by inspection of means from post-test to follow-up test and significance testing of the difference between these means. Tables of raw data, showing the progress of participants from pre-test to post-test to follow-up test were also convergent with this finding, and showed that this pattern of maintenance was consistent for the great majority of individual participants, on each of the CAAS tests. In response to the third research question the evidence presented supports the statement that participant students showed maintenance of post-intervention automaticity rates when tested again one year later.

For these students, who have experienced persistent LD, the findings potentially mean that rather than falling further behind their average-achieving peers as they progress through school, improved facility with basic academic skills, achieved through participation in the *QuickSmart* programs, has resulted in a sustained change in performance. In turn, this improved performance has the potential to increase students' engagement with, and participation in, the full range of learning experiences that schooling in the middle-school has to offer.

This finding is also consistent with the characterisation of automaticity, suggested in Chapter 2, specifically, that automatic processes are mandatory or unstoppable (Bloom, 1986; Shiffrin & Schneider, 1977). That is, when information is well-known enough that it is automatically processed, it cannot be suppressed. Accordingly, when a learner who has mastery of basic academic skills sees a known word, or basic mathematics calculation, they cannot help but read or calculate it with minimal cognitive effort expended in this process. The adage about riding a bicycle that "once you learn you never forget" is very relevant. As long as intermittent rehearsal occurs, knowledge or skills that are automatically processed are, generally, not forgotten.

Summary Discussion

This section reviews and discusses the results reported in this chapter and considers the inter-relationships among these results. At this point it is timely to consider the comments made in the Data Analysis Plan with regard to caution in interpretation of these results, as some of the underlying assumptions were not fully met due to limitations in sample size and cohort selection, as well as the constrained nature of the data.

The first research question investigated changes in proficiency in basic academic skills for groups of middle-school students who experience persistent LD and groups of their average-achieving peers. The results showed that, after taking part in the *QuickSmart* reading or mathematics programs, the participant students demonstrated consistent progress. RM ANOVA and examination of pre-test to post-test means, using log-transformed data, provided statistical support for this assertion. Benefits for individual students were more directly illustrated by the raw data, of response speed values and accuracy rates, included as appendices. These raw data show that, for example, in the Middle Word and Subtraction tests, many participants more than halved their response times and considerably improved their accuracy rates.

Whilst these improvements are notable, the results are more worthy when considered together with results for the comparison (non-intervention) group which, as expected, did not show such rapid performance growth. At the end of the intervention the automaticity rates of the two groups were much closer than they had been prior to the intervention.

The second research question investigated whether the participants in the intervention programs made gains on standardised tests, from pre-test to post-test. Significance testing and reporting of effect-sizes indicated that, at post-test, the participant group in both the reading intervention and the mathematics intervention had made significant test score gains of considerable magnitude. This is an interesting finding as the interventions focused quite narrowly on basic academic skills of reading and calculating while the tests evaluated a wider-range of knowledge and skills including academic work which requires higher-order skills, such as inferring answers and problem-solving.

The third research question investigated whether the participant students maintained gains in automaticity one year after the intervention. A comparison of log-transformed means indicated that, at follow-up testing, in both the reading intervention and the mathematics intervention, there was no deterioration in groups' response latency or accuracy. Gains made during the *QuickSmart* intervention programs were, in effect, maintained one year later.

One means of evaluation the impact of the results presented above is to consider them in terms of implications for the participants' performance and engagement in the contexts of classroom learning and everyday living experiences. In the middle-school years reading fluently and accurately is a pre-requisite skill for a considerable range of content area learning activities, not just English. Most average-achieving students in the middle-school years would comfortably read 150-200, or more, words per minute but many students experiencing LD in reading would struggle to read at half this rate, placing them at a considerable disadvantage in terms of accessing the curricula. In a classroom context, being able to read more quickly and accurately after participating in the *QuickSmart* reading intervention potentially enables the participants to read more text, to spend more time using and interpreting the information, and to better keep pace with the flow of everyday lessons in a range of content area lessons. In everyday living situations the many advantages of improved automaticity in reading potentially enables greater independence and more informed community participation. As electronic media becomes increasingly important for young people in both the social and educational realms, increased automaticity in reading is likely to benefit participants in their access to, and use of electronic information, as well as increasing opportunities for social interaction using electronic media.

Improved automaticity in basic mathematics skills is also likely to benefit students in a number of ways. In a classroom context, a reduction of over two seconds for a simple one digit multiplication computation can have compounding, positive effects. For example, a multiplication algorithm requiring a four digit number multiplied by a two digit number generally necessitates eight simple computations plus procedural work, a daunting and effortful task for a student with LD who does not have automatic knowledge of basic mathematics facts, especially when a set of twenty such algorithms have been set for class work. Automaticity in basic mathematics calculations not only makes simple tasks easier, it also enables participation in more complex tasks as both cognitive capacity and time are available to the student as the result of efficient, automatic processing of basic information. Living skills benefits of increased automaticity in basic mathematics are available in such activities as checking that correct change is given when shopping, understanding and calculating scores in games and sport, and in the many situations where estimating skills are required.

When considered together the results suggest that students in the middle-school years, who experience persistent LD, can, with appropriate intervention, make significant and sustained gains in automaticity in basic academic skills. Further, these gains have a facilitating effect on performance in standardised tests, which not only evaluate basic academic skills, but also include higher-order tasks such as problem solving and comprehension. Access to, and participation in, the full range of classroom teaching and learning activities is also potentially enhanced by improved facility with ‘the basics’. Accordingly, the results of this research suggest that an intervention focus on improving automaticity in basic academic skills is an effective approach for improving the learning outcomes of middle-school ’ students experiencing persistent LD.

The data reported above, in particular the figures showing individual participants’ progress suggest that there may be some interesting and informative narratives behind some of the results. For example, *QuickSmart* reading participant EF – PO was consistently one of the slowest students in the group on measures taken before the intervention, yet she displayed very positive gains in performance on the standardised tests. What factors enabled such improvement? Was her improvement gradual or dramatic? What were her thoughts about participating in the intervention? Similarly, *QuickSmart* mathematics student VP – PN performed very poorly in pre-tests but after participating in the intervention her standardised test raw score was relatively high. Further, a marked change is her confidence to undertake mathematics tasks was noted. A description of this student, her learning growth and development throughout the intervention, and her opinions about the intervention, would be informative for developing clearer understandings about the phenomena of learning difficulties and effective remedial interventions. This challenge is taken up in the following chapter, Chapter 6, which presents detailed profiles of six selected participant students.

Chapter 6

Participant Student Profiles

The research reported in this thesis, up to this point, has relied on quantitative methods to investigate the research questions. However, the mixed methods research design used in the study required that these findings be complemented by a qualitative component, presented here as a theme. The theme sought to explore the learning experiences of individual participant students, and their growth and development in learning throughout the intervention. The rationale for such an approach, driven by the pragmatic orientation of the research, was that by identifying other components that contribute, something can potentially be added to the foundation findings, increasing the scope and comprehensiveness of the study (Morse, 2003). The information presented in this chapter is intended to complement the group results reported in Chapter 5. The findings from this chapter, together with the results from Chapter 5, are considered together in Chapter 7, the final discussion chapter.

Three questions were developed to guide the exploration of the research theme, namely:

a) What learner characteristics did the participants display, particularly in terms of behaviours that might inhibit successful learning?

b) For each participant, what was their pattern of progress and how long was needed to show consistent improvement?

c) What were the participants' opinions about taking part in the intervention?

The first question addressed the characteristics of each participant student as a learner. The second question appraised of each participant student's rate of progress and the duration needed to show consistent improvement. The third question analysed each participant's opinions about the intervention.

The research theme is explored through the presentation and analysis of profiles of six students who participated in the *QuickSmart* intervention programs. The profiles are descriptions of the participant students, focusing on learning behaviours they demonstrated, and utilising data collected during the intervention period.

This chapter has four sections. Firstly, information about participant selection and the organisation of the profiles is presented. Following this, in two sections, are, three profiles of *QuickSmart* reading program students and, three profiles of *QuickSmart* mathematics students. Finally, an analysis of the profiles, when they are considered together and in relation to the theme's exploratory questions, is provided.

Participant Selection and Organisation of the Profiles

This section contains information about the selection of six students represented in profiles. The profiles were designed to follow a consistent structure and this is approach is described. And an overview of the data used to develop the profiles is also provided.

The six students profiled in this chapter were selected from the group of students who were available for pre-, post- and follow-up-test measures of automaticity in basic academic skills (CAAS assessments). Consistent with qualitative research data collection procedures, participant students for the profiles were selected purposefully (Creswell, 2003), to help understand the phenomenon of learning difficulties as experienced by students in the middle-school years. Thus, the selection of six students for profiling from the available group of seventeen was not random but purposive, based on the researcher's need to describe students that best illustrate the research inquiry. This is referred to as typical case sampling (Kemper, Stringfield, & Teddlie, 2003). Attempts were made to include in the six profiles students with varying competence levels (as demonstrated in pre-intervention assessments), students of both genders and year groups, indigenous and non-indigenous students, and participant students from each of the two intervention programs.

The profiles presented follow a pre-specified structure. Each profile begins with personal and background information about the participant, including their age at the end of the intervention (the delayed start of the intervention for the Year 7 students meant that ages at the start of the intervention were not chronologically consistent). A description of the student and their learning behaviours then follows. This description draws on information from the researcher's classroom and intervention observations, information from class teachers, and at times includes anecdotes about the participant's approaches to learning, recorded during the intervention. Some analysis of the participant's assessment results are then provided, supplemented by graphs which show the participant students' progress throughout the intervention on three CAAS sub-tests. Participant students' responses to questions in an exit survey are then reported, and the profiles conclude with a brief commentary on gains made during the intervention.

Thus, the data utilised to develop the profiles consisted of demographic and background information collected for each participant, notes from observations of the students in their classrooms and from conversations with teachers, as well as some anecdotes recorded as field notes. PAT data are referred to and CAAS data collected at intervention beginning, end and follow-up are also utilised.

Additionally, CAAS data collected from participant students' performance on one sub-test at the end of most *QuickSmart* lessons was also used, and are displayed in graphs. Younger and less-able reading intervention participants *were tested* mostly on the CAAS Elementary Word test as it was most appropriate to their ability levels, then as proficiency improved they increasingly undertook the Middle Word and Sentence sub-tests. Similarly, in the mathematics intervention, younger and less-able students most commonly undertook the CAAS Addition sub-test, moving onto Subtraction and Multiplication later in the intervention. This explains why participant students do not show the same number of testing occasions for each sub-test, as displayed in the graphs. Also, some variability in CAAS sub-test performance over time was to be expected as there were some unavoidable interruptions to the intervention such as school holidays, school camps and student absences.

In review, the selection of participants to be profiled for the exploration of the theme was based on an attempt by the researcher to make an informative and representative selection of participants who portrayed the range of abilities and demographic factors present in the participant student group (middle-school' students experiencing LD). The profiles consist of a description of the student, informed by data and observations recorded throughout the intervention, progress graphs, exit survey responses and some commentary. The profiles presented aim to provide an 'up-close' view of the individual participant, and their progress and development throughout the intervention.

***Quicksmart* Reading Participant Student Profiles**

Although the participants in the *QuickSmart* reading intervention program were all nominated by their teachers as students with LD, they displayed varying levels of ability at the commencement of the intervention. Most, if not all, were aware that they were poor readers and consequently they lacked confidence in reading, and found reading to be an effortful process. Most participants also displayed a limited repertoire of reading strategies for decoding and comprehending text. At the conclusion of the intervention there was still considerable variability in reading ability, even for students at the same grade level. However, most participant students displayed an expanded repertoire of reading strategies, and increased confidence in reading familiar and unfamiliar texts. The following three profiles detail the progress of the selected participant students.

Profile One – Student RM-PN. Student RM-PN (Ron) was a Year 5 male participant in the *QuickSmart* reading intervention. He was deemed to be a low-achieving reading program participant (relative to the other reading participants) at the beginning of the intervention. His age at the end of the intervention was 10 years and 6 months, making him one of the youngest participants. Ron and his family identified as Indigenous. Ron lived with his father, a single parent and younger siblings, and had attended his current school since kindergarten.

Ron presented as a shy student with a friendly personality but limited self-confidence. He was quite small in stature relative to other children in his class, and he preferred not to be the centre of attention. Pre-intervention information from the class teacher indicated that Ron did not achieve well academically in any subjects, and that, at times, he had difficulty attending appropriately to tasks. In many ways Ron struggled to keep up with his peers and he had limited social connections with them.

The researcher’s classroom observations showed Ron to be a quiet, passive student. He was seated towards the front of the room and required individual or small group assistance to complete class work. He appeared to be easily distracted by other students, and had difficulty initiating and completing work. Ron liked to draw cars on his workbooks and work sheets, and at times during the intervention he would talk to the researcher about cars his father was repairing.

During the intervention lessons Ron seemed to respond well to the structured approach of the lessons and enjoyed reminding the researcher and his lesson partner about what activities came next. He liked the simple bingo-type games, and was often keen to keep playing a game after someone had won, until the spaces on the game cards were full. Throughout the lessons it was advantageous for Ron if any equipment not needed for the current activity was put away as he tended to want to manipulate equipment, such as egg-timers, and would then loose focus on the task at hand. Ron frequently required prompts to attend to task as he was readily distracted by activities outside the classroom, and this was particularly the case if a class soccer game was in progress. However, once prompted Ron would willingly try to re-focus on the desired activity.

Ron's CAAS results, previously presented in Appendices E, F and G, showed that he did make gains in automaticity as a result of participating in the *QuickSmart* reading intervention. Ron also demonstrated very large gains in reading comprehension as measured on the PAT standardised comprehension test after the intervention (PAT Comprehension pre-intervention 9th percentile, post intervention 61st percentile).

Ron's performance over time on the three CAAS reading tests is displayed, below, in Figures 6.1, 6.2 and 6.3. Comparisons of pre-intervention (first data point on graph) and post intervention scores (second last data point on graph) in the Elementary Word and Middle Word CAAS tests show decreased response latency and increased accuracy whilst the same comparison on the Sentence test shows decreased response latency and also a decrease in accuracy. Although this result appears counter to what would be expected, it is, at least to some extent, off-set by the very large improvement in response latency. At the beginning of the intervention Ron could read the sentence and select the correct answer only with very slow response latency, later his response rate was much improved but with some cost to accuracy.

Comparisons, from post-intervention to follow-up, show that Ron maintained or improved accuracy on all three CAAS tests. The same comparison for response latency showed a minor increase (Elementary Word test), and a minor decrease (Middle Word test), as well as a large increase on the Sentence test, off-set by a gain in accuracy. However, Ron's follow-up response latency on the CAAS sentence test was still well below initial pre-test response latency.

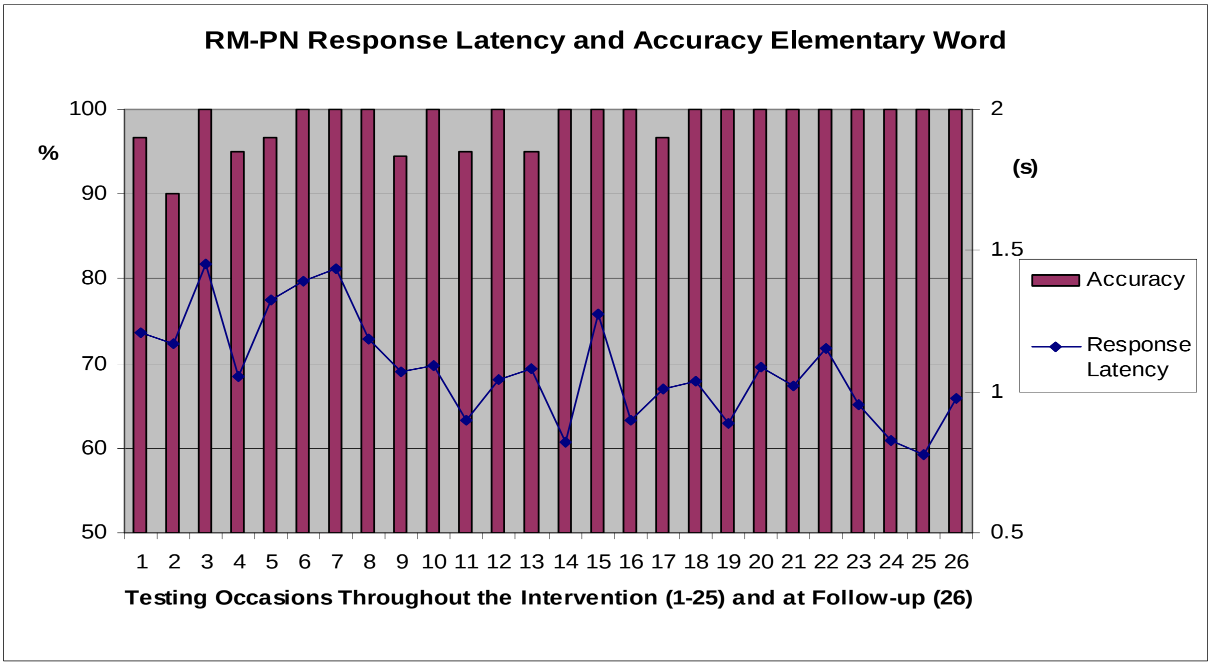

Figure 6.1 Participant RM-PN's automaticity progress over time - CAAS elementary word.

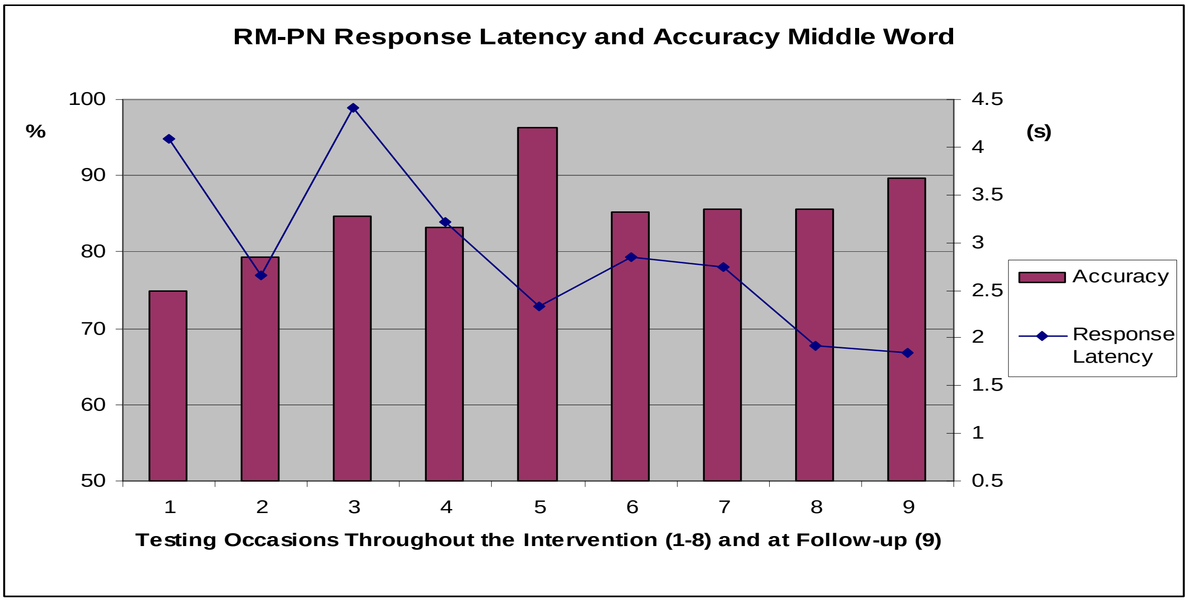

Figure 6.2 Participant RM-PN's automaticity progress over time - CAAS middle word.

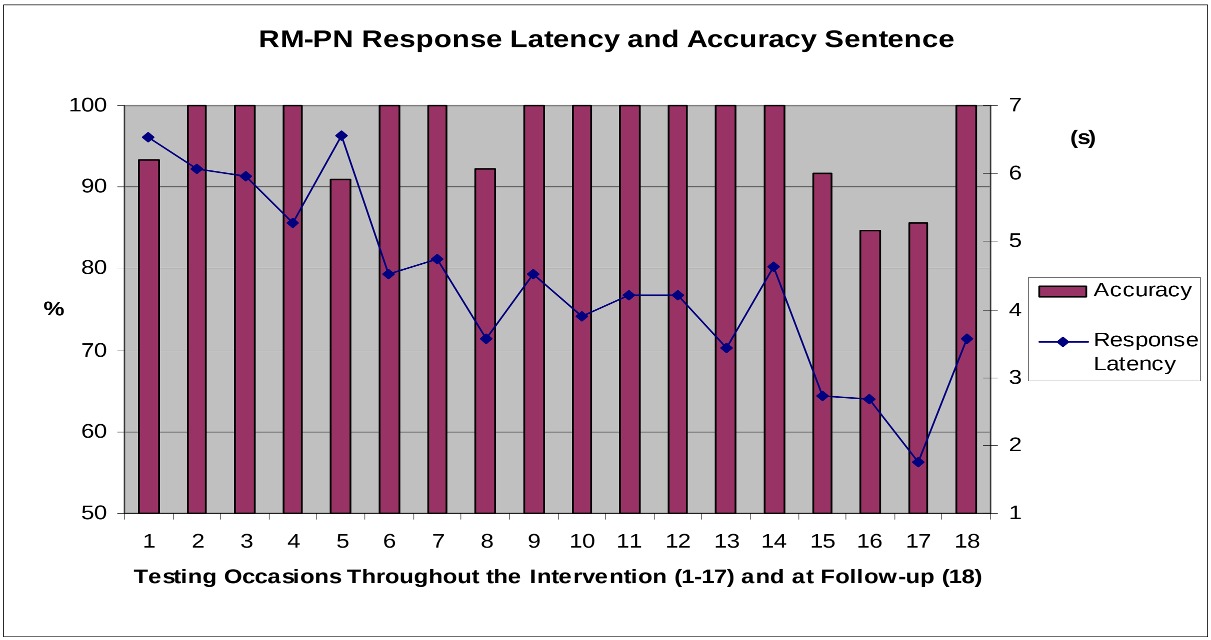

Figure 6.3 Participant RM-PN's automaticity progress over time - CAAS sentence.

Ron's responses to the survey questions, recorded on videotape on the day of the post-intervention assessment, are transcribed below.

1. *Do you think the QuickSmart program has been useful to you? Why?*
   Yes, it makes you read better and learn better.
2. *Do you use QuickSmart learning in your classroom? How? On what sort of work?*
   Yes in passages reading and mathematics sometimes. We are doing stuff about 'Gold' now and it helps me to do worksheets and to understand and read.
3. *What part of the QuickSmart program have you found most important to know about and use, at school or out of school?*
   Mainly reading.
4. *What were the best and worst things about being in the QuickSmart program?*
   I liked Dingo Bingo (game) the best. Nothing the worst, mmm, except missing out on soccer games.
5. *Any other comments you'd like to make about the QuickSmart program?*
   It rules!!!

Ron's responses to the questions show that he was aware that his reading had improved during the intervention, and that he noticed some positive effects on his work in the classroom.

At the conclusion of the intervention Ron remained a hesitant reader but his reading proficiency had increased. As Ron was one of the lowest performers in the participant group at the beginning of the intervention his progress during the intervention and at follow-up were very pleasing. Ron’s distractibility was an apparent barrier to effective learning for him.

Profile Two - Student TH-PN. Student TH-PN (Toni) was a female Indigenous participant in the *QuickSmart* reading program, aged 10 years and 5 months at the end of the intervention, the youngest participant. She was deemed to be a high-achieving reading program participant (relative to the other reading participants) at the beginning of the intervention. Toni presented as a talkative and outgoing girl who seemed quite mature and worldly for her age.

Toni was one of the most proficient students from the Year 5 participant group at pre-test. Despite this she was still a below average reader in her class group and the class teacher was concerned due to Toni’s poor achievement on assessment tasks. He described Toni’s reading performance as ‘erratic’ — at times she appeared to be able to read well, other times her reading was quite poor. The teacher also mentioned that Toni’s reading comprehension was very poor such that even when she read the words accurately she often showed poor understanding of the information in the text.

