The Effects of a Basic Facts Fluency Programme within a Self-Regulated Learner Framework on the Fluency of Single-Digit Multiplication Facts with Year 5 & 6 Students.

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Abbreviations

SCC = Standard celeration chart

TFR = Target fluency rate (45 correct answers per minute)

CAPM = Correct answers per minute.

SRL = Self-regulated learner

T1 = Time period one (data obtained before programme commencement)

T2 = Time period two (data collected at the end of the programme, four weeks after commencement)

T3 = Time period three (data collected at maintenance, five weeks after T2)

Trad = Traditional instruction group

RCI = Reliable change index

ANOVA = Analysis of variance

ANCOVA = Analysis of covariance

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Abstract

Fluent recall of basic facts is essential to the development of more complex mathematics skills (Burns, Zaslofsky, Maki, & Kwong, 2016). However, many students struggle to develop fluency with basic facts (Tait-McCutcheon, Drake, & Sherley, 2011). This can lead to other maths difficulties (Gross, Duhon, Shutte, & Rowland, 2016; Ministry of Education, 2016c) which cause students to fall further behind their peers (Church, 2017). The present study used an experimental design to investigate whether a basic facts fluency programme, implemented within a self-regulated learner (SRL) framework, could lead to increased fluency with multiplication facts for Year 5 and Year 6 New Zealand students (9-10 years old). It also investigated the extent to which the SRL programme altered students' basic facts practice behaviour outside of school hours. The study found that the SRL programme resulted in rapid fluency development that was maintained over time. Nomothetic and idiographic analysis confirmed that the programme was suitable for use within tier one of the response to intervention framework. In addition, the study also found that students who received the programme altered their practice behaviour outside of school hours. The results from this study show how elements of self-regulated learning and precision teaching can be successfully combined to enhance students' mathematics achievement.

Chapter 1: Introduction

Fluent recall of basic facts is essential for the development of more advanced mathematics skills (Burns et al., 2016; Johnson & Street, 2013). By reducing the demand on working memory, fluent recall of basic facts enables students to devote more attention to the overall purpose of a mathematics problem (Burns, Kanive, & DeGrande, 2012; Burns et al., 2016; Hurst & Hurrell, 2016; Neill, 2008; Sweller, Ayres, & Kalyuga, 2011). This, in turn, helps students to develop a deeper understanding of mathematics (Gross et al., 2016). Compared to their less fluent peers, students who are fluent with the recall of their basic facts also enjoy more opportunities to respond to complex mathematics tasks (McCallum, Skinner, Turner, & Saecker, 2006). This causes less fluent performers to fall further behind their peers, a phenomenon commonly referred to as the Mathew effect (Merton, 1968). Given the close link between fluent basic facts recall and the development of more advanced mathematics skills it is perhaps not surprising that fluency is also associated with additional positive outcomes. These include an increased willingnes to exert effort and increased student motivation (Codding, Hilt-Panahon, Panahon, & Benson, 2009). In addition, basic facts fluency is associated with successful independent living (Codding, Chan-Iannetta, Palmer, & Lukito, 2009; Gross et al., 2016; Patton, Cronin, Bassett, & Koppel, 1997). Specifically, basic facts fluency plays a role in both money and time management. These skills are required in numerous contexts including employment, further education, home and family life, leisure pursuits, personal responsibility and relationships, health, and community involvement (Patton et al., 1997).

Despite the importance of fluent basic facts recall, many students find learning multiplication facts difficult (Steel & Funnell, 2001; Tait-McCutcheon et al., 2011). In fact, Steel and Funnell (2001) found that by the end of primary school one-fifth of all English school students, who participated in the study, had not learned even the simplest multiplication problems. Fluent basic facts recall is also an issue for New Zealand students. Findings from the Trends in International Mathematics and Science Study (TIMMS) show that New Zealand's mean Year 5 score was significantly lower than the TIMMS scale median, a finding due in part to New Zealand's relatively weak performance in basic facts (Ministry of Education, 2016c). Given that this pattern of relatively weak basic facts performance was observable since 2006/2007, it is perhaps not surprising that Year 9 students also exhibited a relative weakness in basic facts knowledge (Ministry of Education, 2016d).

These findings highlight the need for effective tier one programmes that can increase students' fluency with basic facts, a primary objective of the current study. Tier one refers to the first of three tiers that compose the response to intervention (RTI) model. The RTI model is based on evidence-based practice and continuous monitoring across all three tiers (Tunmer & Greaney, 2010). The three tiers include a universal tier (tier one), a targeted group tier (tier two), and an individualised support tier (tier 3). Tier one focusses on enhanced classroom instruction. This instruction should result in adequate yearly progress for 80-90% of students (Johnson & Street, 2012). Continuous progress monitoring allows educators to identify students who are not responding adequately to high quality instruction. These students may then be identified for more intensive interventions. Effective tier one programmes are an essential aspect of the RTI model. Without effective tier one programmes, students may be overidentified for tier two or tier three interventions. This puts added stress on schools' limited resources. Alternatively, inadequate tier one instruction can lead to under identification of struggling students, which diminishes the preventative aspect of the RTI model (Tunmer & Greaney, 2010).

The current study addressed two gaps in the literature. First, it sought to answer whether a basic facts fluency programme based on *detect, practice, repair*, direct instruction, and precision teaching (PT) methodology could be implemented within a self-regulated learner (SRL) framework. Specifically, it aimed to identify whether this programme led to increased basic facts fluency with Year 5 and 6 students when compared to students receiving regular classroom instruction. Second, it investigated the extent to which the SRL programme altered students' basic facts practice behaviour outside of school hours. Whilst there is general agreement around the need for students to engage in high quality practice to develop basic facts fluency, there is little research on how a classroom based intervention can influence student practice behaviour outside of school hours. This is surprising given what we know about how students develop fluency with basic facts. The primary consideration when teaching basic facts is ensuring sufficient time is allocated to practice (Kameenui & Simmons, 1990). In addition to allocating sufficient time, teachers must also consider how this practice is distributed. Research from Schutte et al. (2015) suggests that basic facts practice is most beneficial when it occurs in small increments spread across the day. Traditionally both practice frequency and duration are limited to the amount of time apportioned to mathematics learning during a child's day at school. However, if a programme could facilitate additional high-quality practice outside of school hours, it could overcome this barrier. This, in turn, should result in students developing fluency with basic facts within shorter time periods.

