

Centre for Cognitive Research in Learning and Teaching



The *QuickSmart* Program

**Allowing Students to Undertake Higher-Order Mental
Processing by Providing a Learning Environment to Improve
Their Information Retrieval Times**



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Executive Summary

Students who have problems with learning face a myriad of difficulties in accessing the curriculum in today's classrooms. These students often need intensive support to bring them 'up to speed' in basic skills such as reading fluency and the recall of number facts. Catering to the educational needs of these students poses a considerable challenge to classroom teachers.

The research described here focuses on the role of automaticity in developing students' fluency and facility with basic academic facts. The program is described as a fourth-phase intervention. This follows the initial teaching of the content by the classroom teacher and subsequent attempts to address students' difficulties. The third phase occurs when the teacher receives collaborative support from a specialist within the classroom. The fourth phase refers to intensive focused instruction associated with the student being withdrawn from class for a number of periods a week over an extended time-frame.

The main aim of the *QuickSmart* research program is to investigate the effect of improved automaticity of basic skills on higher-order processes, such as problem solving and comprehension. One significant feature of the *QuickSmart* intervention is that it is directed towards students in their middle years of schooling where there has traditionally been a dearth of focused and intensive support available.

The research program, conducted by University of New England's Dr Lorraine Graham and Professor John Pegg, and special education teachers, Ms Anne Bellert and Ms Jenny Thomas, has focused on students with learning difficulties in their middle years of schooling. Dubbed *QuickSmart* because *quick* in response speed and *smart* in strategy use is what the program encourages students to become, the initiative was funded during 2001 by federal Department of Education, Science and Training (DEST) under its Innovative Programs in Literacy and Numeracy scheme and is currently supported by an Australian Research Council (ARC) Discovery grant (2003-2005).

Results indicate that students' improvement in information retrieval times can lead to subsequent gains on tests of higher-order tasks. Also, the learning outcomes achieved during a thirty-week intervention program remained available at that same level for a further year without direct teaching maintenance. This result is particularly important because any 'effective' intervention must show that gains in student learning are maintained.

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Background to *QuickSmart*

Importance of Automaticity in Basic Skills and Higher-Order Tasks

Teachers readily observe that students with learning difficulties are visibly ‘slowed down’ by their lack of automaticity. Just as a person beginning to play a sport or a musical instrument is slower and more error prone than an expert, students with learning difficulties require longer to process all aspects of a task. Their effortful attempts also tend to be less successful than those of many of their classmates.

In general, poor readers take more time to decode words and have more difficulty constructing meaning from text because their limited working memory capacity is allocated almost entirely to decoding. Similarly, students with difficulties in numeracy tend to use time-consuming, inefficient, or error-prone strategies to solve simple calculations. In contrast, average-achieving students may recall number facts in less than a second by effortlessly accessing learned information.

Developing automaticity in basic skills is particularly important for middle-school students because they need to comprehend what they read and to problem solve in order to engage appropriately with the middle school curriculum. Students are better able to focus on higher-order skills when the sub-skills of decoding and calculating are less effortful for them. Therefore, mastering basic academic skills through focused practice and the development of efficient strategies provides middle-school students with a greater opportunity to participate successfully in classrooms.

Situating the *QuickSmart* program

The *QuickSmart* project addresses both literacy and numeracy outcomes for educationally disadvantaged students. Its purpose is to provide necessary tuition and support to students who are currently experiencing difficulties in these areas within a motivational learning environment. The assessment and intervention program used in *QuickSmart* is a new initiative for Australian education, although it is based on, and extends, research findings from the United States (e.g., Nicolopoulou & Cole, 2000; Royer & Tronsky, 1998; Royer, Tronsky & Chan, 1999). The intervention aims to improve students’ information retrieval times to levels that free working memory capacity from an excessive focus on basic mundane or routine tasks. In this way, students can become better resourced to undertake higher-order mental processing, hence fostering the development of appropriate literacy and numeracy skills.

The *QuickSmart* program is a theory-based educational intervention for middle-school students designed to enhance students' fluency in reading and numeracy by improving their information retrieval times. Students are selected to participate in this program if they have a record of experiencing persistent and significant learning difficulties in these areas, and have been resistant to academic improvement despite previous attempts to overcome their learning problems.

Based on an analysis of the diagnostic information obtained from each participating student, instructional interventions are designed to strengthen students' problematic skills, e.g., letter naming, word naming, comprehension, recall of number facts, and basic computation. These interventions are based on a substantial body of research related to the importance of particular skills in literacy and numeracy. Specifically for literacy, these are in the form of letter and word recognition, theme effects in text comprehension, and the influence of text characteristics upon comprehension processes (e.g., Graham & Wong, 1993; Graham, 2000; Klingner & Vaughan, 1999; Reynolds, 2000; Troia, Roth, & Graham, 1998). For numeracy, these take the form of the four operations on simple and extended tasks (e.g., Ashcraft, Donely, Halas, & Vakali, 1992; Pegg, 1992; Zbrodoff & Logan, 1996).

The *QuickSmart* program brings together research conducted at the Laboratory for the Assessment and Training of Academic Skills (LATAS) at the University of Massachusetts, Amherst (e.g., Royer, 1985; 1996, Royer & Tronsky, 1998) and related work from the Centre for Cognition Research in Learning and Teaching (CRiLT) at the University of New England in Armidale, NSW Australia. It combines a theoretical perspective incorporating modularity theory, automaticity, and a hierarchical view of students' learning of academic skills, with examples of basic research and practical application.

Researchers from LATAS have developed procedures for obtaining reliable assessments of student performance using a computer-assisted assessment system. Importantly, the assessment tasks used are designed and sequenced in order to target and identify the exact nature of the literacy/numeracy problems a student is experiencing (Royer, 1996). The techniques developed have been successful with students who have specific reading and/or mathematics disabilities, many of whom meet the criteria for being 'treatment resistant' to ordinary instructional methods.

Aims of *QuickSmart*

The primary aim of the *QuickSmart* program is to increase fluency in reading and numeracy for students with learning difficulties in the middle-school years. Focusing on automaticity in reading and numeracy allows the working memory more time and cognitive resources to undertake higher-order processes, such as comprehension and problem solving. The long-term aim of the program is to allow students with learning difficulties to undertake higher-order mental processing with greater efficiency and success.

Significance and Innovation of *QuickSmart*

This program is the first intervention research of its type undertaken in Australia. It represents a different approach to confronting issues associated with the skill deficits that affect literacy and numeracy proficiency. The approach has the potential for wide applicability as its focus is on students' underlying cognitive processes. The approach complements current literacy and numeracy initiatives in public education but emphasises important diagnostic and formative elements to the assessment and understanding of targeted students' learning.

In essence, the **scientific and theoretical significance** of *QuickSmart* lies in its development and evaluation of a theory-based intervention that focuses on improving not only students' accuracy in reading and numeracy, but also their speed of information retrieval. There are theoretical and pragmatic reasons that support the importance of the development of automatic low-level basic academic skills in reading and numeracy. First, it is generally accepted that the cognitive capacity of humans is limited, i.e., working memory has specific constraints on the amount of information that can be processed (Ashcraft, Donely, & Vakali, 1992; Zbrodoff & Logan, 1996). As such, there is good reason to expect that improving the processing speed of basic skills will free up working memory capacity that then becomes available for higher-order comprehension and problem-solving tasks. Research has already indicated that the ability to recall information quickly is often not subject to conscious control, and, subsequently, uses minimal cognitive capacity (e.g., McNamara & Scott, 2001).

Another reason why the automatic performance of low-level academic skills is of prime importance is that it allows for small decreases in time to accrue in undertaking subtasks, again freeing up working memory (Royer, Tronsky, & Chan, 1999). For example, poor readers at all grade levels are characterized by slower than normal development of a sight vocabulary of words they can read fluently and automatically (Torgesen & Wagner,

1998). Similarly, in mathematics, the lack of automaticity can result in a reduced ability to solve problems and understand mathematical concepts (Chard & Gersten, 1999). Improving automaticity in reading and numeracy allows students with learning difficulties to undertake higher-order mental processes such as comprehension and problem solving with greater efficiency and success.

The practical significance of the program lies in the data gathered related to the effectiveness of the *QuickSmart* program of student support. Without doubt, the focus of this work on the low-achieving student is an important one for schools. Also of significance is the focus on essential learning skills, such as reading, comprehension, and basic mathematical skills for middle-school students.

The importance of rigorously evaluating intervention programs 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). It is abundantly clear that educationally disadvantaged students should only participate in interventions that are educationally sound. Interventions based on unsubstantiated ideas have the potential to take up these students' valuable instructional time with little, or no maintained, gains in performance (Strain & Hoyson, 2000). Carefully collected longitudinal data across settings is necessary to bring additional insights into the learning processes used by this cohort of students. An ongoing *QuickSmart* research program (see later in this report) with cross-sectional and longitudinal components continually informs future improvements and developments to the *QuickSmart* program of intervention.

In short, the *QuickSmart* project is an innovative direction for supporting literacy and numeracy skill development in Australian schools. This project involves developing and implementing programs in literacy and numeracy, which aim to increase students' understanding and speed of recall of basic skills. For the purposes of this project, the term 'basic skills' refers to the ability of students to read near age-appropriate level texts and to know and understand mathematics facts associated with the four operations.

Central to the development and implementation of the *QuickSmart* program is close collaboration with parents, teachers and principals of participating schools. Throughout previous and current projects stakeholders are fully informed about the project and involved in its implementation and evaluation.