During the researcher’s in-class observations just prior to the intervention Toni was quite talkative in class and, not infrequently, interrupted other students who were attempting to work. She was also noted to be quite excitable, at times over-reacting to low-level stimuli, and frequently seeking attention from her peers and the teacher. Toni was frequently distractible and distracting, such that her class work suffered, and was often incomplete or rushed.

In the intervention lessons Toni was a very willing and helpful student who seemed to enjoy the attention she received in the small-group learning situation. She was often early for lessons and reluctant to leave, and frequently asked the researcher at lunch time if she could do any extra jobs or decorate the chalkboard in the intervention room. Toni was a very supportive partner for the other student in her lessons, showing maturity as she encouraged him and down-played her own successes.

In instances of reading connected texts Toni showed some learning behaviours that were unusual compared to the rest of the intervention group. When reading an unseen text with minimal picture cues, Toni attempted to read quickly but made frequent errors, and seemed to make up word endings and phrases that were not in the text. However, on subsequent readings of the same text (e.g., in the repeated reading exercise of the *QuickSmart* reading intervention) errors were much reduced, although minor errors in word endings and smaller words were still apparent. Thus, Toni sometimes 'sounded' like a good reader who made a few small errors but this impression contrasted with her test performance.

In discussion with the class teacher it was concluded that Toni had a great memory for words in text she had previously encountered, and she relied on this proficiency, as well as any cues from within the text or pictures, to support her reading skills. Toni's comprehension of texts was noted by both the class teacher and the researcher to be quite poor, and she often employed strategy of bringing in irrelevant information in her attempts to answer reading comprehension questions.

Further, Toni's decoding skills seemed deficient, as evidenced by her difficulty reading previously unseen texts, and her attempts to read quickly resulted in errors (incorrect word endings, inaccuracies with small, common words) which indicated that she did into attend closely to the letters that made up the words. It was likely that when reading, Toni relied very much on context cues, recall of previously encountered words and initial letter clusters as decoding skills whilst neglecting more specific, effective strategies such as blending and segmenting.

Results for Toni, previously presented in Appendices E, F and G, showed that she did make gains in automaticity as a result of participating in the *QuickSmart* reading intervention. She also demonstrated improved reading competency as measured on the PAT standardised reading tests after the intervention (PAT Comprehension pre-intervention 21st percentile, post intervention 75th percentile).

Toni's automaticity rates on three CAAS tests from initial assessment to follow-up are shown below in Figures 6.4, 6.5 and 6.6. In each test Toni's response latency was much improved from pre-test to post-test and maintained or improved from post-test to follow-up. Similarly her accuracy rates were improved or maintained. The middle word sub-test was the most challenging for Toni as the words were more complex and not frequently previously encountered, and the task provided no context cues. This meant that to be increasingly successful in this task Toni had to rely on previously under utilised decoding skills. Her improvements in response latency and accuracy in this task were particularly prominent.

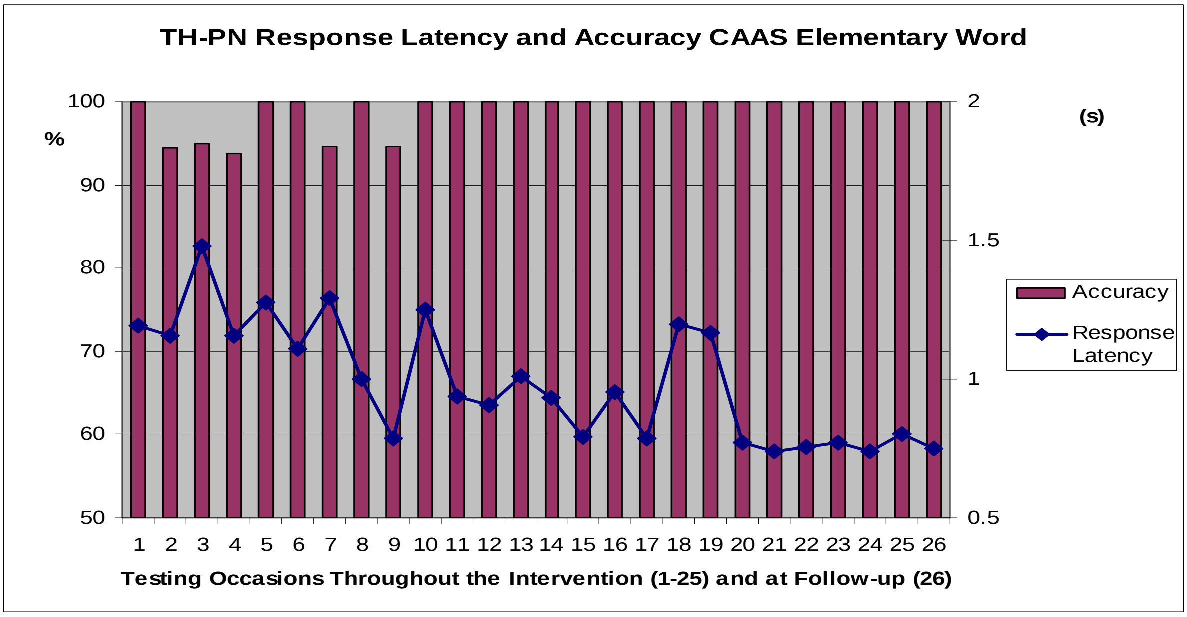

Figure 6.4 Participant TH-PN's automaticity progress over time - CAAS elementary word.

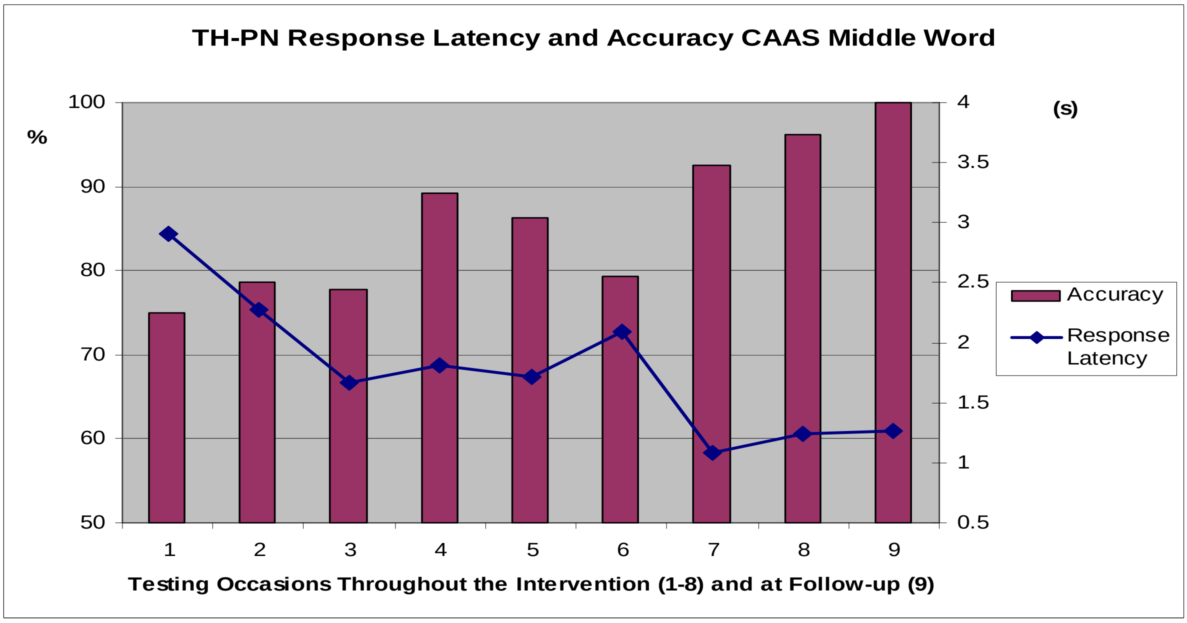

Figure 6.5 Participant TH-PN's automaticity progress over time - CAAS middle word.

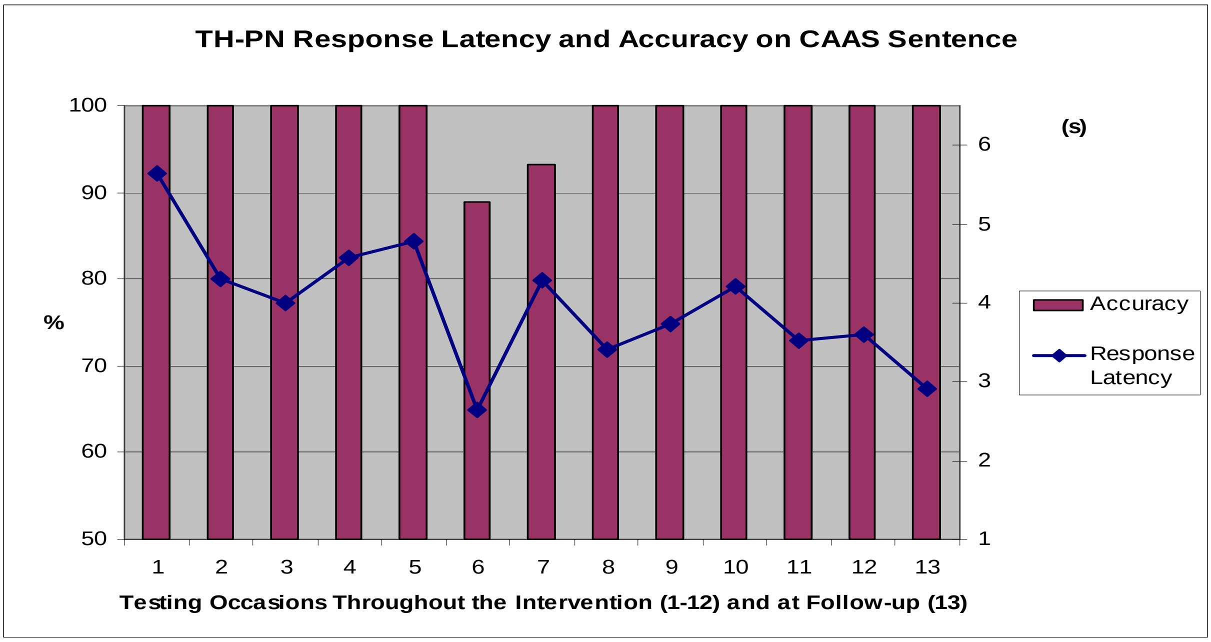

Figure 6.6 Participant TH-PN's automaticity progress over time - CAAS sentence.

Toni's responses to the interview questions, transcribed from video, are now reported.

1. *Do you think the QuickSmart program has been useful to you? Why?*

   Yes, it is easier to read big words and I know to go back and look for answers in the passages. I also got quicker at reading.

2. *Do you use QuickSmart learning in your classroom? How? On what sort of work?*

   Yes, it sort of makes it easier to do work in the classroom – passages, worksheets, *(writing)* stories and spelling.

3. *What part of the QuickSmart program have you found most important to know about and use, at school or out of school?*

   Just reading really. I guess I am just getting better at things.

4. *What were the best and worst things about being in the QuickSmart program?*

   Dingo Bingo *(game)* is the best. Can't think of any worst things.

5. *Any other comments you'd like to make about the QuickSmart program?*

   No.

In her responses Toni indicated that she felt her decoding skills had improved and also her comprehension. She also indicated that the usefulness of these skills was generalised to tasks other than just reading. It was pleasing to hear Toni acknowledge her improvements.

Toni most certainly benefited form her participation in the *QuickSmart* reading intervention and was able to maintain these improvements one year after the intervention concluded. It is interesting to note that although pre-intervention assessments indicated her greatest needs in reading were decoding and comprehension, Toni benefited greatly from an intervention which focused, more broadly, on developing automaticity.

Profile Three - Student EF-PO. EF-PO (Elly) was a female Indigenous student who was in Year 7 in the intervention year. Elly lived with her parents and her five siblings. She was deemed to be an average-achieving reading program participant (relative to the other reading participants) at the beginning of the intervention. At the end of the intervention Elly was 13 years old and coming to the end of her first year of high school.

Elly presented to the researcher as an affable, talkative student although her oral language skills showed limitations in vocabulary (word finding difficulties) and expression. With her peers Elly was less talkative and appeared timid at times. She had one or two close friends in her Year group but she did experience some social difficulties with the larger peer group in Year 7. Elly accessed additional support at school through student welfare programs and was identified by her English teacher as a student who would benefit from participating in the *QuickSmart* reading intervention.

From the outset Elly was an enthusiastic participant in the program, she displayed a positive attitude and motivation to try to improve her reading. Unfortunately, there were two extended absences, each of 1-2 weeks duration when Elly was ill and later, away on a school excursion. Elly demonstrated improvement in skills after just a few lessons, perhaps as the result of increased confidence. Elly was notably enthusiastic in the repeated reading exercise, and she seemed to enjoy and be motivated by the small successes she achieved in this activity, and also in the flashcard activity.

At the beginning of the intervention Elly demonstrated use of some efficient decoding skills to achieve a survival level of reading accuracy but her reading rate was slow, hampered by errors, a lack of confidence and lack of familiarity with words in the text. Elly's reading comprehension and vocabulary knowledge were also poor, resulting in poor understanding of the information she was reading.

At the end of the intervention Elly's individual CAAS results showed a steady reduction in response latency and maintenance or improvement in accuracy (see Appendices E, F and G). Her general reading proficiency had also improved, as measured by the PAT reading tests (PAT Comprehension pre-intervention 9th percentile, post intervention 50th percentile). Further, one year after the intervention was completed Elly maintained gains in automaticity in reading, as shown below in Figures 6.7, 6.8 and 6.9.

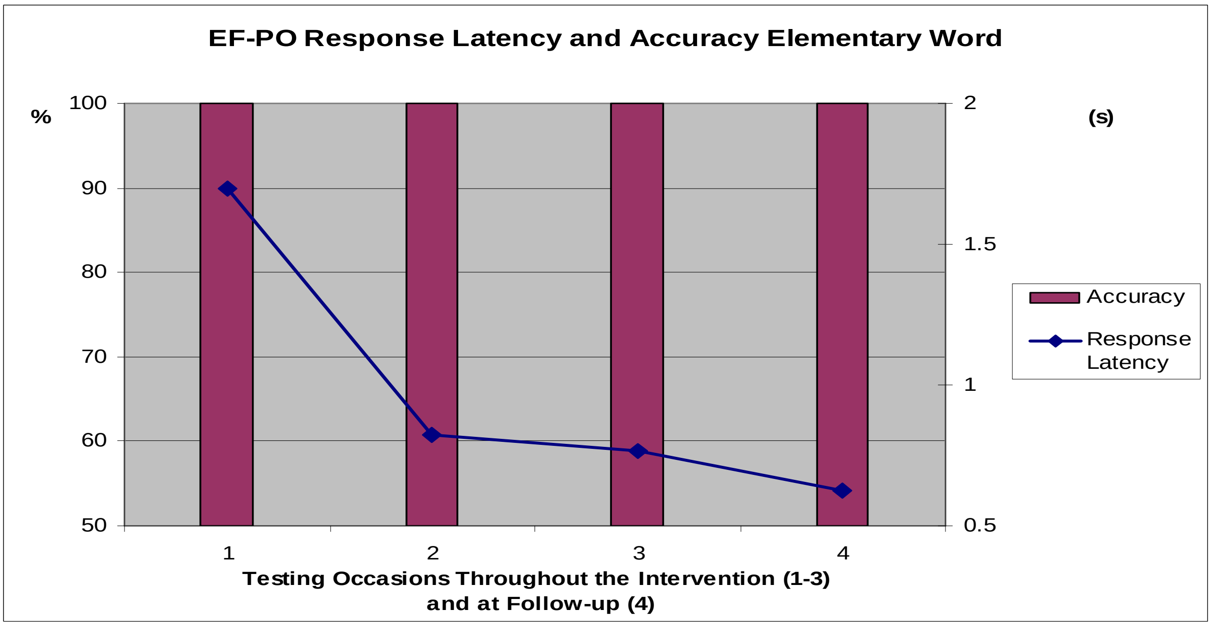

Figure 6.7 Participant EF-PO's automaticity progress over time - CAAS elementary word.

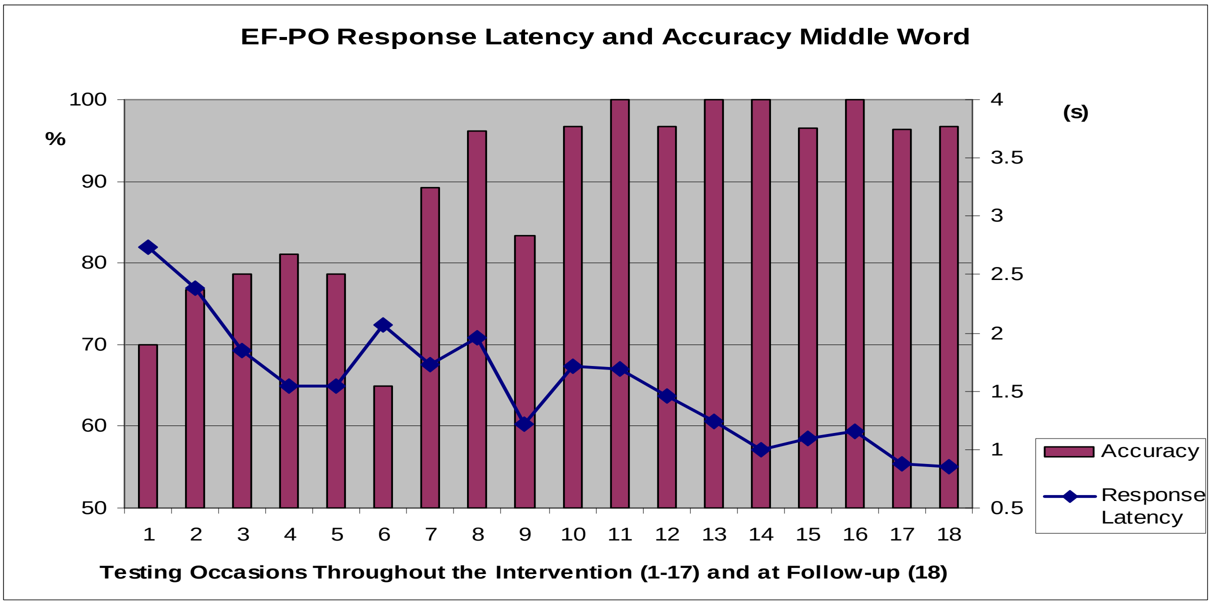

Figure 6.8 Participant EF-PO's automaticity progress over time - CAAS middle word.

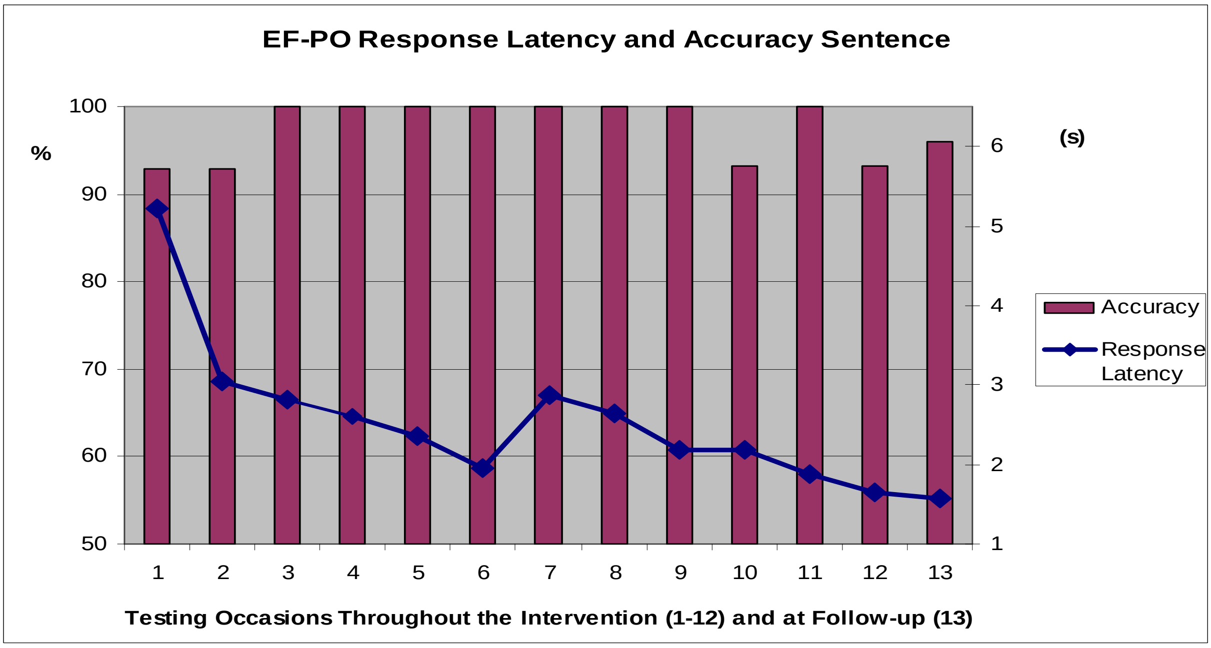

Figure 6.9 Participant EF-PO's automaticity progress over time - CAAS sentence.

Elly's responses to the survey questions are transcribed below.

1. *Do you think the QuickSmart program has been useful to you? Why?*

   Yes because I understand the words much better and it became much easier in reading my English novel.

2. *Do you use QuickSmart learning in your classroom? How? On what sort of work?*

   No and yes, in books some words and passages.

3. *What part of the QuickSmart program have you found most important to know about and use, at school or out of school?*

   To look back at the text to answer questions.

4. *What were the best and worst things about being in the QuickSmart program?*

   Best – I learned more things and understand more. Worst – nothing except I missed subjects sometimes.

5. *Any other comments you'd like to make about the QuickSmart program?*

   I would like to thank the *QuickSmart* teachers.

Interestingly, in her responses about her reading behaviours, Elly did not mention that the improvement in her reading rate but she did emphasise that she had learned new comprehension skills.

Elly was an older student who made significant reading gains as a result of participating in the intervention. In particular she seemed to benefit from the opportunity to read and practice texts which were an appropriate level for her, and from the explicit instruction about word meanings and comprehension strategies. Elly presented as a student who liked reading and was very keen to make the most of the opportunity to read texts at a level which enabled her to experience success.

In review, the profiles of the three *QuickSmart* reading participants, Ron, Toni and Elly reflect the general findings for research questions 1 and 2 presented in the previous chapter. The students made gains in response latency and accuracy from pre-test to post-test and demonstrated marked improvements in performance on standardised tests. Consistent with the group results for the third research question, Toni and Elly maintained or improved response latency and accuracy at maintenance testing. However, although Ron showed maintained or improved accuracy, his response latency increased from post-test to maintenance.

***Quicksmart* Mathematics Participant Student Profiles**

The students nominated to participate in the *QuickSmart* mathematics intervention program demonstrated a range of proficiencies in the pre-intervention assessments. However, at the beginning of the intervention all participants demonstrated poor recall of basic mathematics facts in some or all of the operations, and the great majority relied on some kind of finger counting as a key strategy for solving simple sums. At the conclusion of the intervention the participants all showed improved recall of basic mathematics knowledge and improved understanding of number concepts. Although some participants still relied on finger counting as a strategy under certain conditions, most demonstrated effective use of more appropriate strategies and increased confidence as a result of participating in the intervention.

Profile Four - Student MS-PN. Student MS-PN (Matt) was a Year 5, male, Indigenous student who participated in the *QuickSmart* mathematics intervention. Matt lived with his extended family. He was deemed to be a low-achieving mathematics program participant (relative to the other *QuickSmart* mathematics participants) at the beginning of the intervention. At the end of the intervention he was 11 years and 6 months, one of the oldest Yr 5 students in the intervention, yet he was quite small for his age. Matt accessed extra support at school through integration funding and student welfare programs. Matt’s teacher said he though Matt had an intellectual disability but this information was not verified.

Matt presented as a loud-spoken, happy individual, although his mood was quite variable. In-class observations and discussions with the teacher revealed that Matt was often given differentiated class work – on the same topic as the other students but tasks of less complexity or length. In the classroom he was mostly a compliant student for the class teacher but could be quite disruptive and defiant for other teachers. Even with his own class teacher in the room Matt frequently wandered from his desk, was slow to start work and consistently required individual assistance and reminders to finish set tasks. Occasionally, Matt was noted as a student of concern in school behaviour monitoring protocols.