1.1 Direct versus indirect approaches to learning basic facts

Teaching basic facts can be broadly grouped into either a direct or indirect approach (Baroody, Purpura, Michael, Reid, & Paliwal, 2016). The indirect approach includes strategies such as making ten, splitting numbers into parts, skip counting and pattern analysis (Baroody et al., 2016; Reys, 2009). Proponents of indirect instruction highlight the importance of strategy teaching for developing an understanding of underlying concepts (Kanive, Nelson, Burns, & Ysseldyke, 2014; Poncy, Skinner, & Jaspers, 2007). They believe that this in turn leads to improved transfer (Baroody et al., 2016) and generalisation across problems (Poncy, Duhon, Lee, & Key, 2010). The argument against a purely indirect approach raises concerns around students becoming overly reliant on strategies which can result in errors (Poncy et al., 2007) and disrupt the memorisation of facts (Baroody et al., 2016). Studies also highlight the inefficient use of instructional time associated with an indirect approach (Baroody et al., 2016; Poncy et al., 2007) and point to the need for students to be able to rapidly and accurately answer basic facts (McCallum et al., 2006). The direct approach includes evidence based strategies such as *cover, copy, compare*; *detect, practice, repair,* and *taped problems* (Codding, Hilt-Panahon, et al., 2009; Poncy, Fontenelle Iv, & Skinner, 2013). These strategies can be successfully integrated into the classroom curriculum however, they require increased instructional time to complete (Codding, Hilt-Panahon, et al., 2009). All three of the above programmes use explicit timing procedures which are essential to all mathematics fluency practices (Gross et al., 2014). Explicit timing procedures involve presenting a task along with a specific amount of time within which to complete it. They can be supplemented with the use of rewards, goal setting, and graphic feedback (Codding, Archer, & Connell, 2010; Gross et al., 2014).

A more common perspective, and one endorsed by the New Zealand Ministry of Education (Ministry of Education, 2009), emphasises the need for both direct and indirect instructional approaches. Students start with strategies to develop an understanding of multiplication (Boaler, Williams, & Confer, 2015; Neill, 2008). During this phase, they should have experience with manipulatives and other thinking strategies (Reys, 2009). By developing an understanding of strategies like commutativity, students actually reduce the number of facts they need to commit to memory (Neill, 2008; Stein, Silbert, & Carnine, 1997). However, there is a limit to how far understanding and practising strategies can lead to memorisation (Neill, 2008). Once students can complete the skill somewhat accurately they should move to memorisation (Burns et al., 2012; Dennis, Sorrells, & Falcomata, 2016; Hopkins & Egeberg, 2009).

Stein (1997) suggests that a programme to support mastery of basic facts should have the following six components: (1) specific performance criteria; (2) intensive practice on new facts; (3) systematic practise of learned facts; (4) adequate practice time; (5) a record-keeping system; and (6) a motivation system. Many of these aspects are supported by Reys (2009), who also notes that practice should occur daily and for relatively short durations. Although it is generally acknowledged that practice is essential to developing fluency with multiplication basic facts (Burns, 2005; Ministry of Education, 2009; Poncy et al., 2007), there is a concern that some teachers (Codding et al., 2010) and curricula (Musti-Rao & Plati, 2015) do not allow for sufficient basic facts practice. No matter what instructional approach is applied, repeated practice is essential to the development of fluency (Burns, Ysseldyke, Nelson, & Kanive, 2015).

1.2 Facilitating basic facts practice through precision teaching

Precision teaching (PT) was developed by Ogden Lindsley and applied to classroom contexts from the mid-1960s (Binder, 1996; Lindsley, 1992). PT is primarily concerned with the development of fluency. Binder (1996) defines fluency as "the fluid combination of accuracy plus speed that characterises competent performance" (p 164.). It is typified by behaviour that is "flowing, flexible, effortless, errorless, automatic, confident, second nature, and masterful" (Johnson & Street, 2013, p 23.). Johnson and Street (2013) use the acronym MESsAGe to describe the outcomes that are associated with fluent performance. These five outcomes are depicted by the capital letters in the MESsAGe acronym. 'M' stands for *maintenance*. It states that when a student is fluent in a behaviour they should be able to perform the behaviour on demand, without further practice. 'E' represents *endurance*. Without *endurance*, a student can only perform the skill for short time periods, which would not be consistent with fluent performance. ‘S’ refers to *stability*. *Stability* is defined as the ability to perform a skill in the face of distraction. ‘A’ stands for *application*, which is the ability to apply the skill in other contexts. ‘G’ stands for *generativity*. *Generativity* refers to the ability to perform new responses in different contexts, by blending and combining previously learned skills. Fluency outcomes are determined by identifying at what rate of responding these five learning outcomes are met.

Fluency programmes have led to large improvements in academic performance (Binder, 1996) for students of all abilities (Gallagher, 2006). In fact, fluency programmes have commonly been associated with gains in achievement of two or more grade levels within a year (Binder & Watkins, 2013). The Morningside Academy, which is based on PT methodology, offers a money back guarantee if students don’t make at least two years’ worth of progress, in their weakest learning area, within one year. Supported by over four decades worth of research (Gallagher, 2006), PT is one of the most validated and effective teaching methods (Binder & Watkins, 2013).