***QuickSmart*: The Intervention Program Overview**

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 mundane tasks. Teaching and learning strategies used in this program include explicit strategy instruction, modeling, focused discussion, specific questioning sequences, and guided and independent practice. The instructional focus of the *QuickSmart* program is on developing students' understanding and their effective strategy use, while at the same time providing focused, time aware, and enjoyable practice opportunities.

New Technologies

Upon admission to the *QuickSmart* program students complete an assessment process consisting of listening and reading comprehension tests and Computer-based Academic Assessment System (CAAS) tasks that measure the speed and accuracy of hierarchically arranged reading and basic mathematical tasks. Speed is measured using naming tasks that involve the appearance of a stimulus on the computer screen followed by the student responding into a microphone.

The system provides highly accurate measures of how rapidly students complete the tasks and an examiner then scores the response for accuracy. The CAAS assessment process involves completion of tasks that measure simple perception, letter naming, word naming, pseudoword naming (e.g., plok), concept activation, sentence understanding, number identification, and addition, subtraction, division and multiplication tasks.

The CAAS, which provides on-going data related to students' accuracy and speed of recall, is used as an important and motivating feature of the *QuickSmart* instruction and assessment cycle. Most *QuickSmart* lessons conclude with an assessment on the CAAS system. During these assessments, students aim to increase their accuracy and decrease response time as a means of demonstrating increased automaticity. Students record their results onto graphs that over time become powerful visual representations of their progress.

An Outline of the *QuickSmart* Program

Participants in the *QuickSmart* instruction and assessment program learn to develop effective strategy use and participate in focused practice activities. The program provides students with opportunities to self-monitor and to receive and generate immediate,

formative feedback. The *QuickSmart* program focuses on various domains in reading and numeracy with instruction planned to meet individual students' learning needs.

The programs in both reading and numeracy follow a structured lesson sequence based around a 'focus set' of words or number facts. Teaching and learning strategies include explicit strategy instruction, modeling, discussion, questioning, and guided and independent practice. As mentioned earlier, most lessons conclude with an assessment on the CAAS system to provide the student and the teacher with information about individual student's accuracy and speed of recall of basic academic facts.

Assessment and instruction form a continuous cycle in the *QuickSmart* program. Teacher observations and information gained from questioning students about their strategy use are the basis of instructional decision-making and individualization. Assessment information is also derived from many of the activities in the program such as flashcards, repeated reading, worksheets and the oral reading of books. Importantly, the CAAS assessment system provides on-going data related to students' accuracy and speed of recall.

Another appealing feature of the program is that much of the assessment information obtained during *QuickSmart* lessons is both accessible and understandable to the participating students. Students are able to evaluate their own learning through recording information, such as how many flashcards they read accurately or how many correct words per minute they read. Students are encouraged to use this information to set their own realistic future goals. Assessment information obtained from the CAAS and selected other activities is plotted onto individual graphs in order to provide students with a motivating visual representation of their progress.

The *QuickSmart* program also emphasizes the usefulness and relevance of focus words and number facts to regular classroom activities. This feature of the program is important for developing transfer of learning to other settings. In relation to this point, it is also important to acknowledge that once students' recall of basic academic skills becomes truly automatic, they cannot help but recall this information and have it available for use in other settings and on more complex tasks. It is particularly important that middle-school students have ready access to prerequisite academic skills that enable them to engage fully with challenging academic work.

Some key components of the *QuickSmart* program are:

- A practice routine of about 20 minutes of on-task time, at least 3 times per week.

- Structured and time-efficient lessons which have a set sequence of activities.
- Motivating and timed practice activities aimed at speedy recall of known facts.
- Strategy instruction that is on-going, explicit and individually tailored to students' needs.
- Opportunities for students to self-monitor, and to receive and generate immediate feedback about their performance.
- Instruction that ensures the students experience success.
- Incorporating reflective, metacognitive questioning and responding into lessons – e.g., How did you work that out? Why are you so sure of your answer? This focus of instruction can assist students to develop the language to describe their thinking.
- The use of stop watches, hourglass timers, and wall clocks to assist students to 'externalize' time. These devices encourage students to become more aware of their sense of time and improve their ability to estimate time.
- A long term and consistent intervention approach which provides the practice opportunities that will bring students 'up to speed' so they can share 'the fast track' with their peers.

***QuickSmart* Materials**

Before the interventions begin, each student receives a work folder, which the students can personalise with drawings and stickers. The folder contains information about the program, a timetable of lessons, lists of focus words or facts, reading passages or numeracy worksheets, a 'Help' section for strategy cue cards, and an assessment and graphing section in which speed and accuracy rates, and flashcard scores or oral reading fluency data etc are recorded. Students leave 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 are provided for students to use during lessons.

In addition, sets of flashcards are prepared before the intervention for use in regular practice activities. Each different set of focus facts or focus words requires at least two duplicate sets of flashcards. In numeracy lessons, students also use speed sheets prepared to practice each set of focus facts, as well as carefully prepared worksheets.

For the reading lessons three passages of connected text, containing most or all of the focus words are used for each unit of work. Sometimes these passages are written to incorporate all the words from the word list. At other times focus words are selected from appropriate reading passages about a particular topic. Also in reading lessons, appealing fiction and non-fiction books are made available to the students. Simple games like bingo or memory, and equipment such as dice, hourglass timers, counters, and flashcards are used in most lessons.

***QuickSmart*: The Intervention Program in Detail**

The *QuickSmart* program runs ideally for up to thirty weeks over three consecutive school terms. Participating students are withdrawn from their classes in pairs for three half-hour *QuickSmart* lessons each week with the same instructor. Where possible, the pairings of students match individuals with similar learning obstacles in either reading or numeracy.

To guide the instructional approach, a metaphor and an accompanying mnemonic were developed. In introducing the *QuickSmart* program to participants, the idea of practice making an easy pathway in memory like heavy traffic makes a roadway is explained and explored. The main ideas of the approach are also presented to the students embedded in a mnemonic associated to the pathway metaphor. The key word, 'PATH', is presented as standing for **P**actice, **A**ttention to understanding, **T**ime, and **H**ow to. By using the 'PATH', participants in the *QuickSmart* intervention learn to develop effective strategy use (**H**ow to) that flows from clearer understandings (**A**ttention to understanding) as they participate in fun and focused practice activities (**P**actice) that externalize time as a dimension of instruction (**T**ime). The program also provides students with opportunities to monitor their own learning and to receive and record immediate, formative feedback.

Instructional methods used in the *QuickSmart* intervention focus on a variety of practice and recall strategies to develop understanding and fluency with basic academic skills. Each lesson involves revision of the previous session, a number of guided practice activities featuring overt self talk, discussion and practice of memory and retrieval strategies, then games and worksheet activities followed by timed independent practice activities.

Ongoing assessment and instruction form a continuous cycle in the *QuickSmart* intervention. Teacher observations and information gained from questioning students about their strategy use form the basis of instructional decision-making and individualization. Assessment information is derived from many of the activities in the lessons such as flashcards, repeated reading, worksheets and reading books.

Further, the CAAS assessment system, used in most lessons, provides on-going data related to students' levels of automaticity in basic academic skills. Students are also able to evaluate their own learning through recording information, such as how many flashcards they read accurately or how many correct number facts per minute they can recall. Students are encouraged to use this feedback information to set realistic future goals for their performances.

In order to develop transfer of learning to other settings the *QuickSmart* intervention emphasizes equipping students with knowledge that can be used in the classroom and in many other real-life settings. For example, the utility of basic academic understandings and skills is presented to the students by reading a range of different books and magazines, and discussing when to use appropriate comprehension strategies in class activities; or by relating basic mathematics facts to money exchanges or common fractions, decimals and percentages. In addition, where possible *QuickSmart* content is linked to current classroom curriculum.

As already described, the *QuickSmart* program in both reading and numeracy follows a structured lesson sequence based on a ‘focus set’ of words or number facts. An important underlying goal of each lesson is to ‘structure for success’ by providing students with regular and predictable learning sequences. Instructional time is made available for students to practice and improve on what they already know, and to learn and practice new knowledge.

Such circumstances provide potent opportunities for students to become more successful than they were yesterday, or last week, as the result of enjoyable, achievable and personally challenging practice activities. Students are frequently but genuinely praised for their efforts to learn and improve their skills. Often this praise is also an opportunity for reinforcement of effective strategy use, for example “Wow, you got 35 flashcards in a minute, very impressive! One reason I can see that you’ve improved so much is that you’re now adding whole tens instead of counting them as ten ones”. Throughout the entire *QuickSmart* program every effort is made to ensure that students spend the majority of lesson time actively engaged with learning and practice activities.

The *QuickSmart* Intervention: Reading Groups

The *QuickSmart* reading program focuses on improving students’ automaticity of word recognition and fluency in reading connected texts. Instruction is organized into units of three-to-four week’s duration (i.e., 9-12 lessons) that centre on sets of focus words. The sets of around thirty focus words range in difficulty, beginning with high usage three and four letter words, to more complex and demanding sets including words such as ‘destruction’, ‘organizations’, and ‘accommodation.’ The sets of focus words are either linked to a curriculum learning area (e.g., English or HSIE) or a theme of interest to the students (e.g., natural disasters). The focus words are incorporated in two or more passages of connected text relevant to the topic. For example, the passage may be framed as a narrative about natural disasters or as a procedure about writing a report as long as it

uses all the focus words at least once. Students read these passages for repeated reading practice throughout the unit.