Initially a reluctant participant, at times Matt would come into lessons declaring "I'm not doing nothing" but when the researcher ignored this behaviour and proceeded with the regular activities of the lessons Matt would readily join in, especially to play the games. Matt was quite a competitive participant and despite entreaties from the researcher that the important part of the lessons was to 'beat yourself' (personal best times) Matt did delight in out-performing his lesson partner, although this did not happen regularly. As time passed this behaviour also decreased, and he began to take pleasure in achieving personal bests. On an instance of improving his personal best by just one flashcard in a minute he joyfully punched the air and declared 'Yea, you can't get better than that!' Matt made slow progress in the intervention, especially in the early stages but he was an eager participant who seemed to benefit from the many repeated practice opportunities which helped him to develop mastery of some basic mathematics facts.

Matt was a fascinating student to have in the *QuickSmart* lessons as he so often verbalised or demonstrated his thinking processes. This was helpful for the researcher in a number of ways, most particularly because it clearly demonstrated the amount of processing time Matt required for most operations, and was a ready reminder about the importance of allowing enough 'wait time' for Matt (and other students) to answer the questions.

In the early stages of the intervention, when doing addition, Matt would touch his head and say, for example for the sum 4 + 3, "Four in my head and three more, five, six, seven" to support himself as he counted on, using his fingers, from the biggest number. Matt told the researcher that his family played card games a lot at home and he would sometimes relate addition facts to card values 'two and nine, that's like a nine and a two and that's a Jack'.

On one occasion early in the intervention, when presented with a subtraction card Matt said, “Mmm, subtraction, is that adding up or adding down?”. Linked to this thinking, Matt demonstrated relatively sophisticated strategy use when he applied addition to solve subtraction problems. For example, with the sum 18 – 14, he stated ‘The 14 is already taken away (made a sweeping aside gesture) and you’ve just got to count up to see how many is left’. However, Matt’s strategy use was inconsistent and explicit attempts to explain or demonstrate strategies seemed to confuse him. On some days he really ‘got it’ but on other occasions Matt struggled with recall of simple, previously encountered number facts.

Matt benefited from his participation in the *QuickSmart* mathematics program in automaticity of basic mathematics facts and in performance on the standardised test. In the standardised test Matt showed that his general mathematics proficiency had improved (PAT Mathematics pre-intervention 1st percentile, post intervention 13th percentile).

With regard to automaticity, Matt made response latency gains in two of three CAAS tests and accuracy gains in all three CAAS tests, as shown in Appendices J, K and L, and below, in Figures 6.10, 6.11 and 6.12. Although Matt’s response latency from pre-test to post-test in the multiplication test showed an increase, this was offset by gains in accuracy. Matt’s maintenance of response latency and accuracy from post-test to follow-up showed mixed results in addition and subtraction but pleasing improvements in multiplication. However, in each tests at follow-up Matt’s response latency and accuracy were markedly improved from his initial pre-test results.

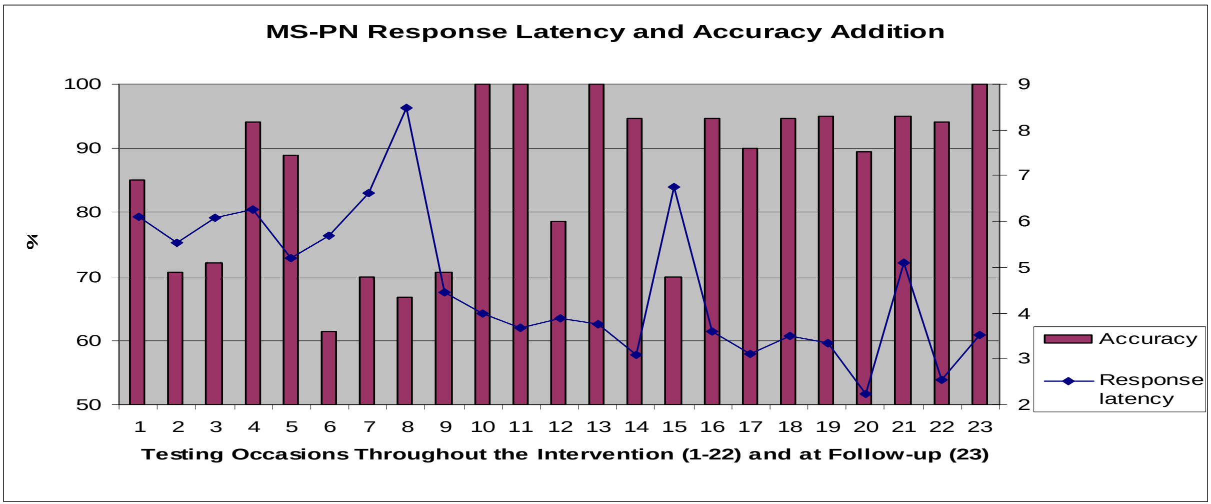

Figure 6.10 Participant MS-PN’s automaticity progress over time - CAAS addition.

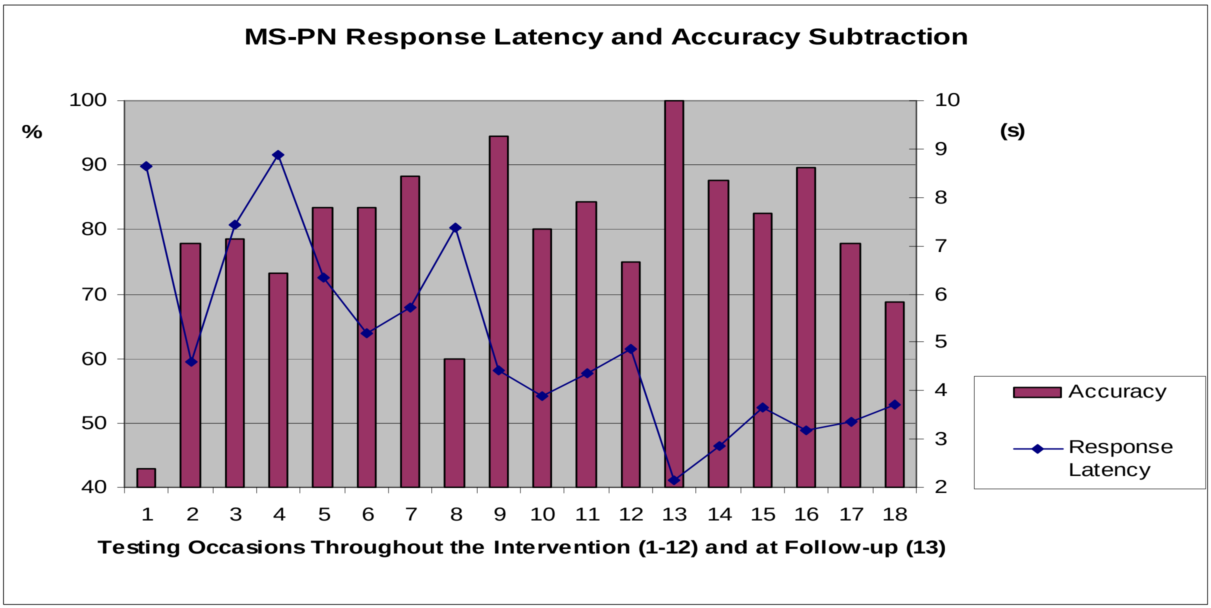

Figure 6.11 Participant MS-PN's automaticity progress over time - CAAS subtraction.

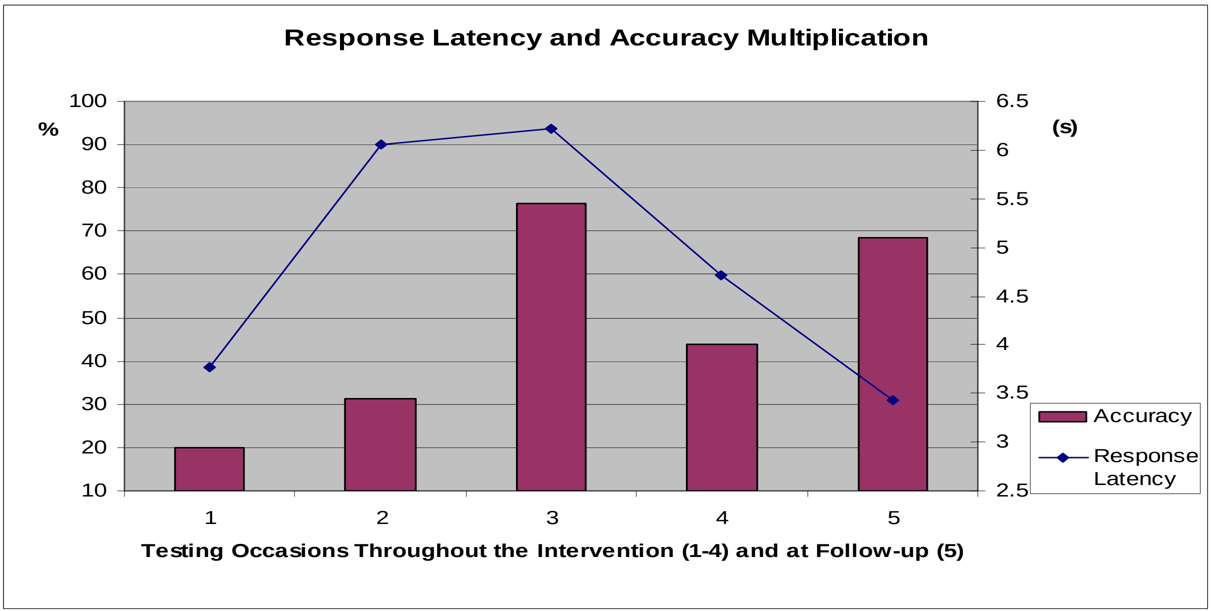

Figure 6.12 Participant MS-PN's automaticity progress over time - CAAS multiplication.

Matt's responses to the survey questions, recorded on videotape at the conclusion of the intervention, are transcribed below.

1. *Do you think the QuickSmart program has been useful to you? Why?*

   Yes, 'cos I've learned and I've missed out on my class work. I just enjoyed the *QuickSmart* maths.

2. *Do you use QuickSmart learning in your classroom? How? On what sort of work?*

Yes, I do a little bit of maths in the classroom in the morning, like times and adding ups and all that in maths. It helps me 'cos I hated maths once but not any more.

3. *What part of the QuickSmart program have you found most important to know about and use, at school or out of school?*

   I dunno, I just like it, every single part of it, and the maths, and you do heaps of work and it brains you up a bit.

4. *What were the best and worst things about being in the QuickSmart program?*

   Best – just to have fun. Worst – nothing except if you get into trouble.

5. *Any other comments you'd like to make about the QuickSmart program?*

   Enjoy it, it's fun.

It appears that some of the questions were a little difficult for Matt to understand but what is evident is that he did enjoy participating in the program. It would seem the success Matt experienced in the *QuickSmart* program had some influence on changing his attitude to himself as a mathematics learner. He also hinted that the structured small group sessions which provided him with a high level of guidance and supervision, resulted in improved quantity of work attempted ("you do heaps of work").

From the researcher's perspective Matt was both a challenging and interesting participant in the *QuickSmart* mathematics intervention, and it was a rewarding experience to work with him in a closely observed teaching and learning situation. It was known before the intervention commenced that Matt experienced quite considerable learning delays compared to his age peers yet it was pleasing to note that he did make and sustain progress throughout the intervention and beyond.

Profile Five - Student VP-PN. VP-PN (Vivian) was a Year 5 female student, aged 11 years and 3 months at the conclusion of the intervention. She lived with her parents and older sister, and had attended her current school since kindergarten. She was deemed to be an average-achieving mathematics program participant (relative to the other *QuickSmart* mathematics participants) at the beginning of the intervention. Vivian's overall academic achievement was below average for her class group and she achieved particularly poorly in mathematics, according to her teacher. Socially, she was part of a small group of girls who sat together in the playground but these girls were not in Vivian's class.

Vivian presented as a shy and very nervous student who at times had difficulty expressing herself. She was timid with her peers but showed a little more confidence when interacting with adults. As the intervention progressed Vivian became more out-going in the intervention sessions, and she began to express her answers more freely.

In-class observations just prior to the intervention indicated that Vivian was a quiet, anxious student who had limited interactions with peers or the teacher. She struggled to verbalise when asked to answer questions in whole class or small group settings. This difficulty could be attributed to lack of confidence and difficulty formulating her ideas into words, as Vivian's speech and language seemed to be age appropriate when she did manage to express herself. The class teacher said that Vivian had difficulty completing many of the set tasks, that she seemed to have poor concentration and that he had observed her peering off into space for extended periods. She rarely completed homework and was frequently absent from school due to minor illnesses.

Vivian responded well to the assurance that the intervention would help improve her mathematics skills, and she quickly became an enthusiastic participant, who often asked the researcher if she could attend extra *QuickSmart* lessons. A supportive relationship developed between Vivian and her learning partner for the *QuickSmart* lessons and this seemed to benefit her as she become less nervous and more confident in her responses. On rare occasions when Vivian was paired with a different learning partner she invariably under-performed and demonstrated difficulties in actually saying answers. When discussing this with her, Vivian told the researcher that sometimes she just "shuts down and can't think and I feel sick".

Vivian particularly seemed to benefit from the revision that was the first part of each lesson as this appeared to provide her with assurance that she knew the answers to some of the upcoming challenges. Throughout the intervention Vivian was relatively quick to learn new number facts, and she readily understood and used the strategies that were explicitly taught. From the researcher's perspective it seemed that lack of confidence and a fear of making mistakes were the key difficulties underlying Vivian's poor achievement in the subject of mathematics.

Vivian responded very positively to praise and feedback from the researcher, and her learning partner and she valued highly the graphs in her student folder which showed her progress. On several occasions when Vivian answered a question very quickly and correctly (from recall) she then covered her mouth in surprise and made a comment that she was amazed it was correct as she didn't 'think' about the answer.

Vivian's CAAS results previously presented (see Appendices J, K and L) showed that she did make gains in automaticity as a result of participating in the *QuickSmart* mathematics intervention. Vivian also demonstrated greatly improved competency as measured on the PAT standardised mathematics tests after the intervention (PAT Mathematics pre-intervention 10th percentile, post intervention 58th percentile).

Figures 6.13, 6.14 and 6.15 display Vivian's performance on the CAAS tests administered throughout the intervention and at post-test one year after the intervention concluded. In each test Vivian made impressive gains in response latency and accuracy from pre-test to post-test and generally maintained or improved these performances at follow-up testing one year later.

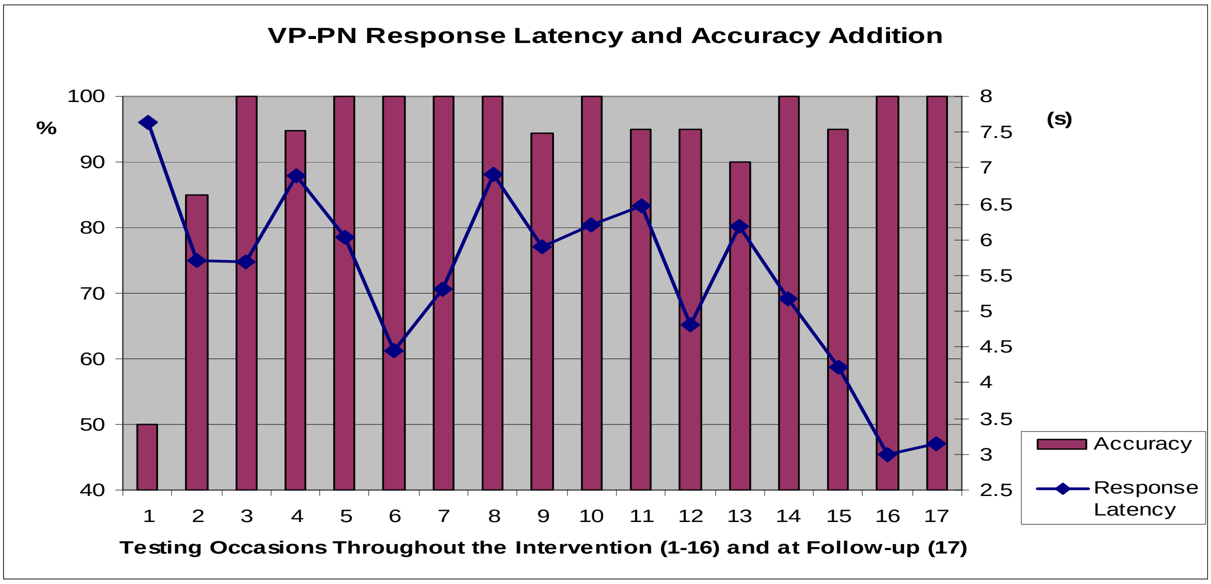

Figure 6.13 Participant VP-PN's automaticity progress over time - CAAS addition.

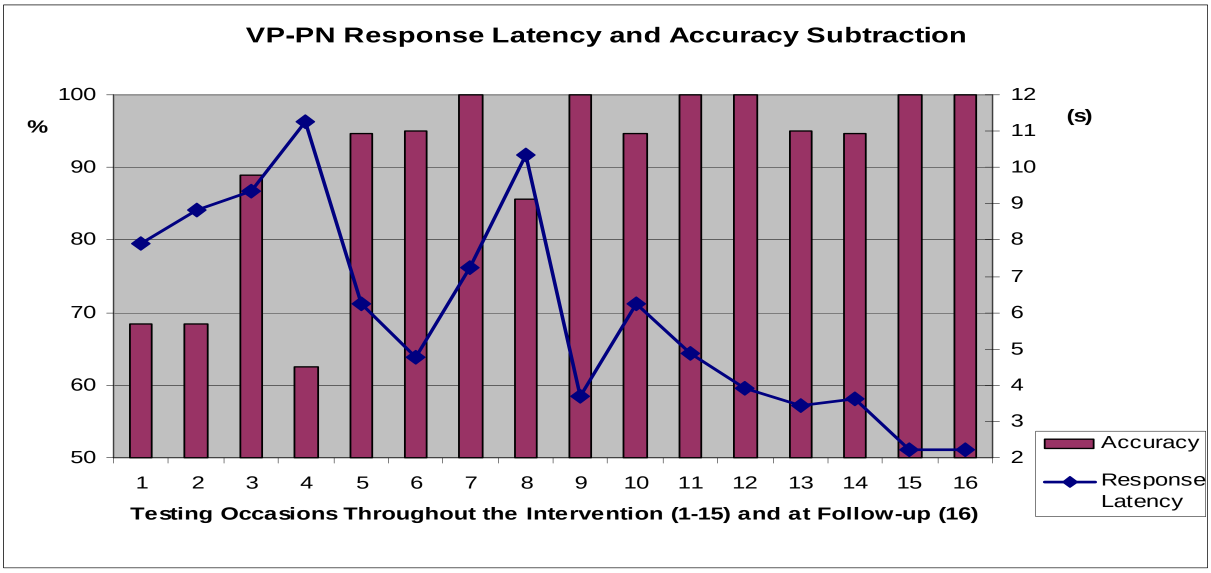

Figure 6.14 Participant VP-PN's automaticity progress over Time - CAAS subtraction.

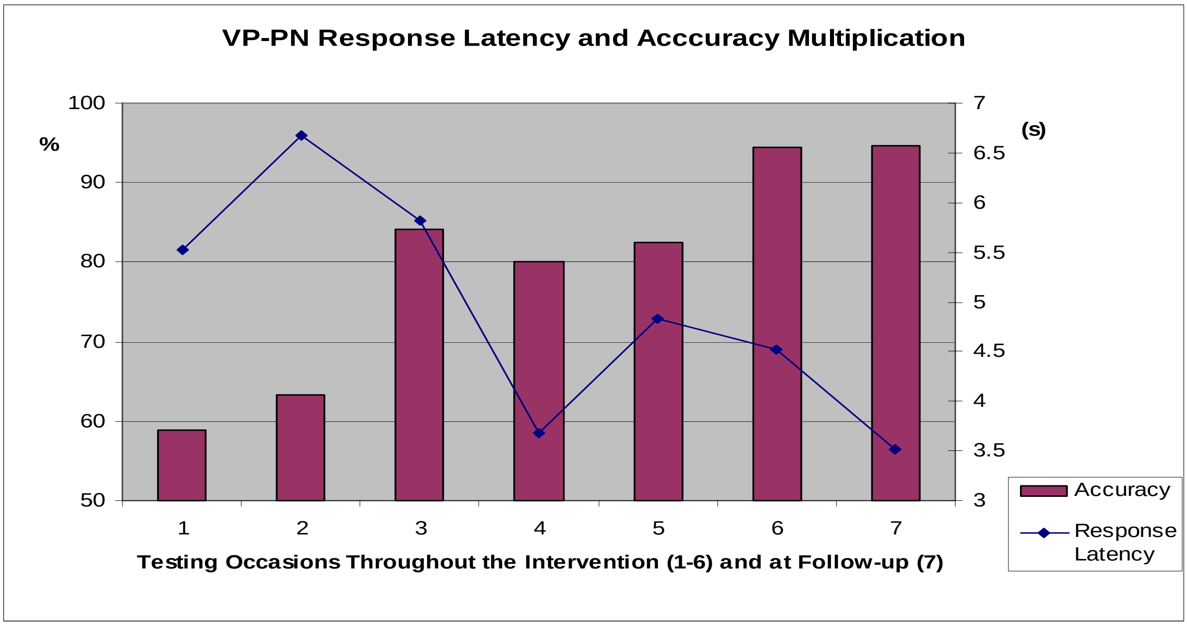

Figure 6.15 Participant VP-PN's automaticity progress over time - CAAS multiplication.

Vivien's responses to the survey questions, recorded on videotape at the conclusion of the intervention, are transcribed below.

1. *Do you think the QuickSmart program has been useful to you? Why?*

   Yes, because it helps me think a bit clearer and know where I am going.

2. *Do you use QuickSmart learning in your classroom? How? On what sort of work?*

   Yes, when Mr M (class teacher) writes up sums on the board, and also times tables and stuff and on worksheets.

3. *What part of the QuickSmart program have you found most important to know about and use, at school or out of school?*

   The part where you have to, ummm, knowing the answers and working it out in your head and not on your fingers.

4. *What were the best and worst things about being in the QuickSmart program?*

   Best – getting to talk to the teachers (*researcher*). Worst – not being able to come to *QuickSmart* lessons on Thursdays.

5. *Any other comments you'd like to make about the QuickSmart program?*

   I reckon it's a pretty good way to spend your time especially to get out of class and still learn something.

These responses showed that Vivien was aware that she had improved in mathematics. Interestingly Vivien was quite aware that her thinking processes had improved and that accurate recall and strategy use ("working it out in your head") were more reliable than relying on fingers as counting aids. Her comments make it obvious that Vivian valued her relationship with the researcher, perhaps because in a small group setting she could access the frequent practice and encouragement required for her to experience success in a subject which had previously provoked substantial anxiety.

Vivian's progress throughout the intervention and her developing confidence in herself as a mathematics learner were very pleasing, particularly as the gain in skills was maintained one year later. It is hoped that Vivian's gains in knowledge and skills during the *QuickSmart* intervention would continue to fuel increased confidence in herself as a proficient mathematics learner.

Profile Six - Student CS-PO. CS-PO (Cody) was a male Year 7 student, aged 12 years and 9 months at the end of the intervention. Pre-test data indicated that Cody was a middle-achieving student relative to the other *QuickSmart* mathematics participants. Cody had attended a local state primary school prior to commencing high school at the catholic college. Cody lived on a farm and enjoyed horse riding as a hobby.

Cody presented as a quietly spoken student, somewhat small for his age. He was a friendly and pleasant student but sometimes displayed 'silly' behaviour and seemed to be quite distractible. During lessons he regularly required prompts and reminders to be on task. When settled, Cody could work steadily for short periods. Cody had accessed additional support in literacy during his primary school years and in high school was identified as a student with LD in literacy and numeracy.

Despite these challenges, Cody did participate well in the intervention. His performance and on-task behaviour in lessons was variable but on most occasions he made a good effort. Cody particularly enjoyed the games segment of the lesson, especially when he won. Cody also enjoyed monitoring and graphing his response rates and accuracy, and genuinely wanted to improve his 'personal best' response times and accuracy.