PT is based on applied behavioural analysis (Gallagher, 2006). Applied behavioural analysis emphasises: (a) solving socially important problems in applied settings, (b) continuous and direct measurement of observable behaviour, and (c) understanding the contingent relationship between behaviour occurrences and environmental factors (Sugai, O’Keeffe, & Fallon, 2012). Many of these tenets can be seen in the five steps employed by PT: (1) the teacher identifies a learning objective; (2) the teacher arranges materials and procedures for learning and practicing the pinpoint; (3) the teacher and the learner time the student’s performance and count its frequency; (4) the learner and teacher chart the learner’s performance on a celeration chart; (5) the teacher and learner review the chart and make decisions about possible interventions to improve the performance (Johnson & Street, 2013).

A fundamental first step in PT involves decomposing learning tasks into observable behaviour that can be recorded and charted (Gallagher, 2006). Measuring the frequency of a behaviour is a key component of PT. Frequency has a precise definition in PT. It is calculated by "placing any count of behaviour over the time spent counting" (Kubina & Yurich, 2012, p110). PT chooses to measure the frequency of a behaviour over time, as traditional approaches, such as percentage correct, are less sensitive to individual differences in performance (Gallagher, 2006; Johnson & Street, 2013) and can provide a misleading picture of programme effectiveness (Gallagher, 2006). Samples of behaviour are typically recorded on a daily basis (Binder & Watkins, 2013) and over brief time periods, often one-minute in duration (Binder, 1996; Binder & Watkins, 2013). Students are then involved in the graphing of this information on standard celeration charts (Binder & Watkins, 2013). The term 'celeration' was coined by Ogden Lindsley to indicate either rate of growth (acceleration) or deterioration of performance (deceleration) over time.

A standard celeration chart (SCC) allows the user to measure the acceleration or deceleration of a behaviour over time. A key feature of the SCC is its linear x-axis for calendar time and logarithmic scale on the y-axis, for frequency (Binder, 1996). Charts that use absolute frequency underestimate performance at low frequencies and overestimate performance at high frequencies. Unlike absolute frequency charts, the SCC measures student growth that is proportional to their previous growth. This more accurately reflects how people learn (Johnson & Street, 2013).

Fluency aims and celeration rates are used in conjunction with the SCC. Both Binder and Watkins (2013) and Johnson and Street (2013) suggest aiming for celeration rates of ×2.0 per week. This represents a doubling in the frequency of the observed behaviour. For example, if a student could correctly answer 15 basic facts per minute at the start of the week and 30 basic facts per minute at the end of the week their celeration rate would be ×2.0 per week. Kubina and Yurich (2012) classify a celeration rate of ×2.0 per week as ‘exceptional’, noting that a celeration rate of ×1.4 per week (40% growth in behaviour) still represents ‘robust’ growth. The use of celeration rates enables teachers to monitor progress. When progress rates are below an acceptable celeration rate this alerts the teacher that changes need to be made to the teaching method or materials (Chiesa & Robertson, 2000). Failure to match expected celeration rates are considered to represent deficiencies in instruction, rather than a deficit within the student. Kubina and Yurich (2012) describe seven decision making guidelines that indicate to the teacher that a programme change needs to be made. These decision-making guidelines are based on learning pictures that depict a range of celerations which represent inadequate progress. For example, the behaviour the teacher is trying to accelerate is decelerating or the behaviour the teacher is trying to decelerate is accelerating. Insufficient progress signals to the teacher that a programme change is required. This could mean that the teacher needs to *slice* back to a smaller set of items from the curriculum or *step* back to an earlier class of behaviour in the curriculum sequence. Alternatively, it could mean that an incorrect behaviour pinpoint was identified from the original error analysis or that the student had simply not been provided with sufficient practice opportunities. It may also signal that the time over which the behaviour was recorded needs to be reduced, as when a behaviour lacks endurance the student may tire quickly. This, in turn, results in choppy or unsteady performance. Insufficient progress may also be due to inadequate or inappropriate reinforcement (Kubina & Yurich, 2012). Once a programme change has been made progress continues to be monitored through the use of SCCs.

PT supports a generative instruction model. A generative approach involves breaking a learning goal into a set of tool skills, component skills, and composite skills. Tool skills are the simplest elements of more complex skills. They form the basis for component skills, which are sometimes referred to as second-level building blocks (Johnson & Street, 2013).

For example, sounding out a word is a tool skill for the component skill of understanding the meaning of a word. Composite skills represent a higher level of performance that is composed of one or more component skills. In this example, that could involve understanding a chapter of text. Fluency training is fundamental to the generative instruction model. PT is used to ensure students are fluent in the component skills required in order to develop more complex composite skills (Chiesa & Robertson, 2000). In a mathematics context, basic facts are viewed as the component skills required to develop more complex composite behaviours (McTiernan, Holloway, Healy, & Hogan, 2016).

1.3 The importance of practice

Practice is a key component of PT. Carl Binder, one of the leading proponents of PT, defines practice as the "repetition of a given response class after it has been accurately established in a repertoire" (Binder, 1996, p 179.) Ericsson, Krampe, and Tesch-Römer (1993) also emphasise the important role practice plays in improving performance. In their research, they have considered the type of repeated practice experts engage in. They observe that it is not sufficient to simply repeat an activity, instead that activity must be specifically designed to improve performance. Deliberate practice researchers define deliberate practice as an activity that is categorically different from activities that could be best described as play or testing (Duckworth, Kirby, Tsukayama, Berstein, & Ericsson, 2011; Ericsson, 1996; Ericsson et al., 1993). Macnamara, Hambrick, and Oswald (2014) offer a concise definition of practice that highlights two key features. Specifically, they define deliberate practice as "engaging in structured activities created specifically to improve performance in a domain" (p 1.). During practice, individuals must also make constant adaptions based on feedback in order to overcome plateaus in performance (Johnson & Street, 2013; Wong & Evans, 2007).

Attaining basic facts fluency is related to the frequency with which practice occurs (Baroody, 1999; Steel & Funnell, 2001). In fact, of the many instructional approaches used to develop basic facts fluency, repeated practice appears to be the key component (Burns et al., 2015). Repeated practice, or item rehearsal, facilitates the transition of items from short term memory to long term memory (Atkinson & Hilgard, 1996). This helps to overcome short term memory's limited capacity. This in turn means that students who are fluent in basic facts can devote more cognitive energy to advanced applications within problems (Burns et al., 2012; Burns et al., 2016; Neill, 2008). It also means that students can respond to more problems during a given time period which leads to additional gains relative to students who are not yet fluent with basic facts (McCallum et al., 2006).