Reading lessons begin with an examination of the focus words to check and develop students' understanding, pronunciation and reading of these words. Phonic approaches to decoding unknown words are emphasized. Flashcards are used in timed practice activities to help develop automaticity. It is worth noting here that flashcards are only used once or twice in the lesson for the duration of one minute – they are a useful activity but only part of the *QuickSmart* program. Simple games such as *word bingo* or *word memory* are an enjoyable and much anticipated part of each lesson. These games are useful for developing familiarity with the focus words and providing fun and focused opportunities for practice.

Repeated reading is an integral strategy used in *QuickSmart* lessons to develop reading fluency. The students practice reading the same passage on a number of occasions. On each occasion they record the time taken and errors made. Students are able to graph their improvement in the number of correct words per minute that they read because repeated practice leads to increased fluency, confidence, and automaticity in reading. Towards the end of most lessons, students also have the opportunity to read for pleasure. They select from a small, but changing collection of high-interest books. The typical reading lesson concludes with an assessment of the relevant CAAS subtasks of usually around five minutes duration for each student.

During the *QuickSmart* reading intervention, students complete one ten-lesson unit of instruction, focusing on strategies for improving comprehension. In particular, the 3H strategy (Graham & Wong, 1993) is taught and practiced by the students. Lessons in this strategy unit follow a set routine that involves reading a passage (with support such as pre-reading if necessary), then predicting, answering, and asking comprehension questions. The 3H strategy is used to develop students' skills in understanding how to use texts and their background knowledge in order to comprehend what they read more effectively. Students complete the CAAS sentence comprehension subtask at the end of these lessons.

The *QuickSmart* Intervention: Numeracy Groups

QuickSmart numeracy lessons aim to improve students' understanding and speedy recall of basic mathematics facts. Instruction in the *QuickSmart* numeracy program is also delivered in units of work of three-or-four weeks duration, focusing on a specific set of

mathematics facts. The focus facts are sets of related number facts ranging in difficulty from combinations of numbers that equal 10, to 12 times tables.

It is important to note that focus facts for each unit also contain related facts such as $3 + 7 = 10$, $30 + 70 = 100$; $2 \times 12 = 24$, and $_ \times 24 = 12$; to facilitate students' observations and understandings about relationships and reciprocity between numbers. The actual unit sequence for each student pair is matched to their learning needs. The focus facts for each pair of students are used in games and activities and practiced using flashcards.

The numeracy lessons begin with a review of the focus facts starting with those already known, and move on to those yet to be remembered. Teacher-led discussion and questioning about the relationship between number facts, and ways to recall them merge into simple math fact practice activities, such as *Three-in-a-Row* and *Same Sums*. These games were developed to complement each set of focus facts and allow students to review and consolidate their learning in a motivating way. Flashcards and timed performance activities, such as speed sheets, are used to assist students to develop automatic recall.

In the last part of the lesson, students practice their skills independently on carefully selected worksheets that are closely related to the lesson content. Numeracy lessons usually conclude with a brief CAAS assessment. Both structured and incidental strategy instruction is a feature of the lessons, with the aim of moving students on from relying on slow and error prone strategies, especially count-by-one strategies, to the use of more sophisticated and efficient strategies, including automatic recall.

Overview

In summary, many students with learning difficulties are 'slowed down' because of deficits in knowing and quickly recalling basic facts. Lack of automaticity in component tasks, such as reading a word or calculating a sum, depletes working memory resources, and effectively becomes an obstacle to higher-order thinking. To date *QuickSmart* research has highlighted the importance of developing automaticity as a means of improving learning outcomes for students with learning difficulties. Although our results indicate that improving the automaticity of sub-components or lower-order skills leads to improvements in higher-order processes, further studies are being undertaken to validate this initiative further and to explore the theoretical framework and practical application of the *QuickSmart* program.

The next section of this Report takes up the research theme, associated with the *QuickSmart* program in more detail.

***QuickSmart* Research**

Conceptual Framework of *QuickSmart*

A goal of the *QuickSmart* program is the development of a theoretical understanding of learning disabilities. This involves working on theoretical descriptions of the origins of learning difficulties and the nature of the cognitive changes that occur when performance improves as a function of intervention. For instance, the data from our research indicates that students who participate in *QuickSmart* interventions become better readers or better at mathematics activities. Understanding the cognitive changes that mediate this improvement requires the development and evaluation of a theory that ties together a description of the problem that students were initially experiencing with a description of the cognitive changes that result from effective intervention.

The conceptual framework used in this research proposes that skilled reading is mediated by memory representations that bind together orthography and phonology. These representations are developed during the simultaneous presence in working memory of the orthographic vision of the word and the sound of the word provided by an outside reader or by the reader himself/herself through the sounding out process. This theory proposes that some readers have difficulty forming these representations because of a deficient ability to maintain quality phonological representations in working memory for a sufficient period to allow the formation of the bound orthography/phonology representations. The framework also explains how intervention activities that create automatically activated bound representations for some words subsequently facilitate the ability of students to read a much larger corpus of words sharing certain features with the words that have already attained automatic status.

In addition to this, it is noted that many researchers no longer support the classic structural tradition of thought. Particularly, Piaget's *structures d'ensemble*, where students are seen to pass through a series of stages that are closely linked to age parameters, and where performance on a certain task is a prediction of behaviour on other tasks, has been challenged by considerable empirical evidence. Instead, the work of Biggs and Collis (1991), Case (1992), Fischer and Knight (1990) to name a few, advance a more inclusive view of structure. While these researchers also ascribe to stages of development, they see these stages as content and context dependent. While constructs such as working memory and information processing qualities are active in setting endogenous limits to understanding, other variables, such as motivation and the teaching and learning environment are also seen as important in developing independence in

learning. The *QuickSmart* program operationalises this framework by working towards freeing up students' working memory capacity within the context of a highly motivational learning environment for improving basic academic skills in literacy and numeracy.

Research focus

The hypothesis for research conducted on the *QuickSmart* intervention is that increased accuracy and automaticity in basic academic skills will result in improvements in higher-order thinking. The rationale behind this hypothesis is that developing automaticity in the sub-component skills of reading and numeracy frees working memory resources and allows middle-school students with learning difficulties to undertake higher-order processes, such as comprehension and problem solving, successfully.

Participant Selection

Primary school students who participate in *QuickSmart* programs meet the criteria of experiencing persistent difficulty in either reading or numeracy, display a good attitude to working in small groups, and have average cognitive potential without major attention difficulties. Likewise, participants from secondary school settings were selected by English and Mathematics head teachers using the criteria that: (a) the students were experiencing learning difficulties in either literacy or numeracy; and (b) they had performed in the lowest two bands on the State-wide Year 7 screening tests; and (c) they had a regular school attendance pattern.

Assessment Materials

The Computer-based Academic Assessment System (CAAS) is a computer program that enables precise measurement of information retrieval times on reading and numeracy tasks. The CAAS assessment system collects vocalisation latency data. Specifically, when a stimulus is presented to a student who responds into an attached microphone, the system records vocalisation latency and a scorer pushes one of the two mouse buttons to register the accuracy of the response. At the end of a task, the software computes a mean and a standard deviation for response latencies. Also, the software automatically cleans the data by eliminating, as outliers, responses two standard deviations from the mean, such as impossibly fast or unusually slow scores. When the student is finished, the percentage of correct responses, as well as the mean and standard deviation of the latency data are immediately available to the teacher and the student.

The standardized tests used as measures of higher-order thinking are the Progressive Achievement Tests (PAT) in Reading: Comprehension and Vocabulary, Form A and B (ACER, 1986), and the Progressive Achievement Tests in Mathematics, Tests Form A and B, 2A, and 2B, and 3A and 3B (ACER, 1997). These tests are multiple-choice pencil and paper tests normed on Australian school children. All assessments are administered and scored according to the instructions detailed in the test manuals.

In summary, students' accuracy and levels of automaticity are tested before, during, and after the intervention using the CAAS assessments. Measures of higher-order thinking are operationalised as performance on standardised tests, in this case the PAT tests. These data, together with CAAS assessments are gathered before and after the intervention for the target students as well as comparison groups of same-age peers. In addition, qualitative data from sources such as interviews and field notes are collected.

CAAS Assessments

Measuring accuracy and automaticity of basic academic skills is an integral part of this research. As already described, the CAAS system is specifically designed to measure response latency and accuracy on a range of basic academic tasks.

Initially, all students are assessed on CAAS sub-tests in either literacy or numeracy. These assessment tasks require the students to respond to processing, reading or mental calculation tasks into a voice onset sensor microphone. The CAAS system records accuracy and response-time data for each student.

The CAAS reading assessment and the CAAS numeracy assessment both have a range of sub-tests. A sub-test contains between 30 to 40 items in reading and 15 and 20 items in numeracy. These items are randomly selected from a bank of between 160 to 250 items stored per sub-test. The only task common to both literacy and numeracy assessments is a simple response time task that measures the speed and accuracy of response to non-verbal stimuli. On this assessment, students are shown either a star '*' or a plus '+' and requested to name the symbol.

The reading sub-tests used were also selected from the range of tests available on the CAAS. Participating *QuickSmart* students and their comparison peers completed the following sub-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); a Comprehension sentence understanding task that assessed the application of semantic knowledge in sentence processing using a

variation of the cloze procedure; and lastly a pseudo-word naming task consisting of pronounceable non-words of 1, 2, or 3 syllables which probes phonemic awareness. These reading sub-tests are administered because they measure a range of component skills necessary for fluent reading.