As the intervention progressed Cody was able to show reasonable recall of basic mathematics facts but at times he demonstrated limitations in applying this knowledge. For example, Cody insisted he knew the nine times tables and confidently showed the instructor a range of strategies he had acquired for solving them, but a few days later, when he encountered the sum 8 x 9, he commenced to work it out using repeated addition rather than applying any of the more efficient strategies he had previously demonstrated.

Results previously presented (see Appendices J, K, L) showed that from pre-intervention to post intervention Cody made gains in response latency on all CAAS tests and gains in accuracy on the addition and multiplication sub-tests, with a slight increase in subtraction accuracy. Cody showed pleasing improvement from pre-intervention to post intervention in performance on the standardised (PAT Mathematics pre-intervention 9th percentile, post intervention 22nd percentile).

Maintenance data indicated that Cody improved from post-test in response rate in the addition and tests, with a very slight decrease in accuracy. In the subtraction test he made gains in both response speed and accuracy. However, in the multiplication sub-test Cody showed a decline in performance from post-test to maintenance. Figures 6.16, 6.17 and 6.18 show Cody's performance on the CAAS tests administered throughout the intervention and one year after the intervention concluded.

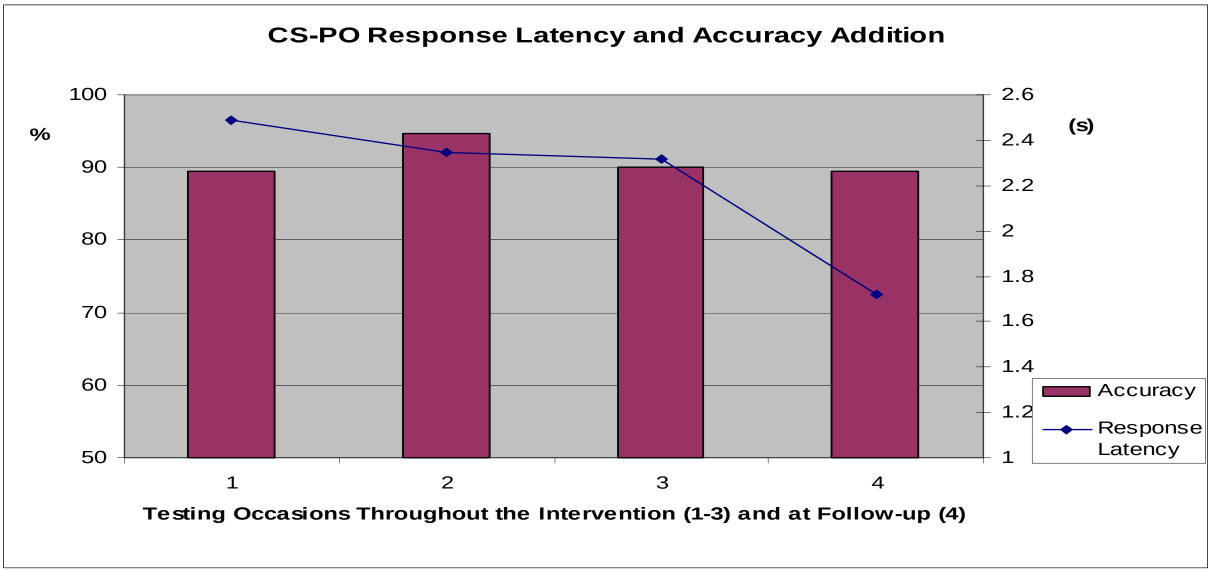

Figure 6.16 Participant CS-PO's automaticity progress over time - CAAS addition.

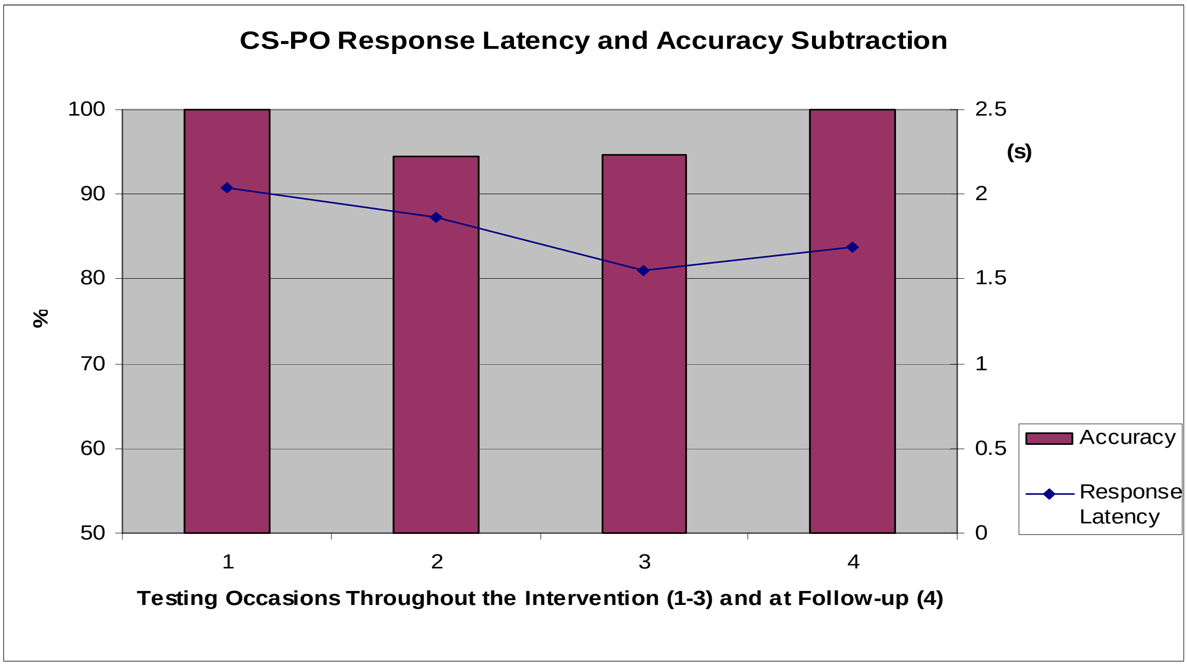

Figure 6.17 Participant CS-PO's automaticity progress over time - CAAS subtraction.

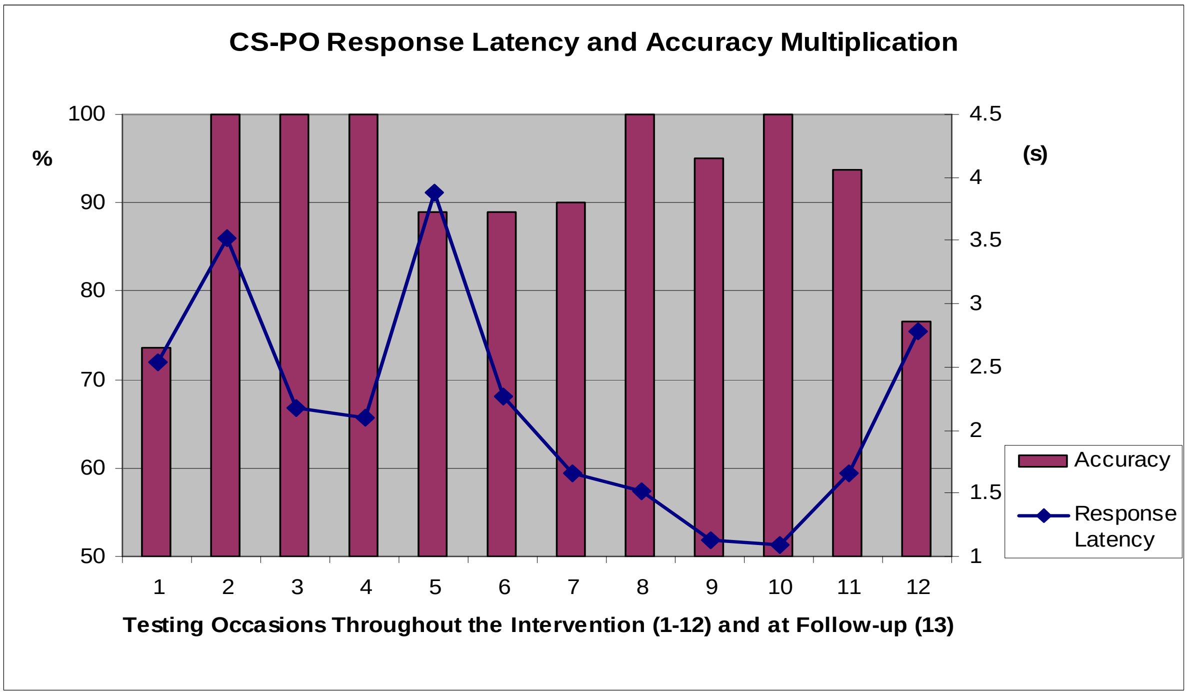

Figure 6.18 Participant CS-PO's automaticity progress over time - CAAS multiplication.

Cody's responses to the survey questions are reproduced below.

1. *Do you think the QuickSmart program has been useful to you? Why?*

   Yes, because it has helped me with all my maths problems

2. *Do you use QuickSmart learning in your classroom? How? On what sort of work?*

   In maths I do when I have to find the answer to hard questions

3. *What part of the QuickSmart program have you found most important to know about and use, at school or out of school?*

   Times tables

4. *What were the best and worst things about being in the QuickSmart program?*

   Best – being with the teacher. Worst – going back to class

5. *Any other comments you'd like to make about the QuickSmart program?*

   No.

Cody's responses in the exit survey indicate that he did think he had improved in basic mathematics skills, particularly in multiplication. However, it seems he is not clear about how to apply the knowledge gained to learning and living situations. His response to question 4 suggested he liked the small-group learning context and the opportunity for more individualised learning assistance but he disliked returning to class, presumably because, in doing so, he would attract attention to himself and his need for additional learning support.

Working with Cody throughout the intervention was quite a rewarding experience for the researcher because he did want to improve his skills and he often made considerable efforts to overcome limitations in his ability to concentrate. Cody's distractibility was a regular challenge for him as he would so easily loose focus on the task at hand. The 'silly' behaviour he sometimes displayed seemed to be a ploy for social acceptance as he attempted to forge an identity for himself in a new peer group. The gains Cody made during the intervention would hopefully assist him in everyday living skills, as well as facilitate greater access to and participation in the subject of mathematics and in numeracy applications required in a range of subject areas in high school curricula.

The three *QuickSmart* mathematics participants profiled, Matt, Vivian and Cody demonstrated individual results in relation to research questions 1 and 2 that reflected the group trend, that is, they reduced response latency from pre-test to post-test and showed pleasing improvement in performance on the standardised tests. Results for maintenance of response speed and accuracy on CAAS sub-tests were not so consistent. Matt showed improvement in response latency in only one sub-test and improved accuracy in two of the three sub-tests. Vivian maintained gains in accuracy in all three sub-tests and also decreased response latency in two of three sub-tests while Cody's results from pre-test to post-test on both CAAS and PAT measures were encouraging but poor performance at maintenance on the multiplication sub-test was disappointing.

The profiles of the six intervention participants presented above clearly demonstrate the diversity of ability, approaches to learning, and reaction to intervention of the students involved in the research program. As anticipated, although all the participant students were nominated as students experiencing LD, there was considerable variability in the gains they made throughout the intervention and at maintenance. More specific consideration of the profiled students, in terms of the objectives for the investigation of the theme, are evaluated in the following section.

Analysis of the Student Profiles

As the theme explored the rather broad topic of the learning growth and development of a selection of participants of the *QuickSmart* interventions, three exploratory questions were developed to target useful, relevant information in the profiles. In this section the information presented in the six profiles is analysed as each question is considered in turn. The participant students' learning behaviours and attitudes, pattern of progress and opinions about the *QuickSmart* interventions are analysed and briefly discussed.

The first exploratory question required a description of each participant with a focus on identifying learner characteristics. This has been broadly addressed in the presentation of the profiles. Figure 6.19 lists learning characteristics displayed by participants (and evident in the profiles) that apparently inhibited learning, and instructional approaches or experiences in the intervention programs that may have supported participants' development of more effective learning behaviours. Recognising learning behaviours that inhibit performance is an informative approach for teachers because it enables them to target specific student learning needs and, to implement effective interventions and appropriate adjustments to teaching and learning.

Learning characteristics that inhibit performance, as displayed by participant students in the intervention programs	**Aspects of the intervention programs that potentially support more effective learning behaviours**
<u>Ineffective approaches to learning:</u>	
Inefficient strategy use	Teacher and peer modeling
Inappropriate strategy use	Use of 'think alouds' as demonstration
Difficulty implementing new strategies	Explicit strategy instruction
<u>Limitations in attention:</u>	
Difficulty attending to task	Short fast-paced learning activities
Poor concentration	A prescribed sequence of lesson activities
Distractibility	Consistent teacher expectations
Lack of persistence	Hands-on activities, timed activities
<u>Poor work habits</u>	
Difficulty commencing a task	Established work routines
Lack of persistence	Pre-teaching and rehearsal
Poor task completion	Rewarding effort as well as achievement
<u>Memory difficulties</u>	
Inconsistent recall	Repeated, practice of the same content
Incorrect recall	Frequent review of previously encountered content
Forgetting	
Slow recall	Linking new learning to prior knowledge
<u>Negative impact of affective factors</u>	
Social difficulties	Small group instruction
Lack of confidence in self as a learner	Supportive learning environment
	Established work routines
Anxiety about learning / performing	Experiencing success
Fear of failure	

Figure 6.19 Participant students' learning characteristics demonstrated during the intervention, and responsive instructional strategies.

The second exploratory question required appraisal of each participant's rate of progress and the duration needed to show consistent improvement. Consistent with the variability inherent in the study population, progress made by individual participant students was also variable, both within and between participants. The CAAS progress graphs included in the profiles show that most students made improvement, in response latency especially, in a 'two steps forward, one step back' kind of progression, with a trend towards improvement but with variable progress and regress within any short time period. Overall, improvements in response latency and accuracy were variable, not consistent. The extent to which this could be a factor of the variation in the test items and the very small increments of time measurement, needs to be considered.

Visual inspection of the progress graphs contained in the profiles suggests that student participants did not make sustained immediate gains, rather multiple exposures to the *QuickSmart* lessons over an extended period of time was required before the participants made notable progress in CAAS assessments. A reasonable benchmark on which to judge mastery of a skill such as making a simple mental calculation or reading a word would be that such skills could frequently be accurately performed by non-LD middle-school students in one to two seconds, (as evidenced by the comparison group CAAS responses at post-test). The participant students profiled above, and, in fact, all participant students of the intervention program, were, unsurprisingly, unable to demonstrate such proficiency at the beginning of the intervention programs, and at the end of the intervention few had reached this level of mastery. This information suggests that participants may have benefited from a longer intervention, especially focusing on more demanding skills such as reading sentences and multiplication calculations.

The third question in the exploration of the theme required recording each participant's opinions about participating in the intervention, and this is presented within the profiles, in students' response to an exit survey. Most participant students' responses to the questions were positive in that participants were able to articulate that they thought they had made improvements in reading or mathematics, and that these improved skills enhanced participation and performance in class work. However, the exit survey results need to be interpreted with some caution due to the nature of the questions and the positive affect of most of the participants who may have wanted to offer responses pleasing to the researcher.

The profiles and analysis provided in this chapter supplement the findings of the research questions by adding descriptions of the participants, their learning characteristics, attitudes to the intervention programs, and their progress throughout the interventions. This information serves as 'rich descriptions' to both enhance the validity and generalisability of the results and to present the participants as contrasting individuals who nonetheless display a range of learning characteristics common to students with LD. An understanding of these performance-inhibiting characteristics is essential for research and educators as they strive to develop more effective practices to support improved learning outcomes for middle-school students experiencing LD.

In the following chapter the overall results for the three research questions and the theme are considered together. In addition, recommendations are made regarding practical implications, and further research.

Chapter 7

Discussion of Results and Conclusions

Students in the middle-school years who experience persistent LD are very much at risk of becoming disengaged and disillusioned with school. Consequent educational under-achievement may negatively impact on workforce participation and living standards throughout the life-span, with flow-on effects for families and communities. It is also more difficult to implement effective remediation programs for older students with LD, relative to younger students because the achievement gap between these students and their average-achieving peers is wider, resourcing is scarcer, and students' negative attitudes to learning have usually become more established. These challenges, which are readily observed when working in regular school settings with middle-school students experiencing LD, contributed to the motivation for developing the research reported in this thesis.

This final chapter considers the findings of the investigation in terms of the research questions and theme, identifies the importance of the findings, and discusses key ideas that emerge in relation to the relevant research literature. Implications for research and practice are also considered. The chapter is organised into four major sections — limitations of the study; summary and importance of the study; discussion of results; and implications.

Possible Limitations of the Study

The results described in the preceding two chapters need to be considered in light of possible limitations imposed by design factors, constraints in the experimental process and factors that limit the interpretation of statistical results. In Chapter 3 limitations to the validity of quantitative data in a quasi-experiment and inherent validity limitations in qualitative data, were identified. A restriction in the amount of testing that was administered to the participant and comparison students was also acknowledged as a limitation. In Chapter 5, limitations associated with meeting some of the assumptions of the statistical procedures utilised were also acknowledged. Other limitations relevant to this study are discussed below.

This study reports results for 38 students, specifically 22 participant students and 16 comparison students. These groups were further defined as reading group students or mathematics group students. Thus, the cohort numbers were small – 10 reading program participants with eight comparison students, and 12 mathematics program participants with eight comparison students. Such a sample size is acknowledged as a limitation for this quasi-experiment, with concomitant restrictions in the statistical analyses that could be applied and in generalisation of results.

The reasons for having such a small cohort in this research are linked with the feasibility of conducting intervention research in a contemporary, regular school setting in regional Australia. Whilst the school staff members who participated were willing partners in the research process, they were cautious and conservative in their approach to the project, resulting in small numbers of student participants, and in limitations imposed on the amount of assessment that could be administered. The constraints associated with having a small cohort involved in the research were identified at the outset of the project (see Chapter 3), and careful consideration was given to selecting a research design that responded to this limitation. Accordingly, a mixed-methods research design was adopted, as it allowed for the collection of both quantitative and qualitative data. Though the limitations that accompany having a small cohort in this quasi-experiment were not reduced by the inclusion of the qualitative student profiles, the depth of the study, and the quality and consistency of the information provided were enhanced by the detailed description of the learning processes of individual participant students.

Another limitation of the study was the lack of a matched control group against which to gauge the progress of the participant students. In educational intervention research there is an ethical issue which needs to be considered regarding using a matched control group in the research design. The issue centres on not providing all available students with the proposed intervention, but withholding what is anticipated to be an effective intervention opportunity from some students in need of it for the purposes of increasing the potential validity of the study. An informed decision was taken by the researcher to use a comparison group design (see Schumaker & Deshler, 2003) because of this ethical issue. The inclusion of a comparison group in the research design provided benchmark data against which to compare the participant students' automaticity rates, although, unfortunately, comparison group data for the standardised tests was not available.

Implementing valid and reliable intervention research in a regular school setting presents challenges to standard experimental research protocols, and these need to be resolved to support, as far as possible, the best interests of all stakeholders. In such circumstances some aspects of the research design are compromised, resulting in limitations in interpretation and generalisability of the results, as acknowledged above. Having considered the possible limitations of the research, a summary of results is now presented.

Summary and Review of Results

The results of the study have highlighted the potential benefits of focusing on improving automaticity in basic academic skills, as an effective intervention for students in the middle-school years experiencing LD. In this part of the chapter the results for each of the research questions and the theme are briefly re-stated before being discussed together. The importance of the findings are then considered.

Results summary. The first research question investigated whether automaticity in basic academic skills for students in the middle-school years experiencing LD could be improved as a result of participating in appropriate intervention programs, specifically *QuickSmart* reading and *QuickSmart* mathematics programs. Another aspect of the investigation was the comparison between performance changes of participant students and those of comparison average-achieving students who did not participate in the intervention programs.

The data for this investigation, which considered response latency and accuracy as indicators of automaticity, were transformed in order to ensure normal distribution, and then RM-ANOVAs were used to analyse results. These analyses indicated that participant students in both the reading and the mathematics intervention programs made gains in response latency (i.e., reduced response latency) that were significantly different to the gains made by comparison students. Inspection of group means verified that participant students' response latency gains were much greater than gains made by the comparison students. Notably, after the intervention, the response latency rates of participant students were similar to those of the average-achieving comparison students. The results for the accuracy aspect of automaticity followed a similar pattern – after both the reading and mathematics intervention programs participant students' accuracy rates were improved and their accuracy rates were not markedly dissimilar to those of the average-achieving comparison students.

Although it was not a focus of this research, this investigation did provide evidence that the *QuickSmart* reading program and the *QuickSmart* mathematics program were notably effective in improving automaticity of basic academic skills for this group of participant students, and that this improvement was sustained one year later. This suggests that improving automaticity in basic academic skills by improving both knowledge and strategy use is potentially an effective intervention focus for older students experiencing LD.

The second research question investigated whether improved automaticity in basic academic skills would facilitate improved performance on standardised tests of more generalised, curriculum-relevant subject-specific knowledge. Results for both the reading and the mathematics intervention programs showed statistically significant differences in post-intervention test performance and effect sizes indicating substantial growth. These results appear to validate the theoretical premise underlying the research – that 'freeing up' working memory from an excessive focus on mundane tasks enables cognitive resources to be allocated to other, novel or higher-order aspects of the task, in this case, resulting in improved test performance.

At the end of the intervention period the results indicated that the participating students had improved automaticity rates and that they had also improved attainment on standardised tests. However, the value of the gains in automaticity would have been limited if they had not been sustained over time. The third research question investigated maintenance of performance gains by repeating the CAAS tests to measure automaticity rates with 17 of the original 22 participant students, one year after the interventions concluded. In terms of both response latency and accuracy, group means for each of the CAAS reading tests were either not significantly different, or showed significant improvement from post-test to follow-up-test. Similarly, in the mathematics intervention program, participant students also showed no significant difference in response latency or accuracy from post-test to follow-up-test one year later. This finding is important because it shows that the students' improved performances on basic academic skills tasks were maintained and that their increased facility remained available for use during their classroom instructional experiences.

The exploration of the research theme yielded relevant information about the cognitive characteristics displayed by older students experiencing LD through detailing the progress of six students through the intervention. The profiled students displayed learning behaviours such as difficulty attending appropriately to tasks, the use of inefficient and inappropriate strategies when attempting to perform basic academic skills, lack of persistence with more challenging work and inconsistent performance on known tasks. These characteristics relate to underlying difficulties experienced by students with LD, as identified in the literature review. Characteristics include inefficiencies in executive functioning, such as working-memory constraints, poor self-efficacy and difficulties with accurate recall.

The progress of the profiled students showed inconsistent patterns in the short term, but gradual progress over the duration of the intervention. It was notable that mastery of very basic tasks such as addition and subtraction with single digit numbers, and reading simple words, required an extended time for some students, not just a couple of practice sessions. Further, some students did not achieve mastery of more challenging tasks, such as correctly reading sentences or providing correct answers to multiplication tasks. This finding suggests that particular students may benefit from longer periods of intervention in order to consolidate their basic academic skills. All profiled students expressed positive sentiments about being involved in the *QuickSmart* intervention programs and most verbalised how it had helped them in both classroom learning and daily living contexts.

Considered together, these results suggest that it is feasible to improve the word reading or basic mathematics skills of students with LD in the middle-school years by implementing an intervention which uses evidence-based strategies aimed at increasing automaticity. From this study it appears that such an effect not only impacts positively on standardised test performance, but also, that improvement in automaticity can be maintained one year after the intervention concludes. Further, the participant students themselves may, to varying extents, overcome the use of inefficient learning strategies, and acknowledge improved performance in both intervention and classroom settings.

Key issues directly relevant to this study's findings include generalised and sustained performance gains related to improving automaticity in basic academic skills for middle-school students with LD, generalised improved learning outcomes resulting from improving automaticity in basic academic skills, sustained improvement in basic academic skills, and supporting students with LD to develop more cognitively effective approaches to learning. More indirectly, the results suggest that framing LD interventions within a cognitive model focused on improving inefficient component skills, may be a credible approach to take with older students experiencing LD.

Importance of Findings. The results are notable because the intervention approach, which focused on remediation of specific component skills in reading or basic mathematics, specifically aimed to address the lack of automaticity in basic academic skills experienced by many middle-school students with LD. The strength of such an approach is the theoretical link it affords to the information-processing framework, and the concomitant recognition of the critical role of efficient utilisation of limited working-memory resources underpinning the effective learning of basic academic skills.