Some researchers believe that teachers do not provide sufficient practice opportunities for students to develop basic facts fluency (Burns, Codding, Boice, & Lukito, 2010; Gallagher, 2006). Whilst the need for regular, structured practice is generally accepted in disciplines such as the arts and athletics, this does not appear to be true for academic disciplines (Gallagher, 2006). Binder (1996) believed this was because educators viewed practice as outmoded and boring. It is possible these views are a legacy of rote learning, which involved repetition without set targets. Irrespective of the root cause, increased time spent in practice does not necessarily lead to improved performance. In addition to providing sufficient practice opportunities, educators must also consider the quality of the practice students are encouraged to engage in. In fact, time spent in practice is only a good predictor of performance when the quality of practice is taken into account (Plant, Ericsson, Hill, & Asberg, 2005; Rosario, Nunez, Valle, Gonzalez-Pienda, & Lourenco, 2013). Evidence for this can be found in studies investigating the link between homework and achievement.

Ramdass and Zimmerman (2011) found that quality measures of homework such as managing distractions, perceived responsibility for learning, goal setting, self-reflection, managing time, and setting a place for homework completion were all better predictors of performance than only measuring the amount of time spent on homework. Özcan and Erktin

(2015) provide a specific example of how mathematics homework can lead to improved academic achievement in mathematics when adjustments are made to improve the quality of the homework set. In their study, this involved enriching the mathematics activities with metacognitive questions. These questions could be broadly classified as reflection focussed (Which main topic did you learn in your mathematics lessons last week?), strategy related (What do you need to know to solve this problem?), organisation focussed (When will you start your homework?), and evaluative (How many problems could you solve?).

Timed practice is a key component of practice procedures employed in PT methodology (McTiernan et al., 2016). PT's strength lies in its ability to encourage large amounts of practice within short time periods (Johnson & Street, 2013). Gallagher (2006) suggests five guidelines for timed drill practice. These include: (a) drills should be kept short, (b) learners should be encouraged to beat their own scores, (c) learners should be taught that it is acceptable to make mistakes, (d) performance records should be kept using SCC. Repeated practice greatly increases students' opportunities to respond, which is associated with improved performance (Burns, 2005). Two of the key considerations when scheduling practice are considering how many facts should be learned and how frequently these should be rehearsed (Kameenui & Simmons, 1990). There is general agreement in mathematics (Burns et al., 2016) and PT literature (Kameenui & Simmons, 1990) that no more than six new facts should be presented in a single session. These should then be practised frequently throughout the day, rather than in one large block (Schutte et al., 2015) before being integrated with known facts for continued rehearsal (Burns, 2005).

1.4 The role of self-regulated learning in developing basic facts fluency

Most basic facts fluency programmes are teacher or researcher directed, making continued practice outside of school hours difficult. Ericsson et al. (1993) identified access to resources, such as teachers or researchers, along with effort and motivation as the three main barriers to engaging in deliberate practice. Self-regulated learning (SRL) programmes may provide a means to overcome these barriers. SRL involves the interaction of cognitive, metacognitive, and motivational processes as well as the use of self-assessment and self-evaluation of learning to direct future learning (Dignath, Buettner, & Langfeldt, 2008; Zimmerman, 1990). Effective SRL interventions are composed of three stages which Zimmerman (2000), one of the foremost researchers on SRL, labels forethought, performance/volitional control, and self-reflection. He emphasises the cyclical nature of this process, noting that feedback from prior performance is used to make adjustments to current learning. Not all SRL researchers use Zimmerman's three phase labels. The terms pre-action, action, and post-action are more widely used to describe these phases (Schmitz & Wiese, 2006).

The development of SRL theory represented a change in approach to the investigation of achievement. Previously, student ability, quality of teaching, schools, and home environments were studied in relation to student performance. In contrast, SRL theory encouraged investigation into how students initiate and maintain their learning in a domain (Zimmerman, 1986). To this end, a number of SRL features have been linked to improved student performance. These include the use of goal setting, self-monitoring, self-evaluation, and organisational skills (Dignath et al., 2008; Zimmerman, 1990; Zimmerman, Moylan, Hudesman, White, & Flugman, 2011). The benefits of SRL programmes are not limited to academic achievement. SRL programmes have resulted in a raft of other cognitive, metacognitive, and motivational benefits. A large number of these are described in the literature review below. Whilst all learners, to some degree, engage in learning during teacher instruction. SRL behaviours are required to promote additional learning without teacher support. The essential features of effective practice, described earlier, can be facilitated through the use of these SRL behaviours.

In contrast to PT, which is based on applied behavioural analysis (Gallagher, 2006), SRL is based on social cognitive theory (Zimmerman, 1986). Social cognitive theory is concerned with the triadic interaction between behaviour, internal cognitive factors, and the external environment (Bandura, 1997). On this basis, SRL theorists believe students are metacognitively, motivationally, and behaviourally engaged in the learning process. In accordance with this belief, SRL theorists emphasise the use of strategies to achieve academic outcomes. This, in turn, is posited to enhance feelings of self-control and the development of positive self-perception. Whilst social cognitive theory and applied behavioural analysis represent differing philosophical positions, it is not uncommon for schools to implement programmes and practices based on both of these theories. For example, positive behaviour for learning (PB4L) is based on applied behavioural analysis (Sugai et al., 2012) and has been adopted by over 740 New Zealand Schools (Ministry of Education, 2017). At the same time, the New Zealand Curriculum also promotes the importance of *managing self* as one of the five key competencies for students (Ministry of Education, 2007), a concept more aligned to social cognitive theory. This study explored how elements from both PT and SRL could be blended together. Essentially, taking key elements from both approaches in order to create an SRL fluency programme that resulted in significant, ‘robust’, and enduring improvement in basic facts fluency for all students.