The numeracy sub-tests of CAAS used in this phase of the research were number naming of two digit numerals; addition (single plus single digit and single plus double digit addition, presented as $4 + 8$ or $78 + 9$); subtraction (single and double digit numerals less than 20, presented as $12 - 9$); triple addition (three numerals less than 20, appearing as $4 + 8 + 3$); multiplication facts (to times 12); and related division facts. Other sub-tests such as *Negative Numbers* and *Hard Multiplication* are available on the CAAS but were not included in the assessments. The numeracy sub-tests used are directly related to the content of instruction but draw from a much wider range of examples than the focus facts used in the program.

During the *QuickSmart* intervention CAAS data are gathered at the conclusion of most lessons on a single sub-test relevant to students' lesson content (e.g., word recognition or addition and subtraction). However, at the completion of the *QuickSmart* intervention participants are assessed on the same sub-tests in literacy and numeracy administered at the pre-test.

Standardised Tests

Levels of students' higher-order thinking are measured before and after the *QuickSmart* intervention. It is important that the assessment measures chosen for this purpose are rigorous, independent of the instructional program, and relevant to the Australian student population. After consultation with colleagues and an investigation into published tests that might be suitable, the Progressive Achievement Tests (ACER) in reading and mathematics were selected to measure this important variable. For the purposes of the *QuickSmart* program, higher-order thinking in reading is conceptualized as word and text comprehension. Similarly, higher-order thinking in numeracy involves knowing how to effectively problem-solve using quickly and accurately recalled basic number facts and strategies. Therefore, for the purposes of this research, students' improvement in higher-order thinking processes, such as comprehension and problem solving, can be shown by their improved performance on standardised tests.

The Progressive Achievement Tests in Reading: Comprehension and Vocabulary, (ACER, 2003) are administered to all *QuickSmart* reading students before the intervention commences, and again, in parallel form, at the conclusion of the intervention. The

comprehension test distinguishes between literal and inferential questions and the vocabulary test measures students' understanding of word meanings.

The Progressive Achievement Tests in Mathematics (PATMaths) (ACER, 2003) is administered to all numeracy students before the *QuickSmart* intervention and after its completion using a parallel form. These standardized tests measure mathematics performance across the range of National Profile strands – number, space, measurement, and chance and data.

Oral Reading Fluency

Oral reading fluency is a measure of reading proficiency commonly used for assessment and screening purposes in New South Wales. Guidelines for fluency rates appropriate to different Year levels suggest that by the end of Year 4, students should be able to read 100 or more correct words per minute with 95% accuracy.

Reading fluency data are collected because they provide simple, clear, and relevant information about students' reading performance. Logically, students' oral reading fluency rates should increase with more automatic word recognition and more practiced decoding skills. In the *QuickSmart* program, reading students undertake oral reading fluency assessments throughout on a range of different texts.

Qualitative Data

In order to monitor the more affective aspects of participation in the *QuickSmart* program qualitative data are also collected regularly. These data consist mainly of interviews, teacher observations, and student anecdotes recorded as field notes.

The students' perceptions of the usefulness and importance of their *QuickSmart* learning experience are gathered through interview and questionnaire data collected at the conclusion of the intervention. Interviews and other measures of attitude and affective factors are not included in the initial assessment phase, however, because we prefer to observe reactions emerge over time, rather than pre-empting or priming students' responses with rating scales and questionnaires before the intervention begins.

Field notes are systematically recorded throughout the intervention. The field notes include observations of students' overt and cognitive behaviours, examples of students' strategy use, anecdotes that illustrate the development of student understandings and attitudes, as well as comments from parent interviews, and notes from meetings with teachers and administrators.

Comparison Data

In order to gain a clearer indication of the effectiveness of the *QuickSmart* intervention for improving accuracy and automaticity of basic academic skills, CAAS and standardised test data are collected from other students in the same grade as the participants in the study. In general, the group of comparison students included in the assessments consists of average-achieving and high-achieving students as nominated by their teachers in each of the areas of reading and numeracy. These comparison students complete the selected CAAS sub-tests in literacy or numeracy at the beginning and the end of the intervention and also participate in the standardised testing sessions.

Comparison data afford important opportunities to examine the differences in accuracy and automaticity levels for students with learning difficulties compared to a sample of average-achieving students. They also facilitate a comparison of the rate of increase in accuracy and automaticity between the participants in the *QuickSmart* program and normally-achieving non-participant same-age peers.

Summary Assessment Schedule

For students in the literacy reading program, data from the PAT standardized tests of comprehension and vocabulary and data from CAAS sub-tests are collected before and after the intervention. Oral reading fluency and accuracy data from the students' reading of a variety of different texts are also collected regularly throughout the intervention, along with data from selected CAAS sub-tests.

For students in the numeracy program, data from the PAT mathematics test are collected before and after the intervention. CAAS sub-test data are also collected at these times. During the intervention, data from specific CAAS tests are regularly collected during short one-to-one sessions with the teacher. Informal data, such as progressive speed and accuracy measures from flashcards, and work sheets are also recorded for each student.

Findings of *QuickSmart* Research

Nine Aims of *QuickSmart* research

The main aim of the *QuickSmart* research program is to investigate the effects of improved automaticity of basic skills on higher-order processes, such as comprehension and problem solving. The underlying rationale for the program is that improving automaticity in component skills, such as decoding or calculating, frees up working memory resources. This freeing up of resources should allow students to focus on inherently attention demanding higher-order cognitive activities, of the sort increasingly required of students in the middle-school years.

The following specific aims are relevant to *QuickSmart* research projects. Outcomes related to each of these aims from the research to date are discussed in the next subsection.

- (1) There will be a deeper understanding of the role of working-memory load in information processing, and how this is implicated in the literacy and numeracy problems students encounter.
- (2) Detailed descriptions of cognitive obstacles, which have precluded students achieving acceptable standards of literacy and numeracy, will be developed.
- (3) Detailed profiles of individual students will be prepared to document their development in literacy/numeracy over the period of an academic year.
- (4) Procedures for overcoming identified common learning obstacles will be noted.
- (5) Insights will be gained into how the procedures developed for individual use may be generalized to suit whole or part classroom, or small group situations.
- (6) Various stakeholder groups, such as university personnel, members of professional bodies, teachers and parents will link together to address mutually beneficial educational goals.
- (7) Approaches, which facilitate classroom teachers' identification of specific stumbling blocks in students' acquisition of appropriate literacy and numeracy skills, will be documented.

- (8) Ways that the technology used in the project may be adapted to assist classroom teachers and support personnel to identify and target particular problems that students face in areas of literacy and numeracy will be explored.
- (9) A set of design features that can be used by teachers and support staff to identify and help rectify particular problems in the areas of literacy and numeracy will be developed.

Findings in terms of the Nine Aims

Aim 1 **There will be a deeper understanding of the role of working memory load in information processing, and how this is implicated in the literacy and numeracy problems students encounter.**

To date our research has highlighted the important role of efficient working memory use in students' successful engagement with academic tasks related to numeracy and literacy. The construct of working memory is fundamental to information processing conceptualizations of learning. While we have not measured working memory capacity directly, we have focused on students' strategy use throughout *QuickSmart* interventions as an indicator of their increasingly efficient use of this information processing 'workbench.'

The students involved in *QuickSmart* programs initially showed very slow information processing times as measured on the CAAS assessments, indicating that they used limited working memory resources to laboriously decode or calculate. As predicted, this inefficiency was at the cost of being able to undertake higher-order processes, operationalized in this research as scores on standardised tests of comprehension, vocabulary, and mathematics performance, with success. Throughout our observations of students' learning we have noted that inefficient strategies, such as slow decoding of previously known words or using count-by-one strategies to solve simple algorithms, negatively affected knowledge, speed of recall and the students' ability to engage with higher-order tasks such as comprehending and problem solving.

As the program progresses, students' more effective strategy use is linked to faster recall of basic facts and efficient word recognition. Consequently, we have inferred that the increased availability of working memory resources freed students to attend to, and engage with, these higher-order tasks.

The use of the computer-based academic assessment system (CAAS) system facilitated the on-going collection of data targeting students' information retrieval times and levels of accuracy. Both these measures are related to working memory inasmuch as improved information retrieval times can free up working memory from an excessive focus on routine tasks. Across all *QuickSmart* projects, all the participating students have showed improved information retrieval times on CAAS tasks and 90% have also showed improvements on standardised tests of reading comprehension, vocabulary, or mathematics performance.

It should be noted that improvement on standardised test scores is a difficult outcome to achieve. This finding indicates that improved automaticity in basic skills can lead to improvements in more generic skills, such as comprehension and problem solving – higher-order skills that are important to all key learning areas.

Aim 2 Detailed descriptions of cognitive obstacles, which have precluded students achieving acceptable standards of literacy and numeracy, will be developed.

Through the continuous monitoring of student performance that is an integral part of *QuickSmart* programs, we have gathered data, observations, anecdotes and quotes from the students related to their learning. A feature of this collection of data is the identification of possible impediments to students' progress. As a result some representative case study descriptions of common cognitive obstacles to achieving age-appropriate literacy and numeracy performance have been developed.