Overall, the findings of this study are important because they are optimistic – the intervention resulted in a marked, sustained gain in basic academic skills for the participant students, and this gain facilitated improved test performance. This positive outcome is contrary to the reality experienced by many middle-school students with LD in Australian schools. Historically, relative to younger students, older students experiencing LD have been somewhat overlooked in the LD field as most of the literature and initiatives in program development and funding have been directed at younger students (Lenz & Deshler, 2004). To varying extents this may have given rise to a tacit acceptance of under-achievement for students in the middle-school years experiencing LD, with common perceptions being that ”once children fall behind, they seldom catch up” (Moats, 2002).

A cluster of issues commonly converge in the middle-school years to subvert improved learning outcomes for students with LD. This was noted by researchers in the ‘Mapping the Territory’ project (Louden et. al., 2000) which presented case studies of support provisions in Australian schools. In this report, the circumstances of students experiencing LD in the middle and upper years were described in the following way:

> . . . with each passing year, they were falling further and further behind their peers. Moreover, schools had few resources with which to support these students and some observed programs did not appear to reach the same high standards as those observed in early intervention settings. (p. 106)

The results of this research challenge the complacency of such circumstances because they show that a well-structured, theoretically sound intervention program, implemented in a regular school setting, can make a significant difference to the performance and participation of students who would otherwise be vulnerable to school failure. Accordingly, the results reported here show that it is feasible for a school-based intervention to ‘narrow the achievement gap’ and provide enhanced opportunities for students with LD in the middle-school years to achieve appropriate learning outcomes. As Deshler (2005, p.124) stated, “While adolescents with LD present significant instructional challenges, there is reason to be optimistic about the magnitude of gains that they can make if they are taught using validated interventions with fidelity and intensity.”

In general, the achievements of the participant students involved in this research underscore the importance of theory-based interventions. Such interventions, when adapted to local contexts and focused on particular curriculum demands, have the potential to make a lasting, positive difference to the academic performance of low-achieving students. The results of this research suggest that a focus on improving basic academic proficiency through targeted, school-based interventions has considerable potential because it boosts the kinds of skills that are necessary for more complex tasks. This is important because proficiency with many of these sorts of tasks is assumed to already be in place for middle-school students (Milton & Forlin, 2003).

The summary of results presented above highlights the potential for focusing on improving automaticity in basic academic skills as an enabling, empowering instructional approach to improve the learning outcomes of middle-school students experiencing LD. The findings of this study are important because they provide evidence that a well-designed intervention, implemented in a regular school setting, has potentially profound effects for the participating students, both in terms of improved learning outcomes and enhanced self-efficacy. Further the findings of this study are important because they contribute to a small but growing body of Australian research into LD in reading and mathematics for middle-school students. The study highlights the contribution gained by considering LD intervention from a cognitive perspective, and in doing so, challenges what appears to be the prevailing ‘status quo’ of accepting of under-achievement and disengagement from middle-school students experiencing LD.

Discussion

One of the key points of relevance for this investigation, identified in the literature review and corroborated in the findings, was the usefulness of applying knowledge about the role of cognitive processes implicit in learning basic academic skills, to an intervention program. Accordingly, the potential of an information-processing approach to assist in understanding and remediating basic academic skills deficits, as experienced by students with LD in the middle-school years, is discussed. Consideration is also given to effective instructional approaches that develop proficiency in reading and mathematics for middle-school students experiencing LD. Specific elements of the intervention that may have contributed to the improved performance of the participant students, that is, the role of feedback, deliberate practice and promoting student self-efficacy, are also considered.

The following discussion is presented under six sub-headings: (i) relevance of the information-processing approach; (ii) learning difficulties in reading; (iii) learning difficulties in mathematics; (iv) deliberate practice; (v) feedback; and (vi) self-efficacy. Each of these are presented in turn, with reference to issues identified in the literature review and in relation to more recently published research literature.

Relevance of the information-processing approach. The information-processing model for understanding cognition, first introduced in the 1960s, has withstood the test of time and remains currently relevant to psychology and education (Dehn, 2006). The information-processing model, when applied to new learning, is closely linked to the construct of working memory. Working-memory capacity, general intelligence and academic learning are highly related (Conway, Kane, & Engle, 2003; Dehn 2008). Working memory is also considered a central feature of executive functioning in the brain, and a key mechanism for the filtering of selective attention (Geake, 2009). Further, the relationship between deficits and inefficiencies in working-memory processes and LD is well established in the literature (e.g., Swanson & Siegel, 2001; Torgesan, Rashotte, & Wagner, 1994).

Although there are some controversies surrounding the working-memory construct (see Dehn, 2008), its utility in terms of understanding cognition and learning is incontrovertible. Advances in the technologies of the cognitive neurosciences are being used to further inform the development of theories and knowledge regarding the critical role of working memory in learning, and to highlight implications for effective teaching (e.g., Geake, 2009). Although the research design for this study did not include measures of working-memory capacity or efficiency, improvements in the efficient use of limited working-memory resources emerged as a key explanation for changes in participant students' performance.

For example, at the beginning of the intervention, participant students could be readily observed squandering their cognitive resources (i.e., working-memory capacity) by relying on inefficient strategies such as sounding out previously known words, guessing words using unreliable cues, or solving basic arithmetic problems by counting on fingers and counting up from one. Cognitive resources were also needlessly expended by expressing negative thoughts about the self or the task, resulting in off-task behaviours. In this way, theoretically, the participant students dissipated their limited working-memory capacity by repeatedly approaching mundane tasks as novel, capacity-demanding problems to be solved or avoided.

This study has highlighted the important role of automaticity in basic academic skills. Improving automaticity in basic academic skills has been demonstrated as a potentially effective approach for remediating LD, particularly during middle-school years. It requires the development of more efficient cognitive processing, especially for lower-order tasks. The theoretical rationale for this position is based on the notion that the cognitive capacity of humans is limited, and particularly, that working memory has specific constraints on the amount of information that can be processed (Zbrodoff & Logan, 1986). Automaticity 'frees-up' limited working-memory resources, re-directing them from an excessive focus on tasks which should be routine (McNamara, & Scott, 2001). In turn, this enables more efficient resource allocation to novel and higher-order aspects of a task, such as comprehension or problem solving, which are inherently demanding of cognitive resources.

The findings of this study indicate that, for middle-school students experiencing LD, an intervention approach focused on developing automaticity in basic academic skills may provide students with LD with the opportunity to learn to use working-memory resources more efficiently and effectively. In this study, the participant students responded positively over time to the opportunity to 'let go' of inefficient strategies and approaches, and, with appropriate feedback and practice opportunities, to move on to using more effective approaches to learning.

The close connection between information-processing concepts, the efficient use of working-memory resources, and automatic processing of lower-order skills, such as word reading and basic mathematics calculations, have been indicated by the findings of this study. Importantly, La Berge and Samuels (1974) described a theory of automatic information processing in reading, which posited that component skills of a task become automated in a hierarchical sequence, with lower-level skills becoming automated first. This concept has been further refined and developed (see Logan, 1997; Perfetti, 1985, 1992; Stanovich, 1990; Tan & Nicholson, 1997), supporting the idea that efficient basic academic skills reflects automatic processing of components of the task, rather than the use of resource-consuming controlled processes (see Shiffrin and Schneider 1977, also Schneider & Shiffrin, 1977). This is an important premise of the research design and intervention used in this study, and stands as a rationale to explain the participant students' change in performance. Accordingly, it is feasible to propose that developing automaticity in basic academic skills is a necessary (but not necessarily sufficient) approach for supporting effective learning for students with LD, especially in the context of the content-driven curricula of the middle-school years.

As a theoretical model, information processing has much to offer in terms of providing a coherent, consistent rationale for the changes in performance demonstrated by the participant students reported in this study. Further, an understanding of the cognitive processes required for mastery of word reading and basic mathematics, especially the construct of working memory and the processes of automaticity, enables educators to target component skills in need of remediation effectively, and to identify potentially effective strategies for students with LD. As Dehn (2008, p. 282) states: "Academic interventions and instructional approaches can be more successful when they address students' processing deficiencies. Moreover, directed efforts to improve cognitive processing performance are appropriate in an educational environment."

Learning difficulties in reading. In relation to developing proficiency in reading for middle-school students experiencing LD, results of this study suggest that developing automaticity in word recognition and reading fluency is a worthwhile intervention focus, with potential for sustained gains in the target component skills, as well as reading comprehension. This is theoretically consistent with influential theoretical models of reading, for example Stanovich's (1980) interactive-compensatory model, Perfetti's (1985, 1992) verbal efficiency theory, and Gough and Tunmer's (1986) simple model of reading. The findings can also be linked to the double-deficit hypothesis (see Wolf & Katzir-Cohen, 2001) which posits that some sub-types of learning disabled students experience a specific processing deficit in naming speed, resulting in lack of fluency and automaticity in word reading. The results are also consistent with research that substantiates the effectiveness of word reading and reading fluency interventions to improve word reading, reading fluency and comprehension (see Chard, Vaughn, & Tyler, 2002; O'Connor, White, & Swanson, 2007).

Although Wolf, Miller, and Donnelley (2000) make a distinction between the terms automaticity and fluency (with automaticity pertaining to the underlying component processes and fluency relating to smooth rates of processing speed in reading), it is feasible to infer that other terms used in the research literature, such as 'word reading' (e.g., Torgesen, 2002), 'reading fluency' (e.g., Chard, Vaughn, & Tyler, 2002) and 'reading rate' (e.g., O'Connor, White, & Swanson, 2007) all describe reading behaviours similar to automaticity, that is, fast and accurate reading of words and connected text. Nonetheless, this range of terminology presents some challenges when interpreting results of this study compared to other studies, as does the fact that many studies of reading and reading fluency focus on younger readers.

As automaticity in word reading and reading fluency are intricately linked to reading comprehension, there is consistent support in the research for the notion that improving reading fluency can impact positively on reading comprehension (e.g., Chard, Vaughn, & Tyler, 2002; O'Connor, White & Swanson, 2007). However, Edmunds and colleagues (Edmunds, Vaughn, Wexler, Reutbuch, Cable, Tackett, & Schnakenberg, 2009) reported some contrasting findings. These researchers, working from the perspective that that the "ultimate goal of reading instruction at the secondary level is reading comprehension", presented a meta-analysis of reading interventions for older, struggling readers focused on elements of interventions associated with growth in reading comprehension.

Their findings indicated that while explicit teaching of reading comprehension strategies had a large effect on comprehension (effect size 1.23), word-level interventions were associated with a small to moderate effect (effect size 0.34), and the few studies of fluency included in the meta-analysis indicated that increased reading rate and accuracy did not always result in improved comprehension reading fluency (effect size -0.03). Further, there was evidence to suggest that the relationship between fluency and comprehension decreases with age and with text difficulty. According to the guidelines outlined for this meta-analysis, the *QuickSmart* reading program would be considered a multi-component intervention because it incorporates the components of word reading, fluency and, to a lesser extent, comprehension. This intervention type elicited a moderate effect on reading comprehension (0.72), similar to the effect size of 0.82 reported in for the *QuickSmart* reading intervention in this study.

Perhaps one of the most common fluency strategies utilised in fluency interventions is repeated reading. This was a strategy regularly utilised in the *QuickSmart* reading intervention program. In an a rigourous review of repeated reading research Chard and colleagues (Chard, Ketterlin-Geller, Baker, Doabler, & Apichatabutra, 2009) found that repeated reading could not be cited as an gold standard evidence-based practice for use in building reading fluency for students with learning disabilities, primarily due methodological flaws in designing and reporting intervention studies. However, the authors did not recommend that repeated reading interventions cease to be implemented; rather they commented that substantial evidence existed to support repeated reading as effective in improving reading fluency, and that repeated-reading practices should be continued, albeit with improved design and reporting incorporated into relevant research protocols. Notably, O'Connor, White, and Swanson (2007) found no effects for repeated reading of the same text compared to continuous reading of different texts on measures of word reading, vocabulary or comprehension. These more recent findings from the research literature about reading approaches indicate that, although repeated reading is a commonly used and reasonably well-substantiated reading fluency strategy (e.g., Chard, Vaughn & Tyler, 2002), further research is needed. This suggests that, until further evidence is gathered, teachers need to consider utilising a range of oral reading practice strategies in their instructional routines (O'Connor, White, & Swanson, 2007).

Learning difficulties in mathematics. Almost all students experiencing LD in mathematics demonstrate problems with accurate and automatic retrieval of basic mathematics facts, an inability to recall arithmetic facts from long-term memory and an inability to store numbers in working memory (Gersten, Jordan, & Flojo, 2005). This has an impact on how students with LD calculate, follow mathematical procedures and solve mathematical problems (Montague & van Garderen, 2008). The findings from this study, in relation to improving proficiency in mathematics for middle-school students experiencing LD, indicated that an intervention focus on improved automaticity in basic mathematics facts was effective, not only for sustained, improved response rate and accuracy for basic mathematics tasks, but also associated with improved performance on a standardised mathematics test.

The theoretical rationale proposed to explain these results is that improving automaticity in basic mathematics represents greater cognitive efficiency, particularly in the application of limited working-memory resources. This is consistent with a substantial body of literature that indicates the critical role of working-memory resources, especially the central executive, in simple arithmetic (e.g., Geary 2003; Lemaire, Abdi, & Fayol, 1996; Kaufmann, 2002; Wilson & Swanson, 2001). The findings of this study are also consistent with research literature that supports direct and explicit instruction in basic mathematics as an effective intervention approach for students experiencing LD (Baker, Gersten, & Lee, 2002; Fuchs & Fuchs, 2001; Pelligrino & Goldman, 1987).

However, it should be noted the body of research on adolescents and students in the middle-school years experiencing mathematics difficulties is quite limited (Bryant & Bryant, 2008), with the focus primarily on problem-solving (Montague & van Garderen, 2008). Issues of differing terminology also exist. For example, the use of terms such as ‘automaticity’, ‘computational efficiency’, ‘drill and practice’ and ‘math-fact recall’ to describe similar skills and approaches, and the somewhat interchangeable use of terms like ‘direct instruction’ and ‘explicit instruction’ confound the interpretation of research findings. Nonetheless, several conclusions can be drawn about effective approaches and strategies that support middle-school students experiencing mathematics difficulties, and the elements of these approaches that are utilised in the *QuickSmart* mathematics intervention.

Both explicit instruction of basic mathematics facts and, to a lesser extent, strategy instruction focused on counting strategies were instructional approaches utilised in the *QuickSmart* intervention. These approaches draw on a considerable body of evidence confirming that such approaches are effective in supporting improved mathematical proficiency for students with LD (e.g., Baker, Gersten, & Lee, 2002; Kroesbergen & van Luitt, 2003; Swanson & Hoskyn, 1998). It is relevant to note at this point that direct instruction and strategy instruction have much in common (Ellis, 2005; Gersten, Chard, Jayanthi, Baker, Morphy, & Flojo, 2009). Direct instruction does not exclude strategy instruction (Montague & van Garderen, 2008), and strategy instruction, often seen as an approach for teaching mathematical problem-solving, is also required for learning basic academic skills, especially for younger students and students experiencing mathematics LD.

Gersten and colleagues (2009) reported findings of a meta-analysis which identified instructional components effective in supporting improved mathematics proficiency for school-age students with LD. Findings from 42 intervention studies were synthesised to identify the following instructional components as most effective: (i) explicit instruction, (ii) use of heuristics (e.g., problem solving strategies), (iii) student verbalisations, (iv) range and sequence of examples (systematic variation of the content according to a specified sequence), and (v) use of visual representation. Similarly, a practice guide in education published by the Institute of Educational Sciences (Gersten, Beckmann, Clark, Foegen, Marsh, Star, & Witzel, 2009) made recommendations for effective interventions that support middle-school students experiencing LD in mathematics based on evidence standards. Relevant recommendations include: (i) ensuring an intervention focus on whole numbers and rational numbers; (ii) explicit and systematic instruction, including verbalization; (iii) guided practice and cumulative review; (iv) opportunities for students to work with visual representations, (v) regular opportunities to build fluent retrieval of basic arithmetic facts, and (vi) progress monitoring.

Elements of both the findings of Gersten and colleagues' meta-analysis (2009) and the practice guide recommendations (Gersten et. al, 2009) identify a range of approaches consistent with those used in the *QuickSmart* intervention, including systematic and explicit instruction, strategy instruction, student 'think-alouds' and a systematic approach for selecting lesson content. Teaching strategies for mathematics word problem solving are reported in the research literature on mathematics LD as being effective (e.g., Baker, Gersten, & Lee, 2002; Xin & Jitendra, 2006). Future implementations of *QuickSmart* mathematics intervention may also benefit from incorporating an expanded of strategy instruction focus, to include word problem solving as well as counting strategies.

Montague and van Garderen (2008) noted the potential of self-regulation and self-monitoring strategies for improving the performance of students with LD in mathematics. Likewise, Fuchs, Fuchs, Powell, Seethaler, Cirino and Fletcher (2009) also emphasised the critical role of progress monitoring in intensive interventions. As such, progress monitoring by the teacher is a key element in effective instruction because it ensures that the intervention is appropriately targeted and having the desired effect (Foegen, 2009; Fuchs et al., 2009). Progress monitoring by the instructor, and the students themselves, was an inherent part of the *QuickSmart* programs. On completion of the assessment tasks students were keen to see and record their results and compare them to previous performances. In this way, students' monitoring of their own progress appeared to motivate self-regulation. Instructor monitoring of student progress provided important information that was used to fine-tune the instructional content and sequencing, to better address the learning needs of individual participants.

There is also support in the research literature for the effectiveness of small group instruction for students experiencing LD in mathematics (Bryant & Bryant, 2008). This fits with the model used in the *QuickSmart* mathematics intervention. Small group instruction was advantageous, probably because the participant students were better able to access the learning conditions necessary for improvement, including have more opportunities to practice and to receive immediate feedback from the instructor and other students (Vaughn, Hughes, Moody, & Elbaum, 2001).

In terms of the quality of mathematics instruction for students experiencing LD, the research literature continues to caution that classroom teachers may not have developed the necessary paedogogical knowledge, or understanding of the diverse learning and behavioural needs of students experiencing LD in mathematics (e.g., Maccini & Gagnon, 2006; Montague & van Garderen, 2008). Additionally, current materials and teaching methodologies may be at odds with proven instructional strategies and approaches for teaching students experiencing LD in mathematics (Woodward & Brown, 2006).

Contemporary mathematics curricula based on problem-solving or discovery learning approaches, are thought to be too complex, unstructured and confusing for many students experiencing LD (Bryant & Bryant, 2008; Montague & van Garderen, 2008). Problem-based learning as a curriculum priority and a core classroom teaching approach is fraught with challenges when implemented with students experiencing LD because these students commonly lack the necessary prerequisite skills and strategies, and their teachers may lack training to implement such an approach systematically and with adequate scaffolding for students with LD. Consequently, attempting to solve inappropriate problems can result in cognitive overload and confusion for the students (Westwood, 2011). Students with LD should not be denied opportunities to participate in peer collaboration and the sharing of mathematical reasoning to derive solutions, however, their identified need is for consistent, systematic, explicit instruction in basic mathematics skills and strategies. Therefore, developing automatic recall of basic number facts and applying computational procedures needs to be a core component of instructional programs for older students experiencing LD in mathematics (Westwood, 2011).

Deliberate practice. An issue which has been implicit in much of the preceding discussion is practice; in particular, the notion that automaticity develops as the result of repeated practice

(Bloom, 1986; Schneider & Fisk, 1983). The theoretical basis for this position emanates from Shiffrin and Schneider’s (1977, see also Schneider & Shiffrin, 1977) dual processing theory of automatic and controlled processing. When a task is deliberately practised with attention, this practice changes resource-demanding controlled processing into automatic processing, which is relatively free of working-memory demands. In effect, a cognitive reorganisation of the skill is initiated. Accordingly, it can be theorised that, in the study reported here, participant students who improved automaticity in basic academic skills, changed the way they processed basic information, moving from controlled processing to automatic processing, as the result of repeated, focused, deliberate practice.

Deliberate practice is different to the rote repetition of content. Rote repetition simply requires repeating a task. While this may result in the ability to perform the task, in the short-term and within the same context, it is different and less effective than using deliberate practice to develop automaticity. The implementation of deliberate practice involves attention, rehearsal and repetition, resulting in new knowledge or skills that can later be developed into more complex knowledge and skills (Brabeck & Jeffrey, 2010). Access to adequate practice opportunities is particularly important for students experiencing LD, as they need to rehearse strategies and information more frequently than other learners (Mitchell, 2008).

Deliberate practice was a key strategy in the *QuickSmart* intervention programs, taking the form of consistently-encountered, supported and timed tasks sequenced in terms of increasing difficulty. In each lesson the deliberate practice undertaken by the students was highly structured and focused, with the aim of improving performance. The content practised was specific, for example, a selected set of related words or number facts, rather than general practice of reading or doing mental calculations. Practise opportunities were also repeated within lessons and over a number of lessons, providing the participating students with ample opportunities to attend to critical aspects of the task. Within the lesson, opportunities were provided to practise specific items to overcome weaknesses (i.e., extra practice was focused on incorrect items or tasks), and performance was monitored carefully to provide feedback. As a result of successful practice the participant students appeared to be motivated to exert extra effort to improve.

The role of feedback. The benefits of deliberate practice are enhanced when teachers provide students with timely and descriptive feedback. Feedback can come from a variety of sources including teachers, peers, books, computers, parents and the learners themselves (Mitchell, 2008). Feedback can be summative, for example, a percentage rank or grade on a test, or formative when it is ongoing and communicated to the learner in order to modify his or her thinking or behavior to improve learning (Shute, 2009). Educators have understood the potential for feedback to positively influence performance for some time (e.g., Fuchs & Fuchs, 1986; Lysakowski & Walberg, 1982). More recently, the importance of feedback as a key instructional strategy has gained prominence since the publication of John Hattie's work (e.g., 2003, 2005, 2009) supporting the idea that the most powerful single influence enhancing student achievement is feedback. Accordingly, teachers improve student outcomes by initiating effective feedback practices that provide information about how and why the student understands or misunderstands a specific task or content area, and what steps the student must take to improve (Hattie, 2003). Feedback is most effective when it directly relates to the task and allows students to acquire more, different or improved information. Feedback is also powerful when it relates to self-regulation and task completion. Least effective feedback is that which is about the self, and is unrelated to performance on a task (Hattie & Timperley, 2007).

The majority of feedback from the instructor in the *QuickSmart* intervention programs was related to the task at hand, and focused on student performance and strategy use. For example, teacher and student interactions after a task focused on why the student was correct or incorrect ("Great, you counted up form the largest number"), what needed to be changed or improved ("If you come to a word you don't know, try breaking it up into smaller parts and then join them together, don't just look at the first letter and guess"), and what information needed to be focused on or further practised in order to improve ("We need to do some more work with those plus nine sums. Do you remember the strategy we tried yesterday, when you plus ten minus one?"). This kind of strategic feedback provided the student with information that supported improved performance in a much more powerful way than general feedback, such as a simple "Well done", or "Nice work".

In the *QuickSmart* lessons participant students and the instructor also received very specific summative feedback about performance levels on at least three occasions during each lesson. Students' progress was monitored on flashcards, repeated reading or speed sheets, and CAAS assessments. Importantly, the summative performance feedback that students received was regularly presented to them using graphs, enabling them to 'see' their performance trend. Also summative performance feedback was carefully and consistently couched within a framework of ‘personal bests’, with the aim of encouraging students to focus on improving their own performance.

Student self-efficacy. One aspect of the research implementation that was not included in the research design for investigation but nonetheless impressed the researcher was the positive effect that experiencing success appeared to have on student performance. As the intervention progressed, this was readily observable. The researcher, and the students themselves, could see how improved, successful performance led to increased motivation and enhances self-efficacy. Hearing students say they would like to attempt a task again to gain an improvement, witnessing the positive emotions students experienced as they made performance gains, and seeing the students willingly and enthusiastically come to lessons (and sometimes ask for longer or extra lessons) were among the most rewarding aspects of implementing the intervention. Essentially, the intervention programs seemed to engender an attitudinal change from “I can’t” to “I can if I work at it” in participant students. In turn, this improved self-confidence seemed to enable students to become more actively involved in their learning.