Chapter 2: Literature Review

2.1 Search strategy and criteria

The previous section described the links between basic facts, practice, PT, and SRL. This section analyses many of the key studies in these areas and explores some of the fundamental ideas, described in the introduction, in greater detail. Specifically, this section examines what programmes and elements of programmes are associated with enhanced basic facts fluency. It also investigates what role practice plays within these programmes and explores how programmes are designed to facilitate high quality practice opportunities for students. In addition to analysing what effect the reviewed studies had on student achievement, this review also explores the strengths and limitations of the study designs. This section finishes by identifying the gap in the literature that this study aims to address. It also identifies strengths and limitations of the studies that were observed across the literature reviews. It then describes how these observations have influenced the design of this study. Finally, the review elucidates how, and why, programme elements from the basic facts, PT, and SRL literature have been incorporated within the current programme.

Table 2.1 displays the search strategy and selection criteria for three separate literature reviews of the precision-teaching, self-regulated learning, and basic facts intervention literature. As noted in the introduction, the PT and SRL studies were based on two distinct paradigms. These paradigms strongly influenced the design and analyses employed in these studies. For this reason, the decision was made to group these studies according to the literature on which they were based. In contrast to the PT and SRL studies, the basic facts studies represented a more heterogeneous group of studies. Whilst the decision to group studies according to their theoretical underpinnings resulted in three separate literature reviews, important connections across the reviews are also identified.

The first row of Table 2.1 describes the search period and age of participants. A review of the literature found that there were far fewer PT and SRL studies than basic facts studies. For this reason, the decision was made to expand the search period for the SRL and PT studies back to 2000. In addition, the SRL search criteria was also relaxed to include studies with either primary or secondary aged participants. Row two details the terms that were used in each of the literature searches and row three identifies the databases in which these searches were conducted. Row four confirms that additional Scopus searches were undertaken on all of the studies included in this review. This step was included to identify other studies which may have met the search criteria but had not been identified using the stipulated search terms. Row five confirms that only intervention studies were included in the reviews and row six describes the other selection criteria that were adhered to during the literature searches. The final row identifies the number of studies that met the search criteria and were included in the respective reviews.

Table 2.1

Search criteria and strategy

	Precision teaching	Self-regulated learning	Basic facts
Search period & Age	2000-present Primary (5-13)	2000-present Primary and secondary (5-18)	2005-present Primary (5-13)
Search terms	The following terms, and combinations of these terms, were searched: Precision teaching, PT, elementary, primary, K12, middle school, education, mathematics, psychology, study, intervention	The following terms, and combinations of these terms, were searched: SRL, self-regulat*, elementary, primary, K12, high school, middle school, education, mathematics, psychology, study, intervention	The following terms, and combinations of these terms, were searched: multip*; basic fact*; subtract*; divis*; incremental rehearsal; "basic fact*"; self-administered folding-in procedure; math facts in flash; taped problems; *detect practice repair*; *cover, copy, compare*; peer tutoring; self-instruction; self-monitoring
Databases searched	University of Canterbury Multi Search, Australian Education Index, British Education Index, Education Source, Eric, PsychInfo, WorldCat, ProQuest dissertation and thesis, and Google Scholar		
Scopus search for all studies found	Yes	Yes	Yes
Intervention only	Yes	Yes	Yes
Selection criteria	1) Studies met the criteria outlined above. 2) Studies were written in English. 3) Studies were limited to those applying PT to developing basic facts fluency. 4) Studies took place within a school setting. 5) Programmes were implemented at a class level.	1) Studies met the criteria outlined above. 2) Studies were written in English. 3) The intervention included promotion of cognitive, metacognitive, and/ or motivational strategies. 4) The participants were human. 5) Only studies applying SRL to mathematics were included. 6) Studies took place within a school setting.	1) Studies met the criteria outlined above. 2) Studies were written in English. 3) Studies included some form of intervention. 4) Studies which included students with a learning difficulty (LD) or emotional behavioural disorder (EBD) were included but not studies involving students with extremely low cognitive ability. 5) Studies took place within a school setting.
Number of studies	5	16	45

2.2 Precision Teaching

Only five studies met the search criteria described above for PT. Table 2.2 provides a comparison of these studies according to a number of criteria, which are organised into seven columns. Column two identifies the number of students who participated in each study and their age. It also notes whether the study included students of all abilities, or was limited to participants who had a learning difficulty. Column three identifies the focus of the mathematics programme and column four describes the design of the study. Both column five and six report the programme delivery. Column five states whether the programme was primarily delivered by a researcher or teacher. Column six describes the programme in terms of the duration of each lesson, the number of sessions which were administered, and the time frame over which the programme ran. The final column identifies the main results from each study. Strømgren, Berg-Mortensen, and Tangen (2014) found only two studies that used PT to build fluency in basic facts with typically developing children in regular school settings. They also observed that there were no studies that involved the random assignment of students in primary schools to either a PT intervention or ‘treatment as usual’ condition.

Whilst all five studies identified in the current review focussed on typically developing students within a regular classroom setting, it is interesting to note that the students across each of these studies were performing more poorly than their peers. This resulted in studies that involved relatively small numbers of participants. In fact, in three of the five studies, the programmes were run with less than eight participants. Of these studies, both Chiesa and Robertson (2000) and Gallagher (2006) adopted a similar approach. The struggling mathematicians received a PT intervention whilst the rest of their classmates continued with their regular instruction. During these studies, pre-test and post-test scores were obtained for all participants. This enabled the researchers to measure the improvement in performance made by the students in the PT intervention over the course of the programme. It also enabled the researchers to compare the PT students to their normally achieving peers at the end of the programme. Small sample sizes are not uncommon in PT literature. Although PT can be used with whole classes, it is more frequently implemented in an individual manner.