The four brief case studies presented below represent useful and integrated ways of presenting our general findings. Overall, cognitive obstacles to learning include poor decoding skills, sustained use of primitive/unsophisticated strategies, lack of engagement with classroom instruction, lack of meaningful practice opportunities, poor levels of self-efficacy and self-confidence, anxiety, and poor motivation related to personal conceptions of the value of academic learning.

More specifically, our systematic observations suggest that students may be precluded from achieving acceptable standards of literacy and numeracy due to:

- inefficient strategy use, e.g., use of fingers to count, trying to decode words letter by letter;
- poor recall of previously 'known' knowledge – for example having to sound out a word that had recently been decoded correctly;

- failure to transfer learning, i.e., students often demonstrate necessary understanding of the conceptual base but frequently do not apply this knowledge to the task at hand, e.g., students showed that they understood subtraction as it relates to addition but could not use an addition calculation they already knew to work out the answer to a related subtraction question;
- poor motivation to practice, e.g., poor readers did not read much for leisure, poor number thinkers did not practise their times tables;
- reading as word calling, which we have dubbed ‘staccato reading’, rather than the meaningful reading of text which is both expressive and fluent;
- poor decoding skills and a lack of age-appropriate vocabulary;
- generally negative beliefs about academic tasks and the self as a learner, e.g., “I hate maths ‘cos I’m dumb at it.”, “I can’t do these!”.

The following case studies use pseudonyms instead of *QuickSmart* students’ actual names.

Greg was a Year 5 student who benefited greatly from the *QuickSmart* reading intervention. He dramatically improved both his word recognition response speed, as measured by the CAAS system, and his comprehension and vocabulary scores on the standardised tests. Greg’s initial word recognition speed was an average of 1.13 seconds, considerably slower than that of his average-achieving peers who recorded an average of .738 seconds. At the end of the intervention Greg was reading lists generated by the CAAS system at an average of .79 seconds per word. This result compares favourably to the end of year average of his peers’ scores of .752. On the CAAS sentence comprehension measure, Greg began with an average response speed of 6.09 seconds compared to the 3.87 seconds that his average and higher-achieving classmates recorded. By the end of the intervention Greg had decreased his average speed to 4.4 seconds. This represented a considerable improvement but was still slower than the average of 3.76 seconds recorded by the other Year 5 students at the end of the school year.

Greg was keen to participate throughout the intervention, and responded well to the structured practice opportunities and to the program’s instructional emphasis on strategy use. He worked well with his peer partner during *QuickSmart* lessons and was keenly supported by his parents at home. Greg, by nature, is somewhat laconic with a dry sense of humour. He responded positively to the structured small group situation that allowed the development of an easy rapport with the instructor and was geared to success. The

extra confidence that Greg developed in his reading, vocabulary and comprehension skills showed most convincingly on his standardised test scores. Before the intervention Greg was placed at the 21st percentile for comprehension and the 31st for vocabulary knowledge on the ACER Progressive Achievement Tests. After three terms of *QuickSmart* instruction, Greg scored at the 72nd percentile for comprehension and the 79th for vocabulary, an improvement of 51 and 48 percentile points, respectively.

Eve has severe reading difficulties and receives support on a weekly basis from a specialist teacher to improve her reading skills. As a participant in the Year 5 *QuickSmart* numeracy program, Eve worked hard to improve her numeracy skills. She met with considerable success over the course of the intervention.

On the initial CAAS assessment, Eve's lack of strategy use was notable. For example, to work out the answer to $15 - 15$, Eve used her fingers and counted backwards from fifteen by ones to arrive at zero. That a number minus itself always equals zero was one of the first understandings we aimed to consolidate for Eve.

At the beginning of the *QuickSmart* program, Eve recorded average response speeds for addition, subtraction, multiplication and division of 4.03 seconds, 3.61 seconds, 5.6 seconds and 4.56 seconds. Her average and high-achieving peers recorded average times of 2.69 seconds, 2.49 seconds, 3.03 seconds, and 3.75 seconds on the same operations. By the end of the intervention, Eve's times had improved to 2.38 seconds for addition, 1.31 seconds for subtraction, 1.89 seconds for multiplication and 1.84 seconds for division. All Eve's CAAS times were recorded with at least 80% accuracy. In contrast to this improvement, the average end of year scores of the Year 5's who did not participate in the *QuickSmart* program were relatively stable at 2.05 seconds for addition, 2.14 seconds for subtraction, 2.02 seconds for multiplication and 2.79 seconds for division. The accuracy range for these students' scores ranged from 67% to 100%.

Eve regularly recorded the fastest response times on CAAS assessments of any of the Year 5 students in the *QuickSmart* numeracy program. To celebrate her success, she challenged her principal to a number-fact contest. She also recorded good improvement on the standardised test of mathematics and problem solving. Eve's score on Form A of this test before the intervention placed her at the 5th percentile. Following the *QuickSmart* program, Eve scored at the 68th percentile on Form B. Her scores represent an impressive improvement of 63 percentile points.

The CAAS assessment system, administered at the beginning of the intervention indicated that **Kathie**, a Year 7 student, had not mastered her addition, subtraction, multiplication,

and division facts. Kathie applied herself to the practice opportunities available during *QuickSmart* lessons and improved her performance. At the beginning of the intervention her average CAAS times for addition, subtraction, multiplication, and division were 4.225 seconds (89.5%), 3.694 seconds (94.7 %), 3.8 seconds (80%) and 4.79 seconds (89.5%). Kathie's accuracy rates are provided in brackets after her response speed values.

After participating keenly and working well with her partner in *QuickSmart* lessons, Kathie improved both her speed and accuracy scores. At the end of the intervention, Kathie's scores were 2.79 seconds (94.1%) for addition, 1.583 seconds (94.7%) for subtraction, 2.79 seconds (89.5%) for multiplication; and 2.8 seconds (94.7%) for division. These scores compared favourably to those of a comparison mathematics student nominated by the teacher as a student of average ability i.e., 2.43 seconds (73.7%), 2.48 seconds (89.5%), 1.72 seconds (94.7%), and 2.78 seconds (84.2%).

Notably, Kathie regularly reported that she used the academic skills she was reviewing during *QuickSmart* lessons in other classes and in real-life situations such as shopping. On one occasion, she recounted how she surprised and pleased her parents by automatically knowing how much change to expect after buying an item from a local store. Her father's comment was that, "Whatever you are doing in that program at school, you keep doing it!"

Steve is a Year 7 student who participated in the reading intervention. Although his reading fluency at the beginning of the program was near an age-appropriate level, Steve read with little understanding. He benefited particularly from the comprehension strategies that were taught as part of the *QuickSmart* program. Throughout the intervention, the instructional emphasis for Steve was on vocabulary understanding and improving his comprehension of text. Steve's results at the end of the three terms of the *QuickSmart* program indicated that both his fluency of reading and his understanding of what he read had improved.

Steve began the *QuickSmart* program by recording average response times of 1.01 seconds (85.7% accuracy) for middle school vocabulary words (such as notorious, visualise, eventually), 2.96 seconds (100% accuracy) for sentence level comprehension tasks, and 2.11 seconds (88.9%) for vocabulary match assessment tasks. At the end of the program, his time and accuracy levels on these same tasks were .63 seconds (96.7%), 2.9 seconds (100%) and 1.76 seconds (100%).

Steve's improvement was also evident on the comprehension and vocabulary standardised tests administered before and after the *QuickSmart* program. Initially, Steve recorded a

comprehension score at the 29th percentile and a vocabulary score at the 31st percentile. At the completion of the intervention, his percentile ranks were at the 40th for comprehension and the 43rd for vocabulary. These scores evidence an improvement of 11 percentile points for comprehension and 12 points for vocabulary.

These descriptions of student performance couched in case-study descriptions are potentially interesting and useful to teachers and special education professionals for identification, assessment, and programming purposes.

Aim 3 Detailed profiles of individual students will be prepared to document their development in literacy/numeracy over the period of an academic year.

We have constructed comprehensive profiles of students who have participated in the *QuickSmart* program. Detailed individual information from the CAAS assessments conducted over the course of the intervention, as well as standardised test results, task measures, information from class teachers, and recorded observations of students' learning behaviour are used to inform the profiles developed for each participant. These profiles contributed to the brief case-study descriptions already presented and to illuminating findings in relation to other aims of the project.

Not surprisingly, the profiles show that the individual learning strengths and weaknesses vary for each student. However, some commonalities in the students' profiles have emerged. For example, each student's development in literacy/numeracy evidences a decrease in negative self-talk and poor strategy use as these become replaced by more positive thinking focused on higher-order strategies. To varying degrees, each participant in the *QuickSmart* program also developed greater automaticity in basic skills and a more varied and responsive repertoire of strategies to help them solve academic challenges.

Aim 4 Procedures for overcoming identified common learning obstacles will be noted.

A main theme of *QuickSmart* is that many of the common learning obstacles that originally precluded participants from achieving age-appropriate academic outcomes in literacy and numeracy can be overcome by explicit strategy and content instruction, and the systematic use of focused and timed practice activities. Attempts to overcome basic skills deficits require consistent and long-term intervention. Such interventions should be designed to maintain interest and promote students' intrinsic motivation and sense of self-efficacy through repeated success. Some very useful procedures for overcoming learning obstacles are features in the *QuickSmart* program. Many of these procedures are also

identified in the research literature relating to effective instruction for students with learning difficulties. These include:

- a structured and predictable lesson sequence;
- content based on topics of high interest to the students;
- repeated opportunities for students to succeed and to know they are improving, e.g., recording and graphing of results;
- graduated prompting which is responsive to students' needs;
- externalising time in a low key but focused and consistent way, e.g., through the use of stopwatch, hourglass timers, repeated tasks, etc.;
- timed, focused drill and recall activities;
- explicit strategy instruction;
- explicit instruction focused on developing metacognitive awareness by asking students to become aware of and explain their thinking processes;
- a long-term, intensive intervention; and
- the use of an explanatory metaphor to focus students' attention on their learning processes and the purpose of the intervention.