The researcher’s observations of enhanced confidence and motivation were confirmed by the students themselves. Their positive comments on the exit surveys suggest that, to varying extents, students were able to overcome some of the limitations associated with the negative ‘self’ factors that are so commonly experienced by students with LD. This change can plausibly be attributed to the powerful effects of breaking the failure cycle (see Westwood, 1995). Experiencing success and having realistic attributions for that success apparently eroded attitudes of learned helplessness and supported the development of confidence and motivation, resulting in positive attitudes to learning mathematics.

The discussion presented in this section supports the notion that information processing is a relevant and informative perspective from which to consider learning difficulties in the middle-school years. In particular, the inefficient use of limited working-memory resources, and the role of developing automaticity in basic academic skills to promote cognitive efficiency for students with LD, has been highlighted. In the discussion of LD in reading and basic mathematics it was of interest that many of the strategies and approaches highlighted in the research literature as effective for students with LD were reflected in the *QuickSmart* intervention program. Further, the role of deliberate practice, the importance of appropriate feedback about task performance, and the facilitating effects of ‘breaking the failure cycle’ were identified as key instructional features that potentially contributed to the participant students' performance gains. It is important to now consider the implications of this study for future research and practice in the field of learning difficulties.

Implications

The study reported in this thesis provides evidence of the gains in learning that can be achieved when students in the middle-school years experiencing LD have the opportunity to participate in an intervention utilising validated strategies and approaches that target academic skills necessary for participation in everyday classroom teaching and learning activities. This section discusses the implications of the study's findings, and is presented in terms of implications for research and implications for practice.

Implications for research. The research reported in this thesis has a pragmatic orientation, with high value placed on the notion of ecological validity. That is, an important aim for this thesis was to produce information that can be generalised across settings, with utility for teachers and researchers working with students who are experiencing LD in contemporary, middle-school settings. This results in some methodological tension between the pursuit of "locally usable" knowledge and the production of research that meets 'gold-standard criteria' of evidence-based findings.

Identified limitations, primarily related to sample size and lack of a matched control group, go to the heart of what is a potentially contentious issue in educational research. In the past decade legislative changes in United States, and similar proposals in Australia, increasingly require that educational research adheres to 'gold standard' practices, such as random-assigned matched group designs, in order for the resulting recommendations to be considered evidence-based or scientifically proven.

Whilst few researchers and practitioners would argue against the intent of these provisions, being that educators be informed about validated effective practices, they do present particular challenges for researchers seeking to maintain high ecological validity in their work. These challenges require that educational researchers, governments and policy-makers need to consider legitimating the use of multiple methodologies, as used in this study, to obtain evidence about the efficacy of educational practices and interventions (see Schumaker & Deschler, 2003; van Kraayenoord, 2006).

Another implication for research is to provide further information about the duration and intensity of effective interventions for older students experiencing LD. In the study reported here the duration of the intervention was 18-22 weeks and the intensity of the lessons was 30-minute lessons delivered three times per week. Information in the student profiles suggested that some students needed quite a long time to gain automaticity in very basic content and that at least some of this time was needed to replace, or move on from, inefficient ways of attempting tasks that the students had come to rely on. It is likely that a longer intervention would be required for some of the students to gain more comprehensive mastery of basic academic content.

Accordingly, the results of this study suggest that a relatively long, intense intervention was required to effect performance change for this group of middle-school students with LD. There is already some evidence in the literature that increased duration can have positive effects for at-risk students (Vaughn, Linan-Thompson, & Hickmann, 2003) and that, for example, many reading fluency interventions are too short in duration to result in generalised improvements in fluency to new texts (O'Connor, White, & Swanson, 2007). However, the length of intervention alone does not determine intensity. Other factors, such as ensuring students maintain a high degree of attention and response; frequent and consistent instruction; and effectively engaging students in activities that contribute to their learning; also require consideration in the instructional dynamic of an intervention (Deshler, 2005).

Other factors linked to duration and intensity of interventions also need to be considered. Wanzek and Vaughn (2008) suggested that further research to examine factors related to intensity (i.e., time, group size, and a combination of time and group size) would provide guidance for educators about effective intervention practices. Torgesen (2002) also noted the need to define the range of instructional intensity available in order to provide appropriate instruction for students experiencing LD. Also, further information is required about the level of explicitness and scaffolding students require to make satisfactory progress within an intervention. Clearly, more specific information from research relevant to older students experiencing LD about intervention duration, intensity and level of explicitness, is needed.

Another implication for research is with regard to considerations about research design. The mixed methods research design utilised in this study was perceived to be a 'good fit' with the research context, that is, LD intervention research in a contemporary school setting. This may have implications for other researchers considering intervention research in a school setting. While including quantitative data in the research design enabled the investigation of specific research questions and added rigour to the study, including the qualitative component in the study afforded extra opportunities to observe and report on important aspects of learning and LD. Through the presentation of individual profiles, 'real' experiences of 'real' students with LD could be contemplated and shared. For example, the learner characteristics of students with LD were illustrated with specific examples of student behaviours observed and reported. Accordingly, it is recommended that a mixed methods research design be carefully considered as a viable and relevant approach for investigating LD in the middle-school years by other researchers working in both intervention and school settings.

A final implication for research, particularly relevant when looking to consider the results of this study in context with other studies in the LD field, is the continuing confound with regard to terminology, diagnosis, identification, causes and consequences of learning difficulties or learning disabilities. Although progress has been made in resolving aspects of this debate, a key task for future research is to provide information to ensure consistent understanding across schools, states and countries, with regard to the identification criteria, and fidelity in implementation of research-validated interventions and strategies for students with LD (see, Buttner & Hasselhorn, 2011).

In review, there are three implications for research emanating from this study. Firstly, that the recognition of multiple methodologies for determining validated educational research outcomes needs to be further considered. Secondly, that more information is required regarding effective intensity and duration of interventions for older students experiencing LD. Thirdly, that the appropriateness of a mixed-methods research design for structuring comprehensive investigations into the complex phenomena of LD in the middle-school years warrants consideration. An accompanying, generic recommendation is that consistency in terminology and identification criteria within the field of learning difficulties be established. Each of these recommendations also requires greater clarity and consistency within and between the disciplines which contribute to research about learning difficulties and disabilities to strengthen the scientific foundations of the field.

Implications for practice. The critical role that teachers have in influencing student learning outcomes was identified in the literature review. Most notably, the provision of quality teaching by competent teachers is a major variable influencing student achievement. This is particularly the case for students experiencing LD (Hattie, 2005; Mastropieri & Scruggs, 2002; Sanders & Rivers, 1996; Schacter & Thum, 2004). When teaching and learning are viewed from an information-processing perspective, educators can gain critical understandings about the cognitive processes of learning and use this information to support assessment, planning and implementing effective educational programs.

In contemporary, inclusive, Australian classroom settings, teachers are increasingly required to make adjustments to their instructional practices to cater more broadly for the learning needs of all their students (see Disability Standards for Education, Commonwealth of Australia, 2005). In order to meet this requirement, an informative way for classroom teachers to consider the needs of their students with LD would be in terms of cognitive processing issues and resulting obstacles to learning. When teachers use the information-processing perspective as a conceptual basis to identify obstacles to learning commonly experienced by students with LD, and strengthen instruction using responsive strategies and approaches, they may better enable students to overcome or work around these difficulties, and more fully participate in a wide range of teaching and learning activities.

There is evidence to suggest that much of the instruction that takes place with adolescents experiencing LD does not adhere to validated instructional practices (see Deshler, 2005). However, the need for more effective instructional approaches by classroom and support teachers for their students experiencing LD cannot be expected to happen without systematic pre-service and in-service professional development provisions. Currently, in Australia, structured teacher professional development is not on-going, and teachers are often expected to implement changes in their practice after minimal and ad hoc professional development. These limitations form a key obstacle to "best evidence being transformed to best practice" (Prime Ministers Science, Engineering and Innovation Council, PMSEIC, 2009).

Comments in the research literature calling for improved professional development opportunities for teachers (e.g. Louden et al., National Center for Learning Disabilities, 2010; Westwood, 2011) reflect needs expressed by teachers themselves. Australian teachers want to address a perceived lack of engagement in learning among students, to improve their attitudes to learning and to ensure that all students experience success and enjoyment in learning (Cuttance, 2001). However, at times teachers are bewildered by the wide range of learning needs in their classrooms and concerned about their own levels of professional knowledge to assist them to cater for students with special education needs (Westwood & Graham, 2003). When surveyed, teachers in regional and remote areas of Australia indicated a high level of unmet need in terms of adequate resourcing to develop appropriate learning support programs that encompass student diversity, and identified a requirement for professional development to support teaching and learning for Indigenous and special needs students (Lyons, Cooksey, Panizzon, Parnell, & Pegg, 2006). This survey confirmed that teachers require on-going, systematic, consistent, high-quality teacher professional development to support more effective teaching for students experiencing LD.

Implications for practice indirectly related to the study reported here include considerations about how teachers, schools and educational systems can best support students experiencing LD to achieve improved learning outcomes. Although the crucial role of effective classroom teaching in improving learning outcomes has been identified, this does not imply that the classroom teacher should have sole responsibility, nor that classroom or intervention support is the only requirement for gaining improved learning outcomes for students with LD. Effective classroom teaching and the provision of appropriate adjustments needs to be supported within a school-wide, and system-wide, approach to service provision for students experiencing persistent LD. Sustainable, effective support for students experiencing LD requires a systematic approach.

The response to intervention framework (RtI, also referred to as ‘responsiveness to intervention’), is primarily a model of multi-tiered service provision (Johnson, Mellard, Fuchs & McKnight, 2006) which also serves as an alternative framework to the achievement-discrepancy model for identifying under-achieving students (Fuchs & Fuchs, 2006). The RtI framework is often cited in relation to early identification and intervention for young students in reading (e. g., Vaughn & Fuchs, 20003), although it is also increasingly applied to provisions for older students with LD in reading (see Kamil, Borman, Dole, Kral, Salinger, & Torgesen, 2009; Vaughn, Cirino, Wanzek, Wexler, Fletcher, Denton, Barth, Romain, & Francis, 2010), and mathematics (see Bryant & Bryant, 2008; Gersten et.al, 2009). Some modifications may be necessary to adjust the RtI framework to a secondary setting, for example, a different process for identification of low-achieving students may be required (Vaughn & Fletcher, 2010).

RtI has been influential in the United States in the last decade, particularly as it applies to identifying low-achieving students (see, Fuchs & Fuchs, 2006). In Australia, where formal identification of students with LD is not routinely required to access school learning support services (Graham & Bailey, 2007), the construct of RtI is particularly relevant in terms of assessment, monitoring and the systematic provision of appropriate instruction for low-achieving students. While early identification of under-achieving students through curriculum-based assessment and monitoring is an appealing and important tenet of the RtI approach, the potential for the framework to inform a systematic, data-driven, responsive approach to the planning and provision of appropriate support for students experiencing persistent LD is most relevant to the current discussion.

The RtI approach incorporates a preventative, multi-tiered intervention strategy in which each tier represents increasingly intense services that are associated with increasing levels of learner need (see Fuchs & Fuchs, 2006; Vaughn, Wanzek, Woodruff, & Linan-Thompson, 2007). Service delivery within an RtI model is often based on a three-tier framework, comparable to that used for service-delivery practices such as positive behaviour support (Johnson, Mellard, Fuchs & McKnight, 2006).

Consistent with the least-intensive to most-intensive design of the multi-tiered RtI model, at Tier 1 students are provided with effective, evidence-based instruction in their classroom with information from universal, curriculum-based assessment and monitoring used to inform instructional decision-making. Students who fail to respond to this core, universal instruction are identified through assessment and monitoring as 'at risk' of not achieving specified learning outcomes. These students then participate in small-group supplementary Tier 2 instruction, or, when necessary, more intensive Tier 3 interventions (Vaughn, 2003). RtI is yet to be widely implemented as an effective service provision model in Australia, however, research on multi-tier implementations in the United States has indicated evidence of growth in student performance, increased task completion, and reduction in special education referrals (see Glover & Di Perna, 2007).

In relation to the current study and its practical implications, the RtI framework is relevant to systematic service provision planning at a classroom, school, and school system level for low-achieving students in the middle-school years. With validation from further research trials, the *QuickSmart* intervention programs could fit within the RtI framework as a Tier 3 intervention. It has many of the critical features of a tertiary intervention, including a focus on small group instruction, mastery of content, frequent progress monitoring, and an extended duration of intervention (Johnson, Mellard, Fuchs & McKnight, 2006). Further, prioritising basic academic skills as an intervention focus is important because improvements are generalisable broadly, throughout the curriculum and beyond (Daly, Martens, Barnett, Witt, & Olson, 2007).

Implementing RtI as a systematic service provision model in Australia has considerable potential benefits for students experiencing LD and their teachers, as well as for school systems. Early identification and effective classroom teaching (Tier 1), and small group evidence-interventions (Tier 2) play a significant role in preventing persistent LD as students progress through school, and in preventing an escalation of costs associated with teaching students with disabilities (see Fuchs & Fuchs, 2006). Also, individualised programs (Tier 3) can become more effective because they more specifically target students with high-level educational needs, rather than students who were taught improperly, or students who could not keep up with the rest of the class (Gersten & Domino, 2006). Further, the implementation of such a consistent and systematic approach to supporting students experiencing LD has potential to promote wider and more rigorous implementation of validated instructional practices, and in doing so, to replace inconsistent and haphazard provisions.

In review, the implications for practice coming from this study are that the cognitive aspects of LD, framed within the information-processing perspective, need to be considered by classroom teachers and learning support teachers when planning and delivering instruction to students in the middle-school years with LD. Further, teachers need to be supported in this and other endeavours to improve low-achieving students' learning outcomes, by the provision of on-going, consistent, high-quality teacher professional development. Additionally, the implementation of a coherent model of intervention, incorporating validated instructional practices, progress monitoring and program evaluation, has great potential to enhance the effectiveness and efficiency of learning support programs. As the resources available to support improved learning outcomes for students in the middle-school years experiencing LD are very limited, it is vital that these resources are used for targeted, validated programs and approaches that fit within a systematic, strategic framework. In this regard the RtI model has much to offer in the Australian context, as way forward for educational systems seeking to provide comprehensive, systematic and effective instruction and intervention for middle-school students experiencing LD.

Overall Summary

This research report began by reviewing the literature related to LD in reading and mathematics, and then identified issues and approaches relevant to students in the middle-school years. The literature review then focused on LD from an information-processing perspective and explored the prospect of improving automaticity in basic academic skills as an appropriate instructional approach for students with LD in the middle-school years. Research questions and a research theme were presented which focused on the effects of improving automaticity, in terms of speed and accuracy, of basic academic skills, the impact of this on standardised test performance, and developing informative profiles of a sample of participating students.

After considering the context of the research, a mixed methods approach was selected as most appropriate for the investigation. The context for the research, an intervention implemented in a regular school setting, presented some constraints, particularly that no control group was available and that the amount of testing was limited. However, a well-considered selection of participants and the use of reliable measurement instruments were perceived to enhance the validity of the study. Another key design consideration was to maintain high ecological validity, in order to ensure that the research reported was relevant to the needs of middle-school students with LD and their teachers in contemporary Australian school settings.

The *QuickSmart* intervention programs for reading and mathematics were selected as the means of improving automaticity in basic academic skills for the participating students. Although the research design did not aim to test the efficacy of the intervention itself, detailed descriptions of the *QuickSmart* reading and *QuickSmart* mathematics programs were provided, to facilitate replication and to enable consideration, after implementation, of instructional features that may have influenced student performance.

Statistical analysis of the results indicated that the participant students were able to improve significantly their automaticity in basic academic skills as a result of participating in the intervention. These gains were maintained one year after the intervention ceased. Specifically, at the conclusion of the intervention, participant students' automaticity in word and sentence reading or in solving basic mathematics calculations was similar to that of the comparison group of average-achieving students. *QuickSmart* students' performance on standardised tests also showed significant improvement. The six profiles of participant students gave insight into 'real life' examples of inefficient and inconsistent approaches to learning commonly displayed by students with LD, and showed how these older students needed a significant number of lessons incorporating repeated, deliberate practice opportunities in order to learn more efficient strategies and improve automaticity in basic academic skills.

Throughout the research process, the information-processing model of cognition for learning was informative and relevant, particularly in understanding the participant students' approaches to learning. The research literature highlighted the critical role of the efficient use of limited working-memory resources in under-pinning effective learning. This was evidenced by observations, at the beginning of the intervention, of participant students' use of slow, error-prone strategies to complete basic academic skills tasks. These students were 'stuck' on components of a task that should require minimal cognitive effort.

The aim of the *QuickSmart* intervention programs implemented in this research was to promote more efficient use of working-memory resources by supporting students to improve automaticity in basic academic skills. The findings of the study, particularly that the participant students improved performance on standardised tests and maintained automaticity gains one year later, suggest that this approach, which promotes more effective use of working-memory resources, was successful. A key practical implication of the findings is that educators facilitate more effective learning by students with LD in classroom and intervention settings by considering the cognitive processes required for learning, and implementing appropriate adjustments and responsive strategies. However, on-going, high quality professional development for teachers is needed to support this endeavour.

The findings of this study support the argument that students in the middle-school years who experience persistent LD can make gains with their learning and that, with effective intervention support, the achievement gap between these learners and their average-achieving peers can be narrowed. Accordingly, the real challenge is for researchers, educators and education systems to overcome complacent attitudes which lead to the acceptance of students in the middle-school years experiencing LD falling further behind their peers. As Deshler

(2005) states: “Clearly, we have a long way to go in implementing what we know”. Although further research about older students with LD is required, evidence-based information is now available to support effective interventions for improving their academic skills. Effective service provision models to support implementation also exist. What is perhaps lacking, and in need of urgent attention, is the financial and policy commitment to ensure that students in the middle-school years experiencing learning difficulties are provided with targeted support which better enables these young Australians to achieve their full learning and living potential, and to take their place as valued, contributing members of our future communities.

POST-SCRIPT

Following on from this research, the *QuickSmart* intervention programs in reading and basic mathematics have been further developed by a research team based at the University of New England’s (UNE) National Centre of Science, Information and Communication Technology, and Mathematics Education for Rural and Regional Australia (SiMERR, see http://www.une.edu.au/simerr/pages/index.php). Currently, the *QuickSmart* intervention programs are implemented in approximately five percent of Australian schools in remote, regional and metropolitan settings, with demand increasing. The *QuickSmart* intervention programs are funded through school and district/diocesan allocations, or from Commonwealth Government initiatives, such as ‘Closing the Gap’ and ‘National Partnerships on Low-SES School Communities’. I have been fortunate to continue my involvement with these intervention programs through my academic association with UNE, and through my employment with the Diocese of Lismore Catholic Education Office, who support the implementation of *QuickSmart* in its parish schools.

The following publications have been based on elements of this research:

Bellert, A. 2009. Narrowing the gap: A report on the *QuickSmart* mathematics intervention. *Australian Journal of Learning Difficulties, 14* (2), 171-184.

Bellert, A 2008. Narrowing the gap in the regular classroom: Successful strategies for teaching and learning in the middle school years. In L. Graham (Ed.), *Proceedings of the Narrowing the Gap: Addressing Educational Disadvantage Conference*, April, University of New England, Australia, pp 63-83.

Bellert, A. & Graham, L. 2006. Caught in the middle: Reaching and teaching middle years students with learning difficulties. *Australian Journal of Middle Schooling*, *6*(1), 3-10.

Graham, L. Bellert, A. & Pegg, J. 2007. Supporting students in the middle school years with learning difficulties in mathematics: Research into classroom practice. *Australasian Journal of Special Education, 31*(2), 171-182 .

Graham, L., Bellert, A., Thomas, J. & Pegg, J. 2007. QuickSmart: A basic academic skills intervention for middle-years students with learning difficulties. (North American) *Journal of Learning Disabilities, 40*(5), 410-419.

During the course of my studies I have been the recipient of the following awards:

Learning Difficulties Australia (LDA) Tertiary Student Award, 2008.
UNE's Faculty of the Professions Inaugural Rod Gerber Memorial Scholarship for Post-Graduate Students, 2009.

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APPENDICES

Appendix A

EFFECTIVE INSTRUCTIONAL APPROACHES FOR MIDDLE-SCHOOL STUDENTS EXPERIENCING LEARNING DIFFICULTIES

Teacher Behaviour	Enables Students to…..
• Making the purpose of the intended content clear to students	• Know why and how the learning might be useful to them
• Delivering a sequence of lessons that are clear, logical, accurate & rich in examples drawn from the students' own experiences	• Build on prior learning, to connect it to their 'reality' thus facilitating greater generalisation
• Using materials & resources that provide visual representation of concepts & relationships	• Learn with modes other than verbal, to access potential learning strengths and understandings
• To facilitate showing, telling, explaining, modeling & demonstrating by both teacher & peers	• Experience a worked example, have a point of reference to connect learning
• Direct, explicit, task-approach strategy instruction & training	• Learn how to do a task or solve a problem independently
• Demonstrating & using think-aloud protocols and self talk	• Verbalise & reflect upon how learning can take place
• Providing opportunity for guided practice of content knowledge, skills & strategies	• Experience successful practice & being a 'successful learner'
• Providing opportunity for lots of independent practice of previously learnt strategies, content knowledge and skills	• Make progress towards mastery and automaticity, this enables participation in other aspects of the task, or in different tasks
• Revising previously taught material at regular intervals	• Consolidate the foundations - to re-visit what is already known, to further develop understandings
• Regular monitoring of students' learning including giving specific feedback about practice and performance	• Become more aware of their progress in learning • Demonstrate and determine what they know
• Pre-teaching the language of the subject – the key vocabulary	• Understand & use keywords and concepts, to master the basic 'tools' enabling comprehension of content
• Regulating the complexity of the academic work by controlling task difficulty or differentiating content & tasks to suit learner needs	• Undertake at least some of the core content successfully by working at an appropriate level
• Ensuring that students are engaged in academic activities for most of the available learning time	• To spend more time on task so that adequate engagement & more learning can take place

Appendix B

CONFIGURATION OF STUDENTS INVOLVED IN THE RESEARCH

Study	Groups	Year 5 n =	Year 7 n =	Gender per Year Group
Research Questions 1 & 2	Reading Participants (n = 10)	6	4	Yr 5 – 4 boys, 2 girls Yr 7 – 2 boys, 2 girls
	Reading Comparisons (n = 8)	6	2	Yr 5 – 4 boys, 2 girls Yr 7 – 1 boy, 1 girl
	Mathematics Participants (n = 12)	6	6	Yr 5 – 2 boys, 4 girls Yr 7 – 3 boys, 3 girls
	Mathematics Comparisons (n = 8)	6	2	Yr 5 – 3 boys, 3 girls Yr 7 – 1 boy, 1 girl
Research Question 3	Reading Participants (n = 7)	5	2	Yr 5 – 4 boys, 1 girl Yr 7 – 2 girls
	Mathematics Participants (n = 10)	6	4	Yr 5 – 2 boys, 4 girls Yr 7 – 1 boy, 3 girls
Theme	Reading Participants (n = 3)	2	1	Yr 5 – 1 boy, 1 girl Yr 7 – 1 girl
	Mathematics Participants (n = 3)	2	1	Yr 5 – 1 boy, 1 girl Yr 7 – 1 boy

Appendix C

THE 3H STRATEGY

1. Head First!

Before reading	What do I know?
During reading	What don't I understand?
After reading	What do I need to find out?

Ask for help if you need to.
Content?
Vocabulary?
How to?

Now use the 3H's to remind you where the answers to questions are found:

2. HERE

In one sentence from the passage.

3. HIDDEN

Join together.
The answer is in two or more parts of the passage, or
The answer comes from joining together information from the passage and information that you already know.