In contrast, Singer-Dudek and Greer (2005) used a simultaneous treatments design to investigate the relative effectiveness of fluency and mastery instruction. These students were taught a composite mathematics skill and their performance was assessed one month and two months after instruction. Strømgren et al. (2014) and McTiernan et al. (2016) both investigated the development of multiplication facts fluency with students who were approximately 10 years of age. These studies included a larger number of participants than the previous studies. However, like the previously mentioned studies, all the participants were identified as struggling mathematicians. In order to obtain this number of struggling mathematicians, students were selected from a range of year groups across the participating schools. In the study by Strømgren et al. (2014) students were randomly assigned into either the treatment as usual or PT condition. McTiernan et al. (2016) took an alternative approach. In their study, they matched students according to each participant's score on the WIAT-II mathematics subtest. This meant that each participant was matched with a pair whose score was no more than 10 points above or below their own score. Interestingly, all of the PT studies chose to exclude normally achieving students from the PT programmes. It is likely that these programmes would also have resulted in accelerated progress for all students, however this hypothesis cannot be confirmed from the PT studies reviewed here.

Fluency aims. A fluency rate of between 80 to 100 math facts per minute, without errors, has been shown to pass the MESsAGe test (maintenance, endurance, stability, application, and generativity; Johnson & Street, 2013). However, all of the procedures in the reviewed PT studies adopted fluency rates that were less than this benchmark. As described above, the MESsAGe acronym was developed by Johnson and Street and adopted by the Morningside Academy (Johnson & Street, 2013). McTiernan et al. (2016) evaluated the effects of the Morningside Mathematics Fluency programme in their study. The fluency rates associated with this programme ranged from 50-60 correct answers per minute for worksheets containing families of facts, up to 70-80 correct responses for review worksheets (McTiernan et al., 2016). Strømgren et al. (2014) set a fluency rate target of 70 correct answers per minute; however, like Gallagher (2006) and Chiesa and Robertson (2000), they did accept fluency rates of 40-50 correct answers per minute throughout the intervention. Singer-Dudek and Greer (2005) took an alternative approach, which is supported by Binder (1996), to developing their fluency aims. They determined their fluency rates by assessing the mean fluency rate of ten adults. Unlike the other four studies, they expressed this rate as digits correct per minute, rather than correct responses per minute. Care must be taken when setting target fluency rates. If the fluency rate is set too low behavioural fluency is not achieved. This means the outcomes typically associated with fluent performance (MESsAGe) may not be attained.

The post-test results in each of these studies fell substantially below the fluency aims used as benchmarks within the studies. This occurred for a number of reasons. In both McTiernan et al. (2016) and Gallagher (2006) students progressed through levelled activity sheets as they met the specified fluency aims. However, the dependent measures used in these studies contained a wide range of basic facts problems, which some students would not have been exposed to during the intervention. McTiernan et al. (2016) observed that prior to the intervention, no student met the fluency aims on any timed probe. By post-test, the number of fluency aims met ranged from 12 to 26, out of a total of 84 fluency aims which compose the curriculum. The post-test results in Strømgren et al. (2014) are considerably lower than the fluency aims used throughout this intervention because of the way the dependent measure was calculated. They presented students with five work sheets containing 250 problems to be completed within 20 minutes. From these results, they calculated a rate per minute. It is likely that if they had limited the post-test to a duration of one-minute, then the mean correct answers per minute would have been considerably higher. Chiesa and Robertson (2000) and Singer-Dudek and Greer (2005) investigated composite repertoires derived from component skills. These included fluent multiplication fact recall for specific multiplication tables. The results in these studies describe student achievement in terms of these complex tasks, rather than the component skills.

Delivery. Gallagher (2006) laments the fact that despite recommendations by educational psychologists, teachers, and others involved in education in England, there has been little interest in PT across the United Kingdom. Chiesa and Robertson (2000) believe that this may be due, in part, to teachers' perceptions that the monitoring required by PT programmes is too demanding of their time. The fact that all PT programmes reviewed here were implemented either in part, or in their entirety, by a researcher may appear to support these claims. However, on closer inspection, some of these studies describe implementation procedures that are particularly efficient. The researchers in both Gallagher (2006) and Chiesa and Robertson (2000) taught students how to score, chart, and understand the information they were plotting on their standard celeration chart (SCC). Students in these studies, were also able to complete the intervention procedures independent of teacher instruction. The researchers returned to these schools once a week to review the SCC and make decisions about the next instructional stage. In Chiesa and Robertson (2000) these decisions were made after individual conferences with the students. The degree to which these interventions could be completed independently is all the more impressive considering that the participants in both of these studies were selected for inclusion because they were lagging behind their peers. The demands on a teacher's time can also be reduced through the use of peer coaching. In fact, this is seen as a key component of PT (Johnson & Street, 2013). As well as reducing teacher workload, peer coaching has a number of important benefits for students. Specifically, students learn about the importance of self-evaluation, self-management, and self-monitoring skills (Johnson & Street, 2013). Students also receive additional learning opportunities from teaching/coaching their peers and develop social and cooperative skills throughout the peer coaching process. As a result, students also receive more frequent feedback (Johnson & Street, 2013). Despite these benefits, only one programme employed peer coaching (Chiesa & Robertson, 2000). Even in this instance, the peer coaching procedure was limited to providing feedback about whether their partner's response was correct or incorrect.

The time required for programme delivery differed substantially across all five studies. The PT programme durations ranged from eight to 36 weeks. Perhaps more interesting is the length of each PT session, which was reported in three of the five studies. These three studies all implemented interventions with sessions that lasted for at least 25 minutes. This is substantially longer than the session durations reported in most of the basic facts programmes (described below). The average session length in the basic facts studies was nearly 15 minutes and only six of the reviewed basic facts studies reported session durations that exceeded 25 minutes. This may be a reflection of the literature from which these programmes have evolved. PT literature emphasises the importance of practice. The Morningside Academy, which is based upon PT, describes three essential phases of learning and teaching (Johnson & Street, 2012). One of these phases involves practicing the performance learned during instruction until fluency aims are met. Haughton, an early proponent of PT, suggested that practice should make up at least half of all time spent on education (Binder, 1996).