Our research findings indicate that the carefully constructed instructional design of the *QuickSmart* program is successful in supporting students in overcoming many of their learning obstacles.

Aim 5 Insights will be gained into how the procedures developed for individual use may be generalised to suit whole or part class, or small group situations.

Teachers who have read or heard about the *QuickSmart* program show considerable interest in it. Those teachers and administrators who have contacted us since 2001 resonate strongly with the general approach taken in this program. Many teachers are interested in when and how they can access the *QuickSmart* program. Currently, we are considering how the procedures developed for *QuickSmart* can be built upon to become a 'continuum' of support for students with learning difficulties. The support may be appropriate within classrooms and/or as an intense withdrawal intervention for some students.

We have developed a model that features whole-class learning activities for early primary classes, graduating to more intensive individual or small group support. The students included in the small group or individual activities would be those who are still experiencing difficulty demonstrating mastery of basic academic skills in their middle-

school years. There is also great potential to continue to develop *QuickSmart* training and resource packages for teachers and teacher aides so that effective and consistent programs can be implemented to meet the learning needs of students with basic skills deficits. This possibility is more desirable than the use of the ad hoc intervention approaches that are common in school settings.

***QuickSmart* – Program Options**

Recommended Year Level	Mode	Type of Support	Content	How Often?
Years 4,5	Whole class	Focused learning/practise of basic facts	Numeracy	3 half hours per week
Yr 5,6,7	Instruction in pairs (withdrawal)	Intervention for students with learning difficulties- Individualised instruction and assessment	Reading and numeracy	Minimum 3 half hours per week
Yr 5, 6	Instruction in small groups (max 4). In-class group activity or withdrawal	Extra instruction and practise for students who are underachieving	Reading and numeracy	3 half hours per week
Yr 7,8, 9	Individual Instruction (withdrawal)	Intensive remedial support for students with learning difficulties	Reading, literacy in the KLA's and numeracy	Minimum 3 half hours per week
All	'Clinic' consultation. Students with parents/teachers aide willing to support student for 3 or more 15 minute practise sessions per week	Individual initial assessment and program design, practise activities and resources, weekly assessment and review session	Reading and numeracy	Weekly for 30 mins
Whole class	Assessment to show individual and whole class learning strengths and needs	Assessment and profile report to teacher, instructional suggestions	Reading and numeracy	As required

Aim 6 Various stakeholder groups, such as university personnel, members of professional bodies, teachers and parents will link together to address mutually beneficial educational goals.

The on-going exchange of information is vital for the success of *QuickSmart* programs. Communication between students, teachers, principals, parents, university personnel, members of professional organizations, consultants and other interested stakeholders has been extremely useful in refining *QuickSmart* so that it better serves our shared educational goals. For example, discussions with parents and students have informed us about children's perceptions of the program. Similarly, discussions with university colleagues have alerted us to other educational perspectives we may include in future programs. Also, discussions with DET and CEO consultants and classroom teachers have enabled us to link *QuickSmart* more closely to current curriculum initiatives.

Aim 7 Approaches, which facilitate classroom teachers' identification of specific stumbling blocks in students' acquisition of appropriate literacy and numeracy skills, will be documented.

Analysis of assessment results coupled with careful observations of student learning have allowed us to document common difficulties that appear to affect students' mastery of basic skills in reading and numeracy. In classroom settings, it is important for teachers to be able to identify these stumbling blocks to students' acquisition of appropriate literacy and numeracy skills. Frequent and consistent monitoring of students' fluency and understanding in reading and numeracy is key to this identification.

In working with teachers over the last four years, we have attempted to alert them to the importance of observing students' behaviours related to automaticity as a way of identifying those students experiencing difficulty with basic skills and locating where these difficulties may be found. Teachers can consistently take simple measures in order to make judgements about a student's level of automaticity. These measures, which can become part of the classroom routine, include:

- checking how many words a student reads in a minute on seen and unseen connected texts;
- recording how long it takes for a student to read a practised passage of at least 200 words;
- monitoring how many flashcards of focus fact words or number facts are responded to in one minute;
- observing a student's strategy use in solving number tasks;
- probing a student's comprehension of a text and the strategies used to recall, recount, and respond to comprehension questions.

The information about task accuracy and retrieval speed gathered by sub-tests of the CAAS computer system can also be very helpful in assessing and refining where students' may be blocked in terms of their development of appropriate literacy and numeracy skills.

Aim 8 Ways that the technology used in the project may be adapted to assist classroom teachers and support personnel to identify and target particular problems that students face in areas of literacy and numeracy will be developed.

As a result of working on a consistent basis with the CAAS system we have gained insights into how this technology can best monitor students' learning of basic academic skills. In addition to the diagnostic function of the CAAS system that has been explored in much of the research from the LATAS at the University of Massachusetts, we have used CAAS as a systematic assessment and instruction-monitoring tool. In the *QuickSmart* program, a brief session on the CAAS was part of almost every lesson.

The CAAS is a motivating system that delivers almost immediate feedback to students on their performance of basic tasks such as word recognition, sentence-level comprehension, and addition, subtraction, multiplication and division operations. Because this system records individual student's average response speed and accuracy data for all assessment occasions, it easily allows the profiling of performance. This information is useful for the purposes of monitoring instructional effectiveness, and students' increases in automaticity and accuracy over time.

In addition, the use of CAAS by pairs of students in their regular classroom settings shows great promise as a motivating way of developing automaticity in basic skills. For example, once students have mastered a set of CAAS assessments they can become scorers for other students on those particular tasks. The structured use of the CAAS system in classrooms has many possibilities.

Throughout the *QuickSmart* programs, we have also built up a bank of relevant, focused and motivational educational games and flashcard activities that provide guided and independent practice opportunities for students. Teachers, teacher aides, and other school support personnel can be introduced to these and then use our ideas as springboards for the creation of similar activities that would suit the needs of their students.

In many of the activities we developed, we found ways to externalise time as a dimension of instruction. We do this through the regular use of simple one-minute and three-minute hourglass timers, and the familiar nature of many of the activities. In the *QuickSmart* program we used the slogan: "A fast game is a good game." This has the effect of

keeping students focused and interested as well as ensuring the practice is fast paced. Activities include:

- *QuickSmart* bingo using lists of focus words, high-frequency words, and homonyms;
- Three-in-a-Row, a simple strategy game which practises focus number facts;
- Speed sheets for practising regular number fact retrieval;
- Strategy sheets which served as prompts for consistent strategy usage;
- Individual graph sheets for recording flashcard speed and CAAS results.

Aim 9 A set of design features that can be used by teachers and support staff to identify and help rectify particular problems in the areas of literacy and numeracy will be developed.

From our current and continuing research we conclude that an effective intervention designed to address deficits in basic skills should include the following elements:

- A practice routine of about 20 minutes of on-task time, at least 3 times per week.
- The practice routine should be tightly structured, follow a set sequence of activities, and must be time efficient.
- It is essential to focus on timed practice activities aimed at facilitating the speedy recall of *known* facts.
- Strategy instruction needs to be on-going, explicit and individually tailored to students' learning needs.
- Opportunities should be provided for students to self-monitor performances and to receive and generate formative feedback.
- It is important to ensure the students experience success. Except in the case of specific memory deficits, most children will improve their accuracy and speed of recall as a result of practice. We suggest that teachers start with familiar facts, incorporate new knowledge that can be linked to what students securely know, and then encourage them to accumulate additional understandings.
- All practice activities should be enjoyable and motivating. Flashcard activities should be used but not overemphasised. Focused games and repeated readings of high interest texts should be included. Regular assessment tasks from the CAAS system can be particularly motivating for students.
- Reflective metacognitive questioning and responding should be an integral part of the program. Ask the students: "How did you work that out?" "Why are you so sure your answer is correct?" Encourage students to become more aware of their own thinking processes. Give students the language to describe their thinking through modelling the kind of self-talk that a successful learner uses. Allow

students frequent opportunities to discuss their thinking, reflect on it, and begin to regulate their own self-talk and strategy use.

- Accuracy and speed of performance are both important to basic academic skills. Utilize stopwatches, wall clocks, hourglasses, egg timers, and the like in order to externalise time. Students should learn over time to ‘trust their heads’ and respond quickly as well as accurately. The emphasis on time and speed should be low key, but focused and consistent.
- Long-term interventions are necessary to address basic skills deficits for middle school students. Only intense programs provide the necessary practice opportunities to bring students ‘up to speed’ in comparison to their higher-achieving peers.

Analysis of Data from *QuickSmart* Interventions

The data that inform the evaluation of the *QuickSmart* intervention include students' standardised test scores, their information retrieval times on CAAS academic tasks, oral reading fluency measures, and opportunistic data from the Year 5 Basic Skills Tests. All of these results are supported by rich observational data and field notes. These qualitative data are particularly important in developing profiles of our students as learners and descriptions of the cognitive obstacles that can prevent their success with basic academic skills in reading and numeracy.