4. In my HEAD

Use what you already know to answer the question.
Use your own knowledge or join together your knowledge and information from the passage

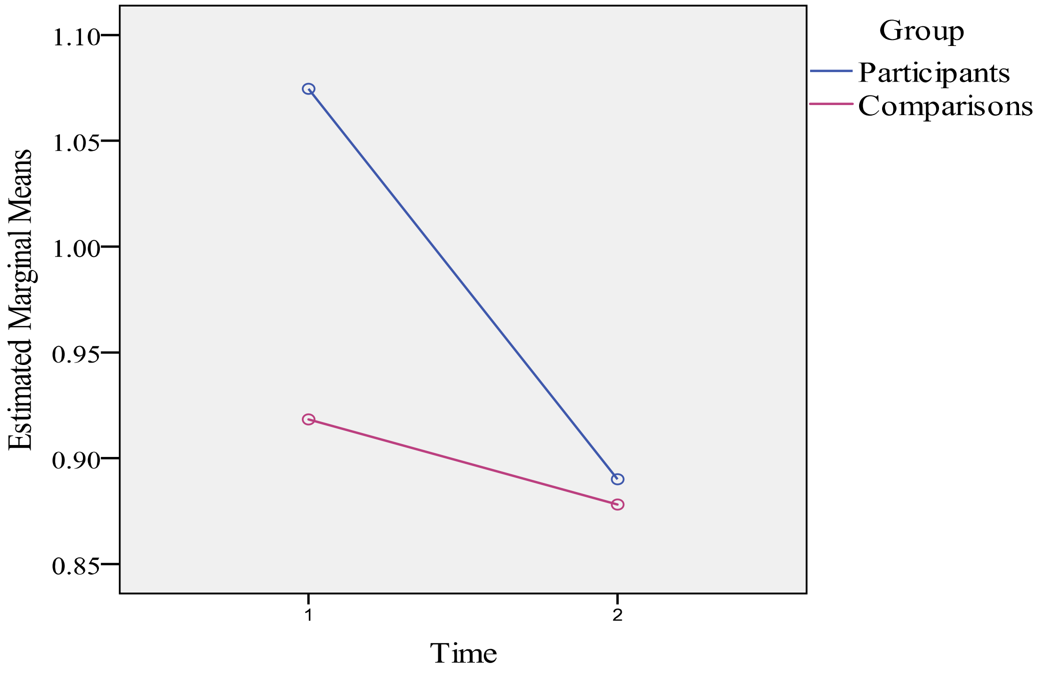
5. Check Your Answers.

Reread each question and your answer to see if they fit together. How confident are you of your answer? After you have finished all the questions, return to any answers you are not sure of. Go through the 3H strategy and check these answers again. You should have a reason for each of your answers. You do? Well done!

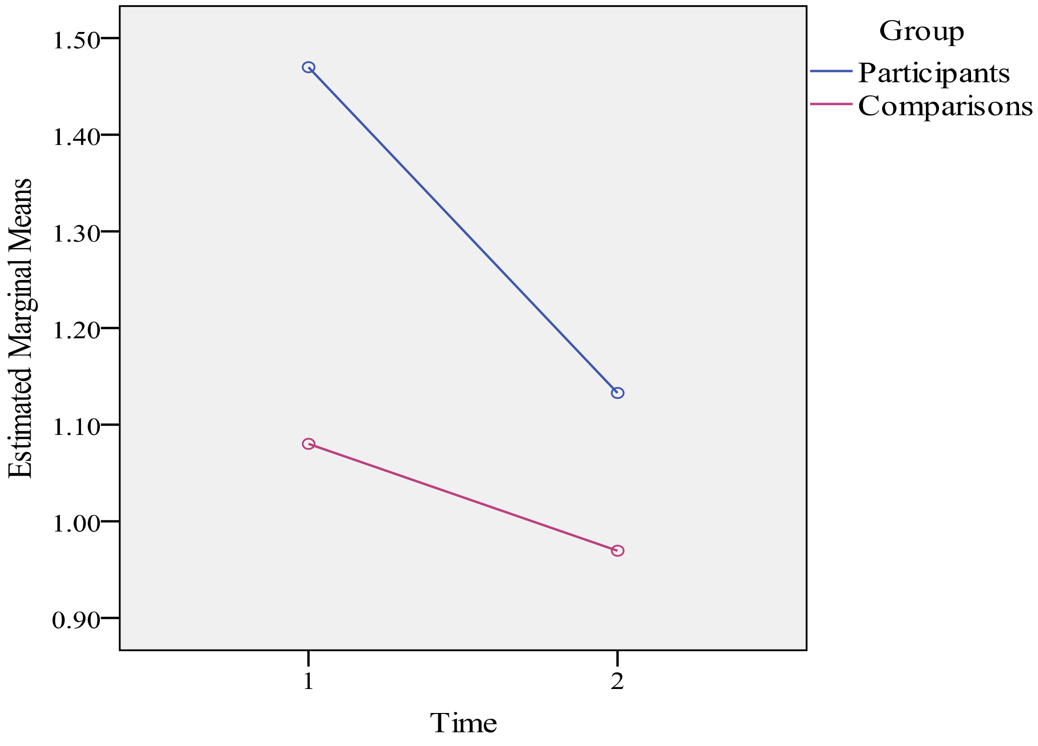
(Graham & Wong, 1993)

Appendix D

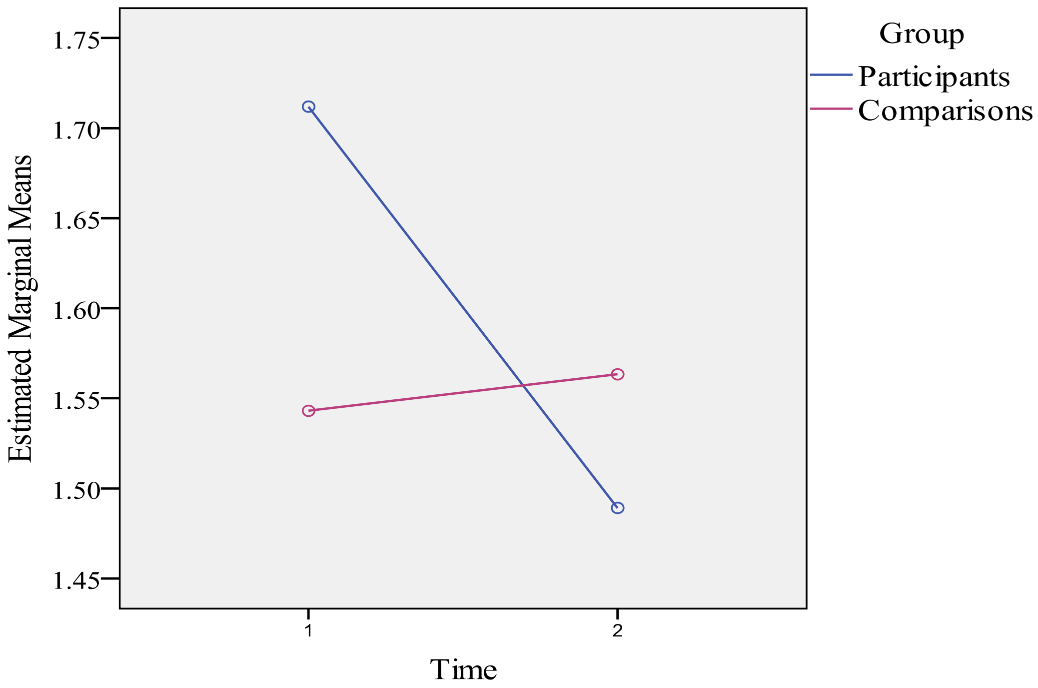
ESTIMATED MARGINAL MEANS FOR CAAS READING RESPONSE LATENCY



Appendix D-1. Estimated marginal means for log-transformed response latency – CAAS Elementary Word Test



Appendix D-2. Estimated marginal means for log-transformed response latency – CAAS Middle Word Test



Appendix D-3. Estimated marginal means for log-transformed response latency – CAAS Sentence Test

Appendix E

PARTICIPANTS' AND COMPARISONS' RAW DATA: INDIVIDUAL AND GROUP MEAN GAINS IN RESPONSE LATENCY AND ACCURACY FOR CAAS ELEMENTARY WORD TEST

Students	Initial Response Latency (s)	Final Response Latency (s)	Response Latency Net Gain (s)	Initial Accuracy (%)	Final Accuracy (%)	Accuracy Net Gain (%)
Participants						
RM - PN	1.21	0.77	0.44	96.6	100	3.4
JP - PN	1.11	0.82	0.29	93.1	89.5	-3.6
GW - PN	1.08	0.82	0.26	97.4	100	2.6
JC - PN	0.88	0.76	0.12	100	100	*
TH - PN	1.19	0.8	0.39	100	100	*
BD - PN	2.17	0.71	1.47	86.2	94.9	8.7
RS - PO	1.31	0.87	0.45	97.1	100	2.9
SW - PO	0.70	0.62	0.08	100	100	*
EF - PO	1.69	0.77	0.93	100	100	*
RF - PO	1.07	0.86	0.22	97.4	94.7	-2.7
Participants' Group Mean *(SD)*	1.24 (.42)	0.78 (.07)	0.46 (.42)	96.78 (4.32)	97.91 (3.66)	1.88 (4.11)
Comparisons						
BLR - CN	0.83	0.86	-0.02	97.4	100	2.6
CR - CN	0.84	0.69	0.15	100	100	*
JR - CN	0.71	0.82	-0.11	100	100	*
LS - CN	0.74	0.72	0.02	97.4	100	2.6
AW - CN	0.72	0.64	0.09	97.4	100	2.6
SKR - CN	0.76	0.94	-0.17	97.4	100	2.6
AM - CO	0.86	0.63	0.23	100	100	*
MH - CO	1.27	0.81	0.46	97.4	100	2.6
Comparisons' Group Mean *(SD)*	0.84 (0.18)	.76 (.11)	.08 (.2)	98.37 (1.34)	100 (0)	2.6 (0)

Note: * = maintained 100% accuracy

Appendix F

PARTICIPANTS' AND COMPARISONS' RAW DATA: INDIVIDUAL AND GROUP MEAN GAINS IN RESPONSE LATENCY AND ACCURACY FOR CAAS MIDDLE WORD TEST

Students	Initial Response Latency (s)	Final Response Latency (s)	Response Latency Net Gain (s)	Initial Accuracy (%)	Final Accuracy (%)	Accuracy Net Gain (%)
Participants						
RM - PN	4.09	1.91	2.18	75	85.7	10.7
JP - PN	5.00	1.09	3.91	0	12.5	12.1
GW - PN	3.60	1.96	1.65	59.1	89.3	30.2
JC - PN	2.71	0.98	1.73	85	96.6	11.6
TH - PN	2.91	1.24	1.67	75	96.2	21.2
BD - PN	5.00	4.16	.84	0	25	25
RS - PO	1.9	1.04	0.86	48.1	100	51.9
SW - PO	1.01	0.65	0.36	85.7	100	14.3
EF - PO	2.74	0.88	1.86	70	96.4	26.4
RF - PO	3.3	1.74	1.55	0	50	50
Participants' Group Mean *(SD)*	3.23 (1.27)	1.56 (1.02)	1.66 (0.97)	49.79 (36.11)	75.17 (33.29)	25.38 (15.08)
Comparisons						
BLR - CN	1.23	0.92	0.31	95.7	100	4.3
CR - CN	0.78	0.76	0.02	100	100	*
JR - CN	0.97	0.99	-0.02	81.8	94.1	12.3
LS - CN	1.00	0.78	0.23	100	100	*
AW - CN	0.78	0.69	0.08	91.3	95.7	4.4
SKR - CN	0.93	0.97	-0.03	95.7	89.5	-6.2
AM - CO	1.83	0.94	0.90	76.9	84.6	7.7
MH - CO	3.54	1.70	1.84	67.9	75	7.1
Comparisons' Group Mean *(SD)*	1.38 (0.94)	.97 (0.31)	0.42 (0.65)	88.66 (11.83)	92.36 (8.94)	4.93 (6.18)

Note: * = maintained 100% accuracy

Appendix G

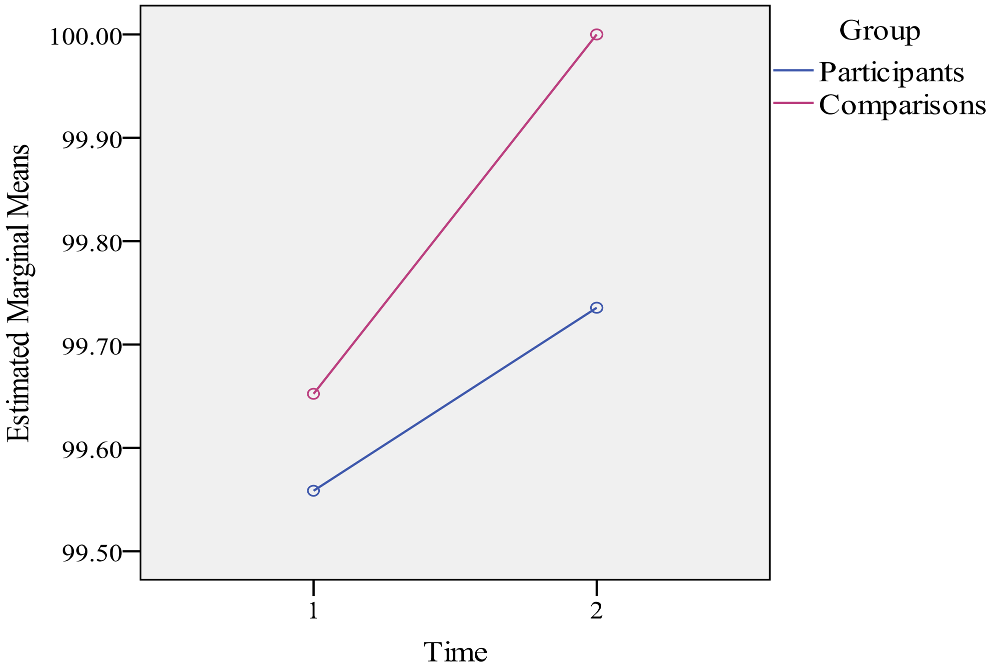
PARTICIPANTS' AND COMPARISONS' RAW DATA: INDIVIDUAL AND GROUP MEAN GAINS IN RESPONSE LATENCY AND ACCURACY FOR CAAS SENTENCE TEST

Students	**Initial Response Latency (s)**	**Final Response Latency (s)**	**Response Latency Net Gain (s)**	**Initial Accuracy (%)**	**Final Accuracy (%)**	**Accuracy Net Gain (%)**
Participants						
RM - PN	6.54	1.75	4.79	93.3	85.7	-7.6
JP - PN	4.55	3.40	1.15	69.2	100	30.8
GW - PN	6.10	4.41	1.69	100	100	*
JC - PN	4.74	4.15	0.59	100	100	*
TH - PN	5.64	3.60	2.03	100	100	*
BD - PN	11.84	4.20	7.65	61.5	92.3	30.8
RS - PO	3.86	3.58	0.28	86.7	100	13.3
SW - PO	2.96	2.97	-0.01	100	100	*
EF - PO	5.22	1.65	3.56	92.9	93.3	0.4
RF - PO	3.85	2.69	1.15	100	93.3	-6.7
Participants' Group Mean *(SD)*	5.53 (2.47)	3.24 (0.97)	2.29 (2.4)	90.36 (14.04)	96.46 (5.04)	10.17 (17.65)
Comparisons						
BLR - CN	2.20	5.07	2.87	100	100	*
CR - CN	3.86	3.89	-0.04	100	100	*
JR - CN	3.61	4.19	-0.58	93.3	92.9	-0.4
LS - CN	3.52	2.78	0.74	100	100	*
AW - CN	4.55	4..21	0.33	100	100	*
SKR - CN	4.58	4.44	0.14	93.3	92.9	-0.4
AM - CO	2.82	2.50	0.32	100	100	*
MH - CO	3.48	2.98	0.50	100	100	*
Comparisons' Group Mean *(SD)*	3.58 (0.80)	3.76 (0.90)	-0.18 (1.15)	98.33 (3.10)	98.32 (3.29)	-0.04 (0)

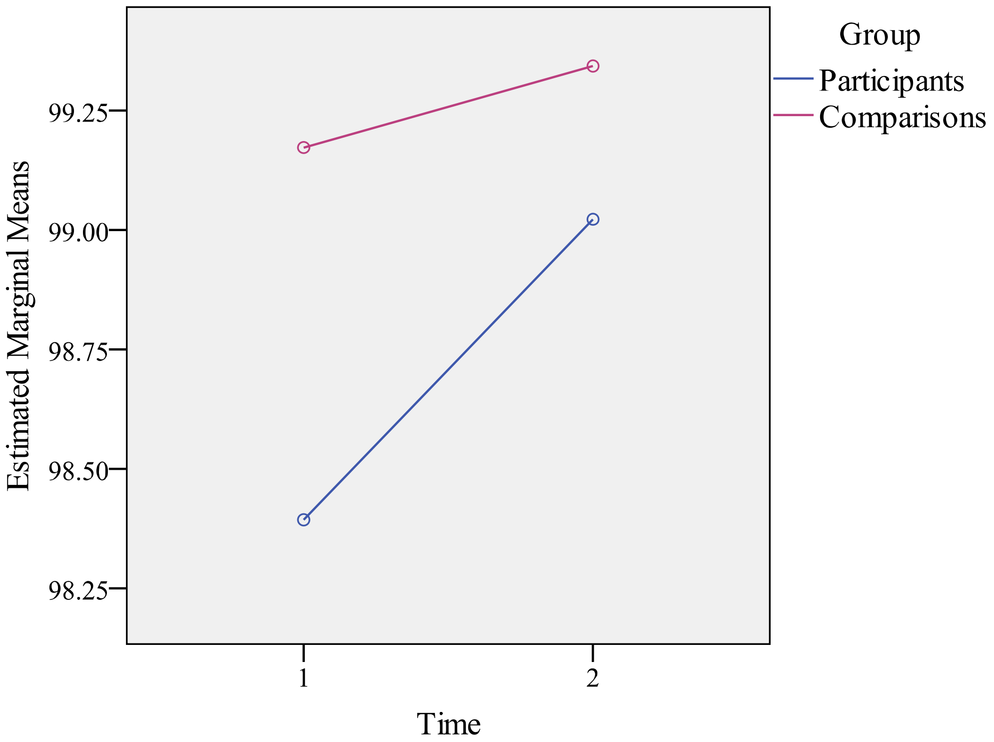
Note: * = maintained 100% accuracy

Appendix H

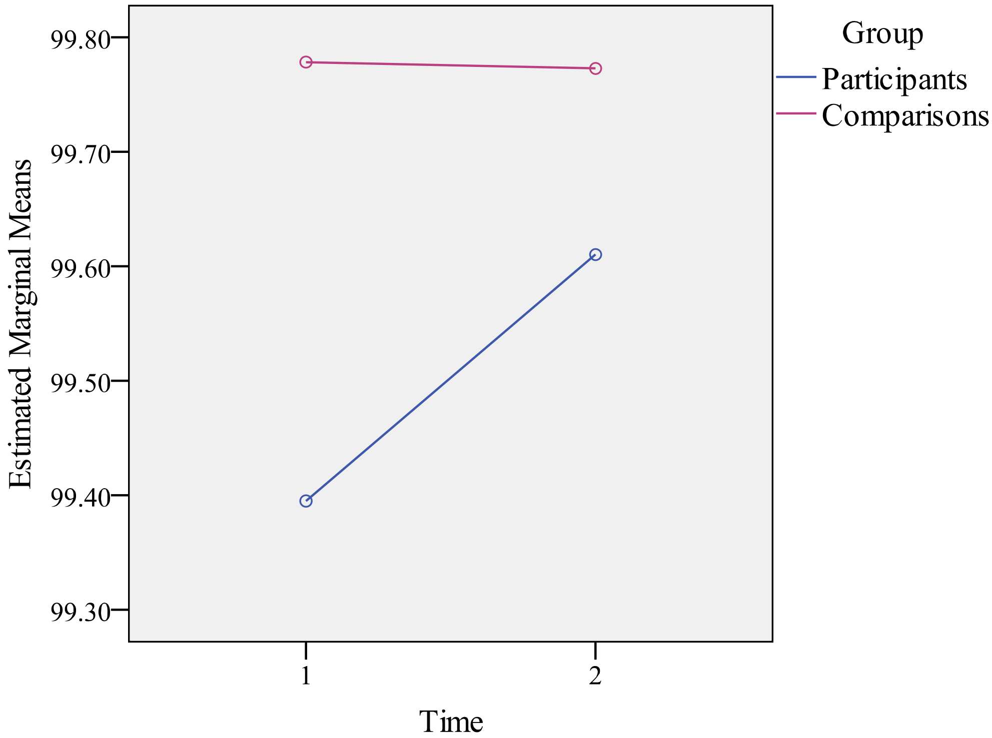
ESTIMATED MARGINAL MEANS FOR CAAS READING ACCURACY



Appendix H-1. Estimated marginal means for log-transformed accuracy – CAAS Elementary Word Test



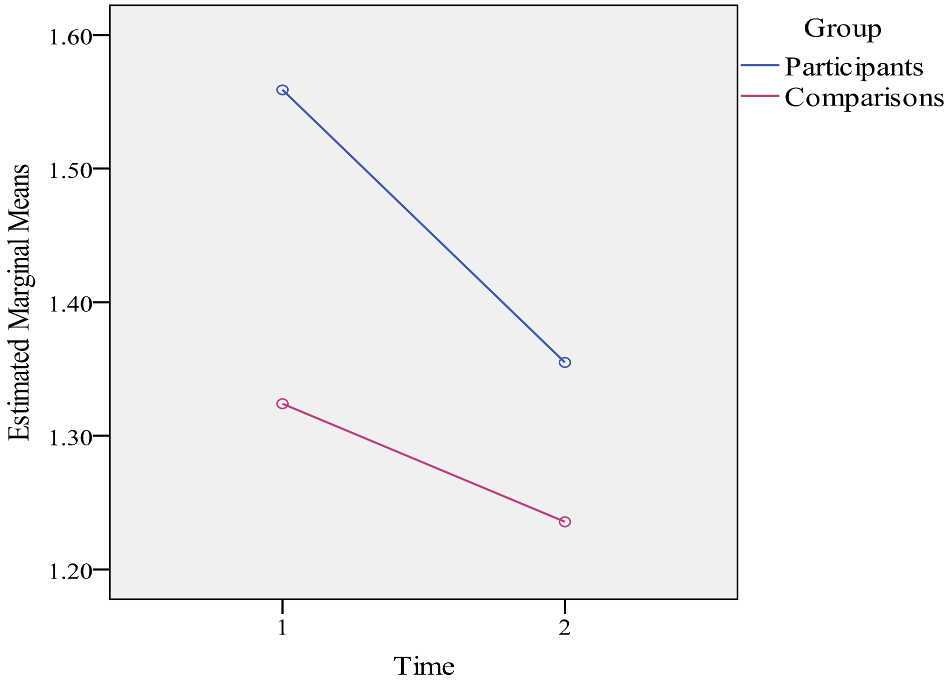
Appendix H-2. Estimated marginal means for log-transformed accuracy – CAAS Middle Word Test



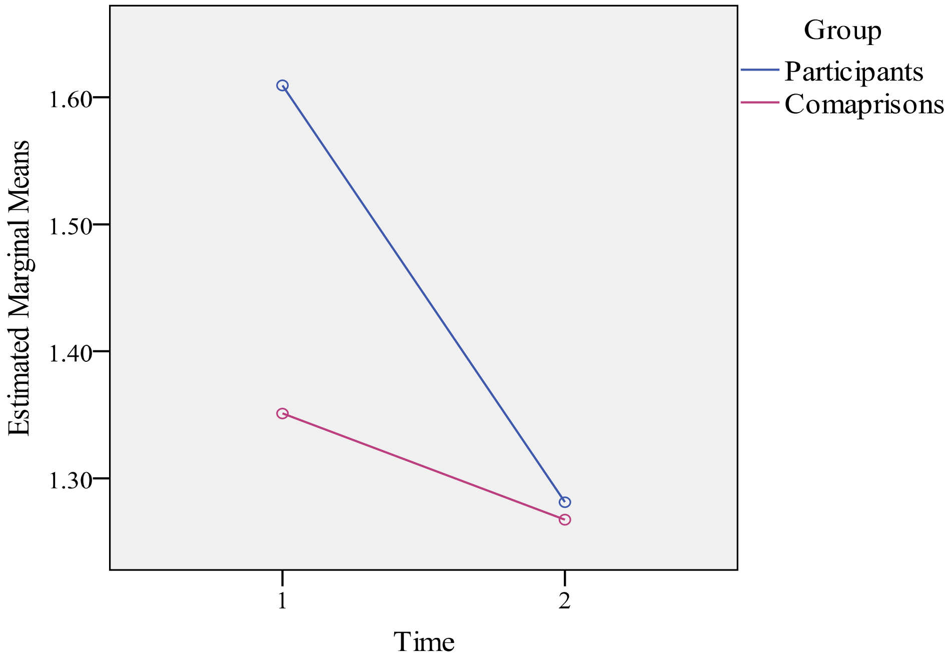
Appendix H-3. Estimated marginal means for log-transformed accuracy – CAAS Sentence Test