Programme effectiveness. It is not possible to directly compare the results described in these studies, due in part to the way these studies reported their results and because two studies reported results at the composite (Chiesa & Robertson, 2000; Singer-Dudek & Greer, 2005) rather than component skill level. Strømgren et al. (2014) reported a medium pre- to post-test effect size for the PT group. Hattie (2012) proposes, that to be considered effective, a programme should exceed a standardized effect size of Cohen's d = 0.40. From the information provided in Gallagher (2006) and McTiernan et al. (2016) it was possible to calculate Cohen's *d*. Respectively, these interventions resulted in pre- to post-test effect sizes of d = 1.16 and d = 1.91, both of which are considered large.

Summary. The results suggest that PT can lead to substantial improvements in students' fluency with basic facts. Notwithstanding these results, some care should be taken when interpreting these findings. Whilst the effect sizes detailed above are impressive, these studies only selected participants who were experiencing some level of maths difficulty. This means care must be taken when generalising these results to all students of this age. Whilst PT is supported by over four decades worth of research (Gallagher, 2006) and considered one of the most validated and consistently effective methodologies (Binder & Watkins, 2013) there is limited research in this specific area. As already noted, previous research has found only two studies that used PT to build fluency in basic facts with typically developing students in a regular school setting. Of these, only one study has used random assignment of students in primary schools to either a PT intervention or 'treatment as usual' control. These findings suggest that additional research is required to confirm that the positive effects of PT, described above, do generalise to all students across a diverse range of contexts. This study aims to contribute to the sparse literature in this area.

Table 2.2

Precision teaching studies

Study (N = 5)	**Participants; age; description**	**Programme description (Math focus)**	**Design**	**Intervention delivered by**	**Duration; sessions; period**	**Results**
Chiesa & Robertson, 2000	N = 5 (25[a]) Age = 9 Lagging behind peers	Precision teaching (Division of two-digit numbers by one-digit, up to and including five, and with remainders)	Pre-test-post-test design	Researcher and teacher	Np; np; 12 weeks	• PT: Pre-test = 1 (SD = 0.71), post = 13.2 (SD = 2.05) • Control: Pre-test = 3.7 (SD = 3.01), post-test = 4.2 (SD = 3.49) [b]Effect *d* = 8.85
Gallagher, 2006	N = 8 (26[a]) Age = 11 Lagging behind peers	Precision teaching (Multiplication facts 1-6)	Pre-test-post-test design	Researcher and teacher	Maths lesson; 60; 12 weeks	• PT: Pre-test = 16.38 (SD = 5.07), post-test = 22.75 (SD = 5.92) (t = 5.49, two-tailed test; p<0.001). • Transfer: Pre-test = 26.86 (SD = 4.75), post-test = 27.13 (SD = 4.58) [b]Effect *d* = 1.16
McTiernan, Holloway, Healy, & Hogan, 2016	N = 36 Age = 10.1 LD	Precision teaching - Morningside math facts (multiplication and division)	Randomised control design	Researcher	25 min; varied; 36 weeks	• Frequency building: Pre-test = 12.9 (7.65), post-test = 33.1 (13.5) • Treatment as usual: Pre-test 11.2 (9.42), post-test = 17.4 (8.85) [b]Effect *d* = 1.91
Singer-Dudek & Greer, 2005	N = 4 Age = Na LD	Precision teaching (Instruction of math facts under fluency or mastery criteria. (Component skills: Single digit multiplication [0-3] and addition facts [sum <10])	Simultaneous treatments design	Researcher	Np; 13-117 learn units; np	Accuracy at 2-month follow-up on composite task: Fluency (student A): 100% Fluency (student B): 83% Mastery (student C): 17% Mastery (student D): 50%
Strømgren, Berg-Mortensen, & Tangen, 2014	N = 48 Age = 10, 11, 12 Lagging behind peers	Precision teaching (Multiplication and division facts)	Restricted random assignment	Researcher	25 minutes; 40; 8 weeks	• PT: Pre-test = 5.16 (SD =2.87), post-test = 8.04 (SD = 4.59) • TAU: Pre-test = 5.07 (SD = 2.21), post-test = 6.21 (SD = 2.05) • X^2 (1,42) = 4.1-, p = 0.043. effect size = medium, Cramer's V = .31, p = 0.43

Note: AS = all students, LD = students with learning difficulties, EBD = students with emotional and behavioural disorders, SD = standard deviation, NP = not provided. [a]Numbers in brackets denote the number of students in the class. The number preceding the bracket represents the number of students who were selected, on the basis of screening data, to take part in the PT programme. [b]Effect size was calculated from data provided in the study.

2.3 Self-Regulated Learning

Whilst a number of studies investigated self-regulated learning, a much smaller proportion of these investigated a specific SRL intervention. In total 16 studies met the SRL search criteria described in Table 2.1. Using similar search criteria, a meta-analysis by Dignath et al. (2008) identified 30 articles on SRL published between 1992 and 2006. However, unlike this review, Dignath et al. (2008) did not limit their search to only SRL interventions applied to mathematics. An overview of all 16 studies can be found in Table 2.3. This overview is organised into six columns. Column two identifies the age and number of participants included in each study. It also describes the design of each study. Column three identifies the name of the programme that was administered. Where a name was not provided the key components of the programme were identified. This column also identifies the measures that were employed during the study. Column four identifies whether the study was primarily delivered by a researcher or teacher and column five describes the programme in terms of its duration, the number of sessions in which it was administered and the time frame over which the programme ran. The final column highlights the main findings from the respective studies.