Standardised Test Scores

The Progressive Achievement Tests (ACER, 2003) in either mathematics or reading comprehension and vocabulary were administered to students participating in the *QuickSmart* program. Although it is accepted that improvement on standardised measures is hard to achieve through intervention research, all of the year 5 participating students and 80% of the remaining students increased their post-test percentile rank scores. Individual improvements of up to 63 percentile points were noted.

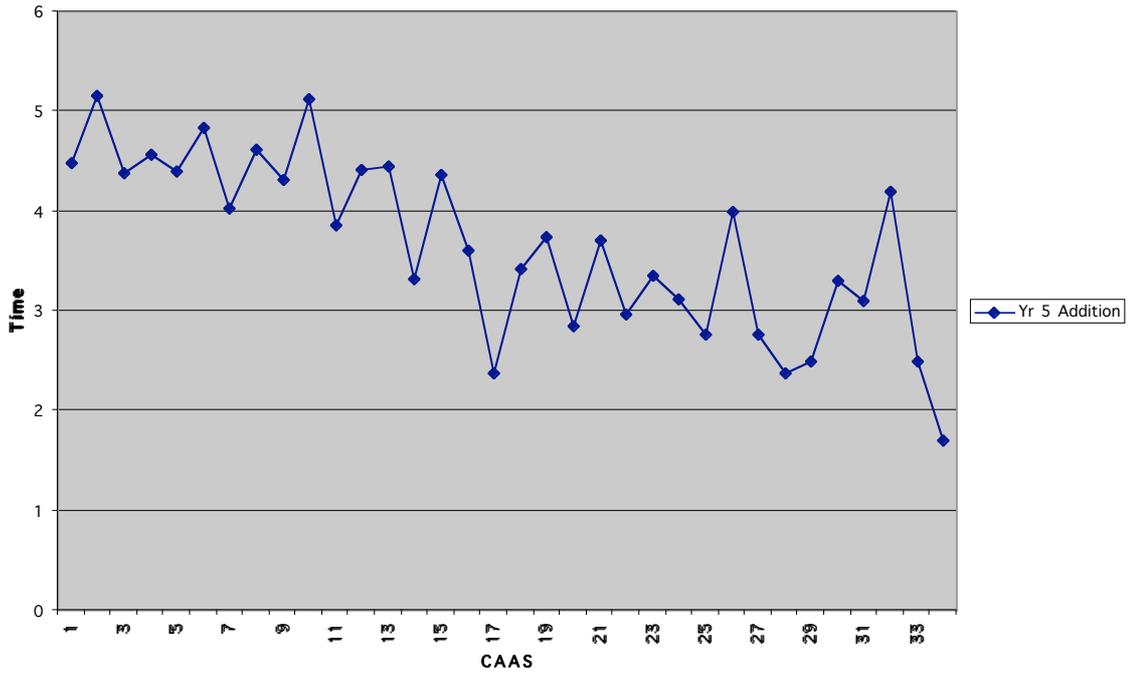
T-test results indicate that the *QuickSmart* students' post-test scores are uniformly higher, at the 0.05 level of significance, than their pre-test scores. This is true for results of the standardised tests for vocabulary ($t_{(9)} = 2.58, p = 0.03$), comprehension ($t_{(8)} = 2.65, p = 0.03$), and mathematics ($t_{(11)} = 2.49, p = 0.04$). These results can be interpreted as support for the hypothesis that increased accuracy and automaticity in basic academic skills results in improvements in higher-order thinking.

Data from CAAS

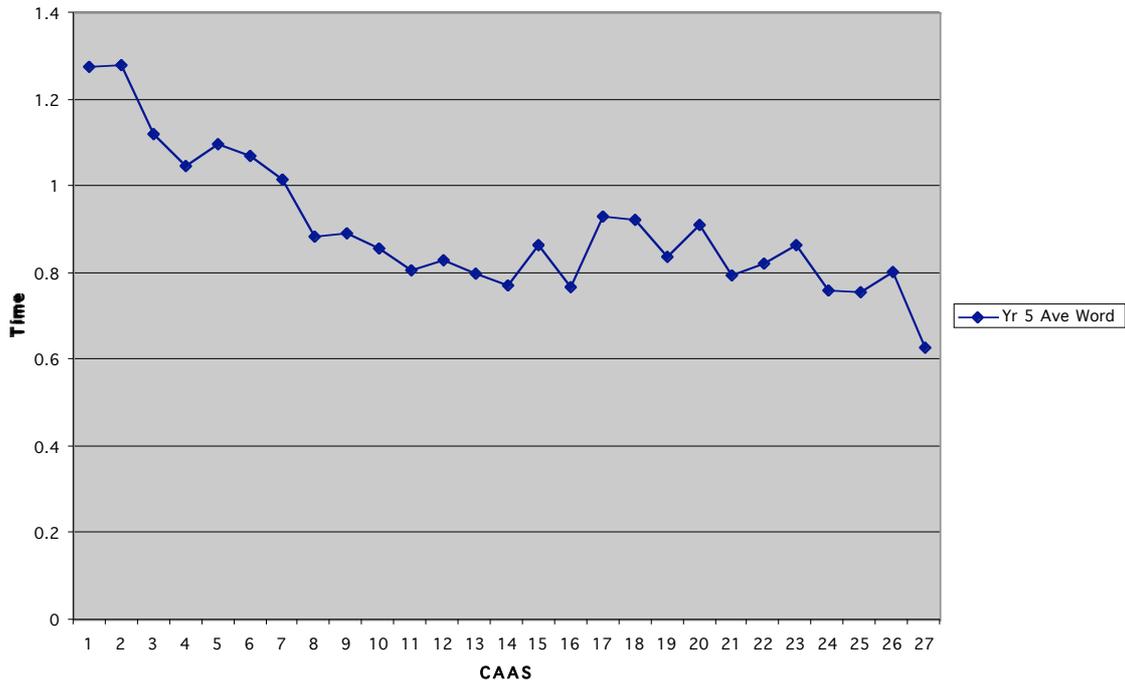
The CAAS system records data relating to retrieval times and accuracy levels on all tasks for all students on all occasions. The analyses presented here include the graphical representation of information retrieval times, and the contrasting of *QuickSmart* and comparison students' CAAS data.

Graphical Representation is an obvious way to summarise an individual's or group trend scores. This approach has been used on selected CAAS tasks throughout the *QuickSmart* program to develop the figure presented below. Graphs of group averages for key tasks from students in the reading and numeracy cohorts are presented in this sub section.

Yr 5 Addition Averages



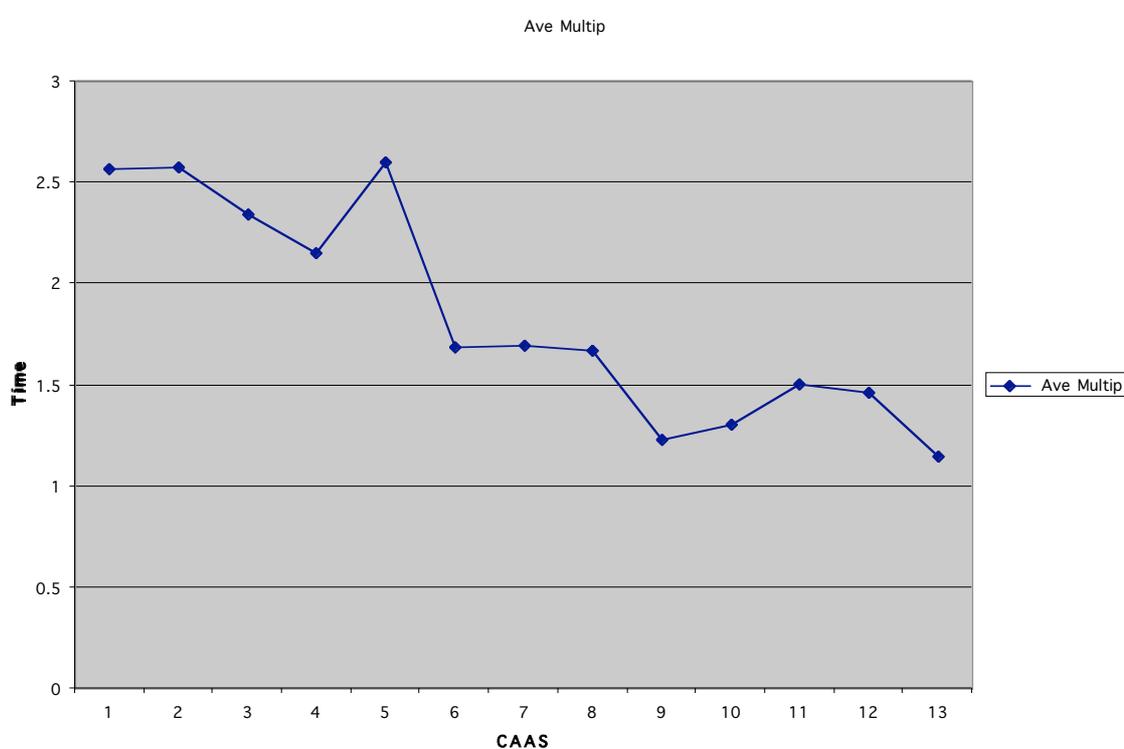
Yr 5 Ave Word



These two graphs drawn above show that the average information retrieval times of students decreased over time. For example, average times for students in the reading group on word recognition decreased from a high of 1.3 seconds to a low of .63 of a second over the course of the intervention. This result indicates that at the end of the intervention students recognised the words presented by CAAS almost as soon as they were shown on the computer screen.