Appendix I

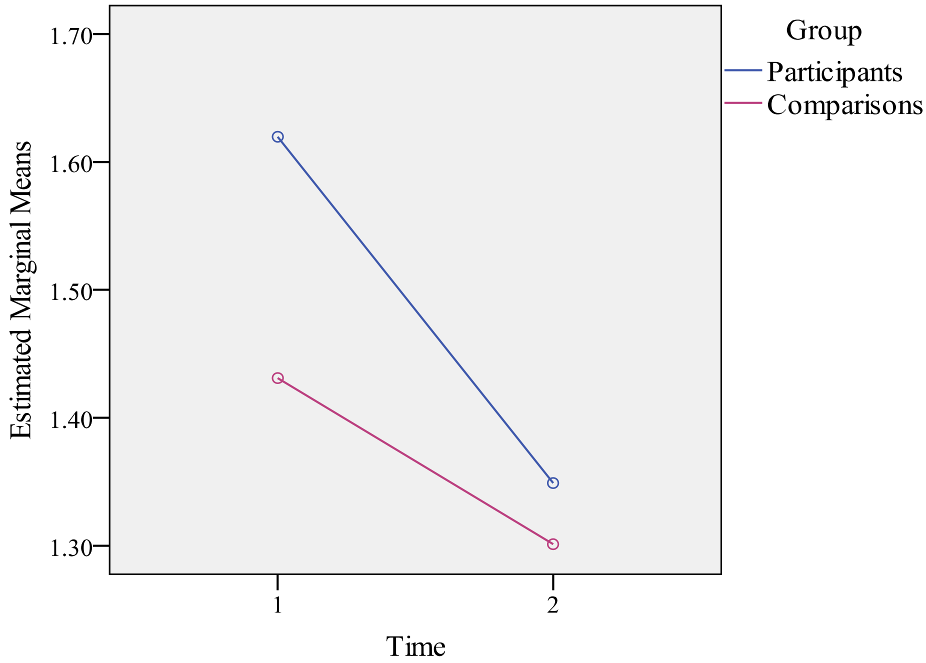
ESTIMATED MARGINAL MEANS FOR CAAS MATHEMATICS RESPONSE LATENCY



Appendix I-1. Estimated marginal means for log-transformed response latency – CAAS Addition



Appendix I-2. Estimated marginal means for log-transformed response latency – CAAS Subtraction



Appendix I-3. Estimated marginal means for log-transformed response latency – CAAS Multiplication

Appendix J

PARTICIPANTS' AND COMPARISONS' RAW DATA: INDIVIDUAL AND GROUP MEAN GAINS IN RESPONSE LATENCY AND ACCURACY FOR CAAS ADDITION TEST

Students	Initial Response Latency (s)	Final Response Latency (s)	Response Latency Net Gain (s)	Initial Accuracy (%)	Final Accuracy (%)	Accuracy Net Gain (%)
Participants						
CN - PN	2.81	1.72	1.09	100	88.9	-11.1
MS - PN	6.12	2.55	3.57	85	94.1	9.1
TS - PN	4.13	3.73	0.41	94.7	100	5.3
VP - PN	7.63	2.99	4.64	50	100	50
NH - PN	3.60	1.60	2.00	95	100	5
YM - PN	4.03	2.38	1.65	100	94.1	-5.9
AN - PO	2.67	1.78	0.88	100	100	*
AMC - PO	2.59	1.70	0.89	100	100	*
CS - PO	2.49	2.32	0.17	89.5	90	0.5
KB - PO	2.63	2.38	0.25	78.9	65	-13.9
BR - PO	3.39	2.09	1.30	100	100	*
KJ - PO	4.23	2.79	1.44	89.5	94.1	4.6
Participants' Group Mean *(SD)*	3.86 (1.58)	2.33 (0.62)	1.52 (1.34)	90.22 (14.4)	93.85 (9.99)	4.85 (18.69)
Comparisons						
BLM - CN	1.72	1.55	0.17	100	100	*
BC - CN	3.11	2.21	0.90	95	100	5
Bon - CN	2.17	1.66	0.51	100	95	-5
JF - CN	3.47	2.51	0.96	94.7	91.7	-3
RR - CN	2.10	1.82	0.28	89.5	86.7	-2.8
SKM - CN	2.55	2.28	0.27	100	100	*
DH - CO	1.72	1.52	0.20	95	100	5
JG - CO	1.06	0.85	0.21	100	100	*
Comparisons' Group Mean (sd)	2.24 (.78)	1.8 (.53)	.43 (.32)	96.77 (3.87)	96.67 (5.1)	-0.16 (4.79)

Note: * = maintained 100% accuracy

Appendix K

PARTICIPANTS' AND COMPARISONS' RAW DATA: INDIVIDUAL AND GROUP MEAN GAINS IN RESPONSE LATENCY AND ACCURACY FOR CAAS SUBTRACTION TEST

Students	Initial Response Latency (s)	Final Response Latency (s)	Response Latency Net Gain (s)	Initial Accuracy (%)	Final Accuracy (%)	Accuracy Net Gain (%)
Participants						
CN - PN	9.56	2.11	7.44	80	94.7	14.7
MS - PN	8.65	3.37	5.28	42.9	77.8	34.9
TS - PN	5.60	2.97	2.62	72.2	100	27.8
VP - PN	7.91	2.22	5.69	68.4	100	31.6
NH - PN	3.35	1.74	1.61	94.7	100	5.3
YM - PN	3.61	1.32	2.30	88.9	100	11.1
AN - PO	2.53	2.04	0.49	82.4	94.7	12.3
AMC - PO	2.13	1.37	0.76	100	100	*
CS - PO	2.04	1.55	0.49	100	94.7	-5.3
KB - PO	2.42	1.84	0.57	80	78.9	-1.1
BR - PO	3.69	1.58	2.11	94.7	94.7	*
KJ - PO	4.73	1.75	2.97	88.9	100	11.1
Participants' Group Mean *(SD)*	4.68 (2.66)	1.99 (.62)	2.69 (2.29)	82.76 (16.17)	94.62 (7.99)	14.24 (13.47)
Comparisons						
BLM - CN	1.50	1.58	-0.08	100	100	*
BC - CN	3.90	3.03	0.87	95	92.3	-2.7
Bon - CN	2.52	2.06	0.46	94.4	100	5.6
JF - CN	4.07	2.10	1.98	95	100	5
RR - CN	2.57	1.76	0.81	89.5	93.3	3.8
SKM - CN	2.41	2.49	-0.08	100	100	*
DH - CO	1.52	1.65	-0.13	100	100	*
JG - CO	1.15	0.93	0.21	100	100	*
Comparisons' Group Mean *(SD)*	2.45 (1.08)	1.95 (.63)	.51 (0.71)	96.74 (3.9)	98.2 (3.34)	2.92 (3.82)

Note: * = maintained 100% accuracy

Appendix L

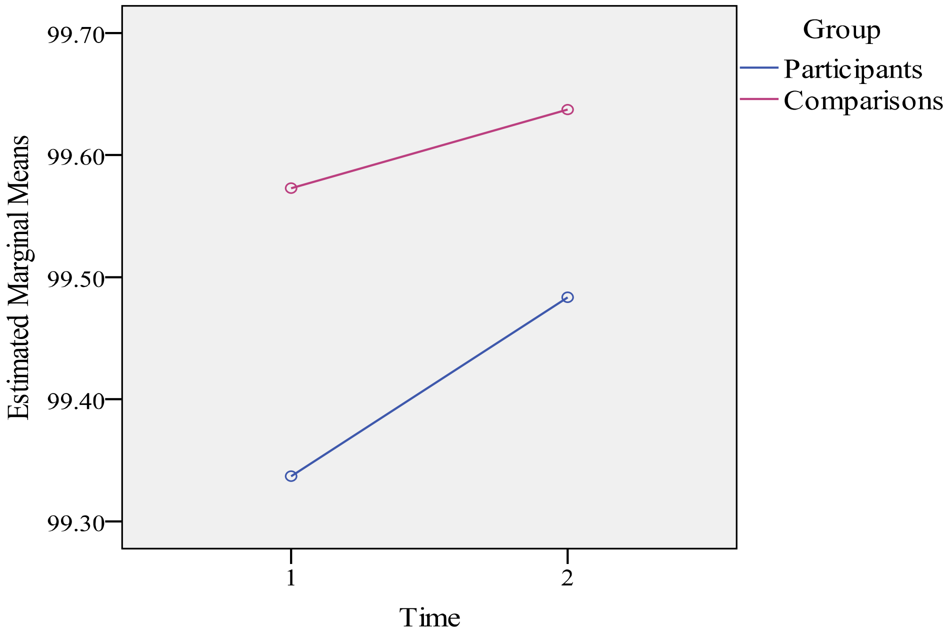
PARTICIPANTS' AND COMPARISONS' RAW DATA: INDIVIDUAL AND GROUP MEAN GAINS IN RESPONSE LATENCY AND ACCURACY FOR CAAS MULTIPLICATION TEST

Students	**Initial Response Latency (s)**	**Final Response Latency (s)**	**Response Latency Net Gain (s)**	**Initial Accuracy (%)**	**Final Accuracy (%)**	**Accuracy Net Gain (%)**
Participants						
CN - PN	7.55	1.49	6.07	60	88.9	28.9
MS - PN	3.77	4.72	-0.95	20	43.8	23.8
TS - PN	11.32	4.23	7.10	50	70	20
VP - PN	5.52	4.52	1.00	58.8	94.4	35.6
NH - PN	6.07	2.01	4.06	68.4	100	31.6
YM - PN	5.40	1.90	3.50	40	75	35
AN - PO	3.26	1.89	1.38	81.3	95	13.7
AMC - PO	3.05	1.55	1.50	94.7	100	5.3
CS - PO	2.54	1.66	0.88	73.7	93.8	20.1
KB - PO	2.30	1.26	1.04	72.2	94.7	22.5
BR - PO	3.80	2.79	1.01	80	89.5	9.5
KJ - PO	2.13	1.79	0.35	94.7	94.4	-0.3
Participants' Group Mean *(SD)*	4.72 (2.67)	2.48 (1.27)	2.24 (2.42)	66.15 (21.98)	86.62 (16.13)	20.47 (11.59)
Comparisons						
BLM - CN	3.72	4.08	-0.36	90	100	10
BC - CN	4.74	2.27	2.47	90	93.3	3.3
Bon - CN	1.70	1.77	-0.07	100	100	*
JF - CN	2.91	1.93	0.98	78.9	80	1.1
RR - CN	3.25	1.73	1.53	66.7	100	33.3
SKM - CN	3.03	2.67	0.36	100	94.1	-5.9
DH - CO	2.94	1.70	1.24	89.5	94.7	5.2
JG - CO	1.11	1.04	0.07	100	100	*
Comparisons' Group Mean *(SD)*	2.92 (1.22)	2.15 (.91)	1.02 (1.04)	89.39 (11.73)	95.26 (6.85)	8.75 (11.97)

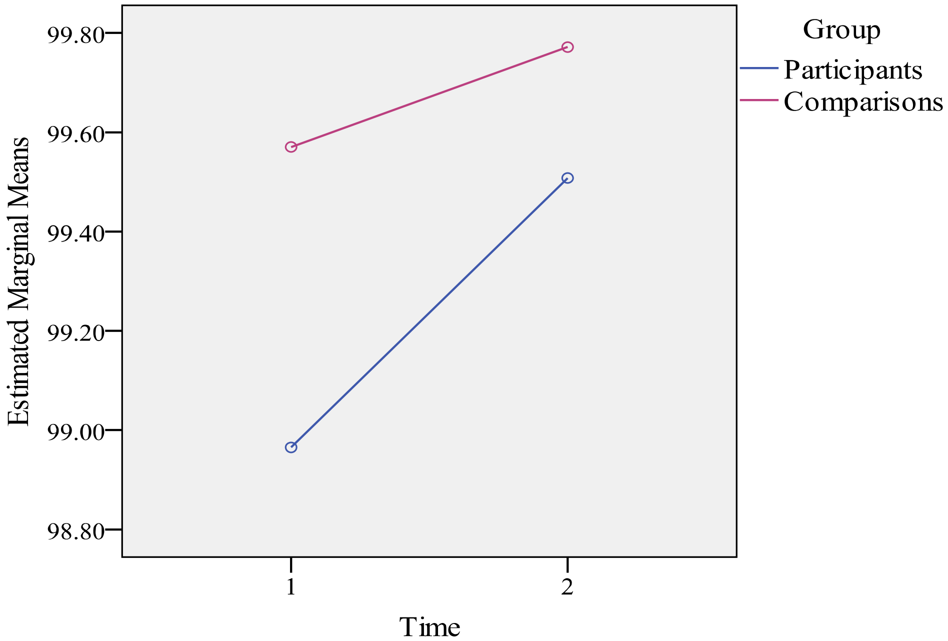
Note: * = maintained 100% accuracy

Appendix M

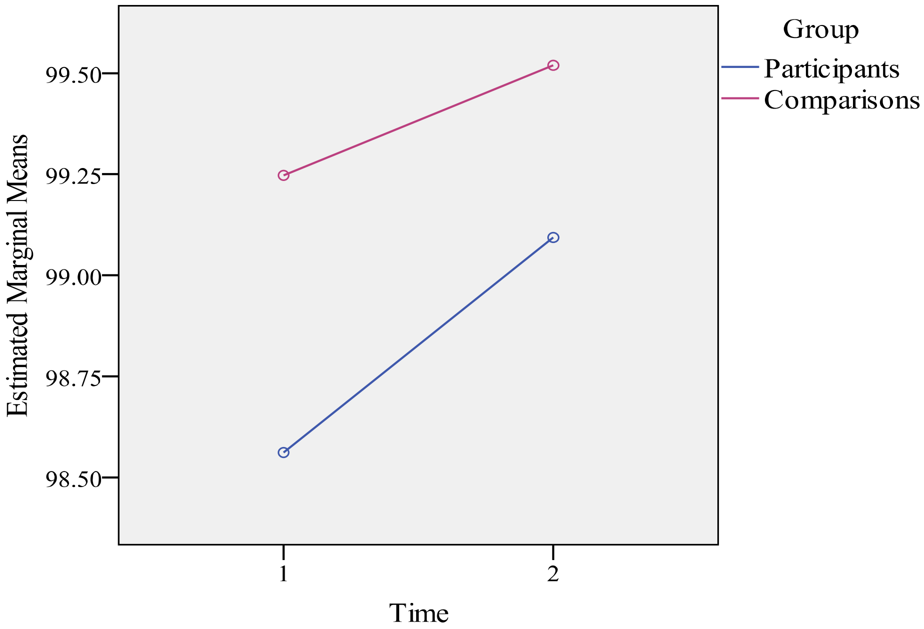
ESTIMATED MARGINAL MEANS FOR CAAS MATHEMATICS ACCURACY



Appendix M-1. Estimated marginal means for log-transformed accuracy – CAAS Addition



Appendix M-2. Estimated marginal means for log-transformed accuracy – CAAS Subtraction



Appendix M-3. Estimated marginal means for log-transformed accuracy – CAAS Multiplication

Appendix N

QUICKSMART PARTICIPANT STUDENTS' INDIVIDUAL AND GROUP MEAN PRE- AND POST-INTERVENTION SCORES - PAT-R COMPREHENSION

	Pre-Intervention			**Post-Intervention**		
Student	**Raw Score**	**Scale Score (pat-c)**	**Percentile**	**Raw Score**	**Scale Score (pat-c)**	**Percentile**
RM - PN	7	24.9	9	17	40.3	61
JP - PN	8	26.9	12	8	26.9	16
GW - PN	10	30.4	21	20	44.3	72
JC - PN	18	41.6	65	21	45.6	72
TH - PN	10	30.4	21	21	45.6	75
RS - PO	13	44.6	22	13	44.6	30
SW - PO	15	47	29	15	47	40
EF - PO	8	37.4	9	17	49.2	50
RF - PO	10	40.6	13	7	35.7	6
Mean	**11**	**35.98**	**22.33**	**15.44**	**42.13**	**46.89**
(SD)	**(3.64)**	**(8.05)**	**17.39**	**(5.25)**	**(6.94)**	**(25.54)**

Appendix O

QUICKSMART PARTICIPANT STUDENTS' INDIVIDUAL AND GROUP MEAN PRE- AND POST-INTERVENTION SCORES – PAT MATHS

	Pre-Intervention			**Post-Intervention**		
Student	**Raw Score**	**Scale Score (pat-m)**	**Percentile**	**Raw Score**	**Scale Score (pat-m)**	**Percentile**
CN - PN	24	48.0	10	27	51	20
MS - PN	4	29.0	0	13	39	1
TS - PN	27	51.0	18	27	51	20
VP - PN	24	48.0	10	33	60	58
NH - PN	33	60.0	53	36	69	90
YM - PN	19	44.0	5	34	62	68
AN - PO	11	40.0	2	30	56	40
AMC - PO	36	65.0	81	36	65	82
CS - PO	19	47.0	9	28	54	28
KB - PO	25	51.0	22	26	52	22
BR - PO	21	48.0	12	30	56	39
KJ - PO	26	52.0	25	21	48	10
Mean	**22.42**	**48.58**	**20.58**	**28.42**	**55.25**	**39.83**
(SD)	**8.72**	**9.07**	**23.69**	**6.57**	**8.08**	**28.7**

Appendix P

INDIVIDUAL STUDENTS' RAW READING RESPONSE LATENCY AND ACCURACY AT PRE-INTERVENTION, POST-INTERVENTION AND FOLLOW-UP

Student	Pre Response Latency(s)	Post Response Latency(s)	Follow-up Response Latency(s)	Pre Accuracy (%)	Post Accuracy (%)	Follow-up Accuracy (%)
RM-PN	1.21	0.77	0.98	96.6	100	100
GW - PN	1.08	0.82	0.84	97.4	100	100
JC - PN	0.88	0.76	0.65	100	100	100
TH - PN	1.19	0.8	0.75	100	100	100
BD - PN	2.17	0.71	0.69	86.2	95	97.4
EF - PO	1.7	0.77	0.62	100	100	100
RF - PO	1.07	0.86	0.7	97.4	95	100
Group Mean	1.33	0.78	0.75	96.80	98.57	99.63
(SD)	(.45)	(.05)	(.13)	(4.9)	(2.44)	(.98)

Appendix P-1. CAAS Elementary Word Test

Student	Pre Response Latency(s)	Post Response Latency(s)	Follow-up Response Latency(s)	Pre Accuracy (%)	Post Accuracy (%)	Follow-up Accuracy (%)
RM-PN	4.09	1.91	1.84	75.00	85.70	89.70
GW - PN	3.60	1.96	1.06	59.00	89.30	76.20
JC - PN	2.71	0.98	0.94	85.00	96.60	100.00
TH - PN	2.91	1.24	1.27	75.00	96.20	100.00
BD - PN	5.00	4.16	1.32	0.00	25.00	61.50
EF - PO	2.74	0.88	0.85	70.00	96.40	96.70
RF - PO	3.30	1.75	2.87	0.00	50.00	84.60
Group Mean	3.48	1.84	1.45	52	77.03	86.96
(SD)	(.84)	(1.11)	(.71)	(36.35)	(28.25)	(14.21)

Appendix P-2. CAAS Middle Word Test

Student	Pre Response Latency(s)	Post Response Latency(s)	Follow-up Response Latency(s)	Pre Accuracy (%)	Post Accuracy (%)	Follow-up Accuracy (%)
RM-PN	6.54	1.75	1.63	93.30	85.70	57.10
GW - PN	6.10	4.41	3.15	100.00	100.00	92.90
JC - PN	4.74	4.15	3.42	100.00	100.00	100.00
TH - PN	5.64	3.60	2.92	100.00	100.00	100.00
BD - PN	11.84	4.20	3.93	61.50	92.30	100.00
EF - PO	5.22	1.65	1.57	92.90	93.30	96.00
RF - PO	3.85	2.69	1.94	100.00	93.30	100.00
Group Mean	6.27	3.21	2.65	92.53	94.94	92.29
(SD)	(2.61)	(1.17)	(0.94)	(14.06)	(5.39)	(15.76)

Appendix P-3. CAAS Sentence Test

Appendix Q

INDIVIDUAL STUDENTS' RAW MATHEMATICS RESPONSE LATENCY AND ACCUURACY SCORES AT PRE-INTERVENTION, POST-INTERVENTION AND FOLLOW-UP

Student	Pre Response Latency(s)	Post Response Latency(s)	Follow-up Response Latency(s)	Pre Accuracy (%)	Post Accuracy (%)	Follow-up Accuracy (%)
CN - PN	2.81	1.72	1.72	100.00	88.90	94.40
MS - PN	6.12	2.55	3.53	85.00	94.10	100.00
TS - PN	4.13	3.73	2.24	94.70	100.00	94.10
VP - PN	7.63	2.99	3.15	50.00	100.00	100.00
NH - PN	3.60	1.60	1.86	95.00	100.00	100.00
YM - PN	4.03	2.38	2.31	100.00	94.10	90.00
AM - PO	2.59	1.70	1.71	100.00	100.00	100.00
CS - PO	2.49	2.32	1.72	89.50	90.00	89.50
KB - PO	2.63	2.38	2.01	78.90	65.00	100.00
KJ - PO	4.23	2.79	5.05	89.50	94.10	100.00
Group Mean	4.03	2.42	2.53	88.26	92.62	96.80
(SD)	(1.68)	(0.66)	(1.58)	(15.15)	(10.58)	(29.48)

Appendix Q-1. CAAS Addition Test

Student	Pre Response Latency(s)	Post Response Latency(s)	Follow-up Response Latency(s)	Pre Accuracy (%)	Post Accuracy (%)	Follow-up Accuracy (%)
CN - PN	9.56	2.11	1.45	80.00	94.70	100.00
MS - PN	8.65	3.37	3.73	42.90	77.80	68.80
TS - PN	5.60	2.97	3.06	72.20	100.00	94.40
VP - PN	7.91	2.22	2.22	68.40	100.00	100.00
NH - PN	3.35	1.74	1.63	94.70	100.00	100.00
YM - PN	3.61	1.32	1.47	88.90	100.00	100.00
AM - PO	2.13	1.37	2.38	100.00	100.00	100.00
CS - PO	2.04	1.55	1.69	100.00	94.70	100.00
KB - PO	2.42	1.84	1.87	80.00	78.90	90.00
KJ - PO	4.73	1.75	3.01	88.90	100.00	94.10
Group Mean	5.00	2.02	2.25	81.6	94.61	94.73
(SD)	(2.81)	(0.67)	(1.01)	(17.39)	(8.84)	(30.03)

Appendix Q-2. CAAS Subtraction Test

Student	Pre Response Latency(s)	Post Response Latency(s)	Follow-up Response Latency(s)	Pre Accuracy (%)	Post Accuracy (%)	Follow-up Accuracy (%)
CN - PN	7.55	1.49	2.36	60.00	88.90	95.00
MS - PN	3.77	4.72	3.43	20.00	43.80	68.40
TS - PN	11.32	4.23	3.07	50.00	70.00	94.40
VP - PN	5.52	4.52	3.52	58.80	94.40	94.70
NH - PN	6.07	2.01	1.38	68.40	100.00	100.00
YM - PN	5.40	1.90	1.95	40.00	75.00	94.40
AM - PO	3.05	1.55	2.62	94.70	100.00	100.00
CS - PO	2.54	1.66	2.79	73.70	93.80	76.50
KB - PO	2.30	1.26	1.27	72.20	94.70	100.00
KJ - PO	2.13	1.79	2.31	94.70	94.40	89.50
Group Mean *(SD)*	4.96 (2.89)	2.51 (1.39)	2.47 (1.05)	63.25 (23.12)	85.50 (17.74)	91.29 (29.32)

Appendix Q-3. CAAS Multiplication Test