Similarly, the students in the numeracy group were able to answer accurately addition sums in an average time of 1.7 seconds by the end of the *QuickSmart* program. At the beginning of the intervention, these same students took an average of 5.2 seconds to calculate each addition task.

The improvement in retrieval times for numeracy students who completed the CAAS multiplication tasks was also dramatic. At the beginning of the program students took an average time of approximately 2.6 seconds to respond to the multiplication examples. By the end of the *QuickSmart* intervention, this average time was more than halved to 1.15 seconds.



Accuracy data offer another perspective upon which to analyse students' results. Overall, accuracy results were uniformly high on selected sub-tests after the intervention for most *QuickSmart* participants. Accuracy in multiplication after the intervention was between 70% and 100% accuracy. *QuickSmart* reading students' accuracy scores on the CAAS non-word tasks after the intervention ranged from 75% to 94%. Non-word reading is recognised as an extremely difficult task for students with significant reading disabilities.

Comparison and *QuickSmart* students

A further filter through which to view the results of *QuickSmart* program is provided by comparing groups of students' response times before and after the intervention. The most appropriate technique is to use *t*-tests and to determine statistical significance. Student's *t*-tests (two-tailed with unequal variance) were applied to detect statistical differences between groups, and paired *t*-tests (two-tailed) were used to detect differences within groups (before versus after). The table below shows how students who participated in the intervention varied from the average and high-achieving comparison students before *QuickSmart* programs began but not after they were completed.

Reading	Non-word	Initial Element	Sentence
Before	($p < 0.05$)	Not significant	($p < 0.05$)
After	Not significant	Not significant	Not significant

Numeracy	Addition	Subtraction	Multiplication
Before	Not significant	($p < 0.05$)	($p < 0.05$)
After	Not significant	Not significant	Not significant

These results indicate that the *QuickSmart* intervention was effective in assisting educationally disadvantaged students to achieve results comparable to those of their same-age peers. In both literacy and numeracy for two out of three sub-tests there were significant differences between the participants and their class-mates before the intervention. After the intervention no significant differences were found between the groups' response times. This finding supports our claim that *QuickSmart* can bring students 'up to speed' in comparison to their peers on basic academic tasks.

The **Oral Reading Fluency** results showed improvements in rates of Oral Reading Fluency on repeated measures taken before and after the intervention. *QuickSmart* reading students showed on average increased oral reading fluency scores ranging from 33% to 100%.

Basic Skills Data

In the course of *QuickSmart* interventions, data have also become available from the *Year 5 Basic Skills Tests*. These results indicate that for a particular participating school, for the first year since state-wide testing began, no students were in the lowest band for either literacy or numeracy. Only one Year 5 student was in the second lowest band for numeracy and two students for literacy.

Of the twelve students participating in the *QuickSmart* program in this school, six had also been students at the school during Year 3. Consequently, these students' Year 3 Basic Skills Test results were also available. Analysis of this opportunistic data indicates that in all cases the students participating in the *QuickSmart* program showed more improvement as measured by the Basic Skills Test in the area targeted by the *QuickSmart* intervention. Stated another way, the students in the *QuickSmart* reading group showed more improvement in Basic Skills literacy results, while the students in the *QuickSmart* numeracy group showed more improvement on the numeracy tests.

Basic Skills Results

Growth Average for the State - 6.5 pts

<i>QuickSmart</i> READING STUDENTS				
	1999 (Yr 3)	2001 (Yr 5)	Band (Yr 5)	Growth Score
<i>QuickSmart</i> Reading Student 1				
<i>BST</i> Literacy Results	41.5	48.5	3	7.0
<i>BST</i> Numeracy Results	47.1	49.9	3	2.8
<i>QuickSmart</i> Reading Student 2				
<i>BST</i> Literacy Results	41.5	56.3	4	14.8
<i>BST</i> Numeracy Results	48.3	57.6	4	9.3

<i>QuickSmart</i> Reading Student 3				
<i>BST</i> Literacy Results	53.0	54.6	4	1.6
<i>BST</i> Numeracy Results	54.8	54.1	4	-0.7

In addition, five-of-the-six students from whom data were available for both Years 3 and 5 showed improvement in the target area greater than the state average of 6.5 growth points. In fact, one *QuickSmart* reading student showed a growth point increase for literacy on the Basic Skills Tests of 14.8 points. The average growth point score for the students who participated in the reading section of the *QuickSmart* program in literacy was 9.2 points compared to their scores of 6.5 for numeracy. The *QuickSmart* numeracy group scored an average of 7.8 growth points on the Basic Skills Test for numeracy, compared to an average of 3.8 points for literacy.

Basic Skills Results

Growth Average for the State - 6.5 pts

<i>QuickSmart</i> NUMERACY STUDENTS				
	1999 (Yr 3)	2001 (Yr 5)	Band (Yr 5)	Growth Score
<i>QuickSmart</i> Numeracy Student 1				
<i>BST</i> Literacy Results	47.4	54.2	4	6.8
<i>BST</i> Numeracy Results	40.2	49.9	3	9.7
<i>QuickSmart</i> Numeracy Student 2				
<i>BST</i> Literacy Results	51.8	55.5	4	3.7
<i>BST</i> Numeracy Results	43.6	51.6	3	8.0

<i>QuickSmart</i> Numeracy Student 3				
<i>BST</i> Literacy Results	48.8	57.7	5	8.9
<i>BST</i> Numeracy Results	53.4	63.9	5	10.5

There is no doubt that we need more *QuickSmart* students in our schools. Results of this initiative based on the achievement of, to date, a total of 166 students from Years 5, 6, 7 and 8 indicate that *QuickSmart* is a sound instructional intervention that addresses successfully basic skills deficits in middle-school students.

Outline of Future Research Directions

Although we acknowledge that additional research is necessary to establish the usefulness of the *QuickSmart* approach to improving the performance of students who have difficulty with basic academic skills, it is clear that this intervention has made a difference to those students involved.

QuickSmart is a program that responds directly to current policy directions and initiatives relevant to education in Australia. The goals of the *QuickSmart* intervention are closely aligned to the Adelaide Declaration on National Goals for Schooling in the 21st Century (1999) which states that students should attain “the skills of numeracy and English literacy; such that, every student should be numerate, able to read, write, spell and communicate at an appropriate level”; and that schools should be socially just so that “the learning outcomes of educationally disadvantaged students improve and, over time, match those of other students.”

The structured approach of the *QuickSmart* program, with its appropriate use of technology and emphases on both practice and strategy instruction, is also very much in tune with how many teachers consider students with learning difficulties can be usefully supported. In many ways, *QuickSmart* is an example of an effective fourth-wave teaching intervention designed for students with academic difficulties in the middle years of schooling whose difficulties have been resistant to assistance offered by their teachers, consultants and usual classroom-based learning support programs.

QuickSmart is particularly attractive because it is a carefully structured program that focuses on improving numeracy skills as well as reading proficiency. *QuickSmart* shares many of the features of effective teaching outlined in the discussion paper prepared for the Taskforce on Indigenous Education (June, 2001). This is particularly relevant because up to one-third of the *QuickSmart* students who have participated since 2001 have identified as Indigenous students. In the *QuickSmart* program, as in other effective interventions:

- there is an emphasis on self-regulation, metacognition and self-esteem, with the goal of increasing independence in learning;
- there is extended practice in the application of taught strategies;
- student progress is regularly monitored and feedback given;
- reinforcement may initially need to be extrinsic, but intrinsic motivation is the long term goal;

- there is a focus on reading to learn through developing reading fluency and vocabulary; and also on teaching metacognitive strategies such as self-questioning, and:
- texts are adapted to help students cope with classroom literacy demands.

Because the *QuickSmart* intervention has a strategy orientation to students' basic academic skill performance, it moves away from addressing academic problems through 'busy' unsequenced worksheet practice. Instead, it offers an alternative approach that is individualised, carefully monitored and designed by professional educators.

As such, *QuickSmart* has appeal for many teachers. Over the course of the last four years we have had more than sixty inquiries from teachers and administrators who are interested in using a *QuickSmart* approach in their schools and classrooms. Individuals from all over the country have contacted us asking for further information, training materials, program documents, and consultative support.

The achievement of students who participated in *QuickSmart* and the interest shown in this program by educators underscores the importance of research-based interventions. Such interventions can be adapted to local contexts and particular curriculum demands, but need to retain the integrity of the teaching approach that has been shown to be effective. Programmatic theory-based research has the potential to make a positive difference to students' academic performance. This is especially so for low-achieving students whose learning needs are difficult for teachers and schools to accommodate successfully.

The *QuickSmart* program represents an innovative direction for supporting literacy and numeracy skill development. However, further research is essential to establish the maintenance of performance gains, the optimal years of school in which to offer *QuickSmart* interventions, and the effect on student performance of offering *both* reading and numeracy programs to the same students.

Additionally, in order to offer the *QuickSmart* program effectively to interested schools much work is required. It is necessary to continue to prepare materials, plan professional development experiences for teachers related to the use of the CAAS system and the *QuickSmart* approach to improving basic academic skills, as well as arrange a system of consultative support to be provided by members of the Centre for Cognitive Research in Learning and Teaching (CRiLT) at UNE.

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