Delivery. Hattie, Biggs, and Purdie (1996) undertook a meta-analysis to investigate the effect of learning skills interventions on student learning. One of their findings from this research was that programmes of shorter duration have the greatest initial impact on performance, an effect that diminishes over time. Specifically, programmes shorter than 30 days were correlated with increased effect sizes. Twelve studies reviewed here detailed the number of weeks over which the programme took place. Intervention durations ranged from one day (Labuhn, Zimmerman, & Hasselhorn, 2010) to 36 weeks (Núñez, Rosário, Vallejo, & González-Pienda, 2013) with an average programme duration of nearly 8 weeks.

A more recent meta-analysis by Dignath et al. (2008) found that, in general, students benefited most when SRL strategies were introduced by researchers, rather than teachers. Interestingly, mathematics was one of two areas which ran counter to this general finding. Dignath et al. (2008) note that teacher competence is one limitation that must be overcome if SRL interventions are to be implemented more widely in school settings. One way of achieving this is by providing more extensive teacher training. Of the 16 studies reviewed here, 11 (69%) were administered by teachers. Whilst not all of these studies described the teacher training process, it is clear that some studies had put significant thought into how best to train teachers. Two of the most extensive training procedures were implemented by Stoeger and Ziegler (2005, 2008). Teachers in these studies took part in three-day seminars which included presentations on the theoretical groundwork of SRL, topics relevant to home study, and training in the use of programme materials. Two additional studies, by Kramarski and colleagues (Kramarski, Itzhak, & Sarit, 2013; Kramarski, Weisse, & Kololshi-Minsker, 2010), also provided detailed teacher training which took place over six hours on one day. Similarly, Núñez et al. (2013) provided extensive teacher training and was the only study to provide two one-day workshops during the programme, in addition to the two one-day workshops held prior to programme implementation. These additional training days were important to maintaining the fidelity of the programme's implementation given the extended length of this study (36 weeks).

The ultimate aim of teacher training is to improve the fidelity with which a programme is implemented, which should in turn lead to improved performance. In this sense, the extensive teacher training undertaken in these studies led to mixed student outcomes. Whilst all studies reported improved student SRL skills, not all programmes led to improved academic performance. In fact, the SRL programmes employed by Stoeger and Ziegler (2005, 2008) showed no significant effect on maths grade. Whilst the programmes did result in improved behaviours which are associated with improved academic performance, the failure to enhance academic performance is a limitation in these interventions. A similar pattern was also observed in the Núñez et al. (2013) study. Whilst this study did result in improved maths achievement (d = .34), the programme had a larger effect on SRL strategy use (d = .98) and self-efficacy for SRL (d = .73). The programmes employed in Kramarski and Mizrachi (2006) also resulted in improved planning, self-monitoring and self-evaluation. Like the Núñez et al. (2013) study, the SRL programmes taught in the Kramarski and Mizrachi (2006) study did result in improved mathematics performance. The amount of improvement made by students was influenced by both the type of SRL strategy that was taught and the type of mathematics skills that were assessed. These findings suggest that the programmes employed in these studies may require a stronger focus on the mathematics skills taught, to result in greater gains in students' mathematics achievement.

Programme design. As early as 1986, Zimmerman defined self-regulated students as being "metacognitively, motivationally, and behaviourally active participants in their own learning" (Zimmerman, 1986, p. 308). The importance of these components is underscored by Dignath et al. (2008), who found SRL programmes that incorporated a mix of metacognitive and motivational strategies had the greatest effect on dependent variables. Given Zimmerman's strong theoretical influence in most of these studies, it is not surprising that 12 of the 16 programmes included metacognitive and motivational components. Whilst most studies tailored their SRL programme to meet the needs and contexts of the participants, one feature was common to almost all studies. Of the 16 studies reviewed here, 14 of the SRL programmes were developed based on research from Zimmerman. Studies most commonly structured their programmes according to Zimmerman's (2000) self-regulatory cycle, which is composed of three phases termed forethought, performance, and self-reflection.

Zimmerman's influence was not limited to studies adopting his phase model for self-regulation. Studies also embraced many other aspects of his work, including SRL learning strategies (Camahalan, 2006; Núñez et al., 2013) and training programme modules (Stoeger & Ziegler, 2005, 2008). The theoretical influence of Zimmerman's work across the studies did not constrain their design. One interesting feature, employed in six of the studies, was the use of acronyms which stood for stages or strategies within the SRL process. Acronyms included IMPROVE (Kramarski et al., 2013; Kramarski et al., 2010; Özcan & Erktin, 2015), STARtUP (Lee et al., 2014), MARS (Ness & Middleton, 2012) and WWWH (Kramarski et al., 2013). The use of acronyms is an innovative approach to teaching relatively complex SRL procedures to school aged students. The most transparent of these acronyms were MARS and WWWH. Unlike the other programmes, the MARS programme emphasised behavioural outcomes as opposed to strategies. The student in the Ness and Middleton (2012) study was encouraged to reflect on a number of questions and statements such as "Do I have my pen or pencil?" and "I will make eye contact with the teacher." These were organised under the following headings: *materials prepared, anticipate, ready to learn*, and *stay focussed* (MARS). The WWWH acronym employed in the Kramarski et al. (2010) study was designed to help students generate self-directed questions through the following words: *what, when, why,* and *how.* Students were taught to use these words to generate context specific questions. For example, "What steps do I need to take in solving a substitution task?" The STARtUP and IMPROVE acronyms were less transparent. The letter 'U' and 'P' in the acronym STARtUP stood for understanding and planning. These stages were further decomposed into *start, given, find, picture,* and *heuristic* which were organised into the shape of a star. This programme was designed to encourage students to become more aware of their thought processes. The IMPROVE acronym represented teaching steps within the classroom. These included introducing new concepts, metacognitive questioning, practicing in small groups, reviewing, obtaining mastery, verification, and enrichment and remediation (Kramarski et al., 2010). Through this process students engaged in four generic self-directed question prompts. These involved comprehension questions (e.g. “What is the task/problem?”), strategy questions (e.g. “What is the strategy?”), connection questions (e.g. “What is the difference/similarity?”), and reflection questions (e.g. “Does the solution make sense?). Kramarski et al. (2013) described IMPROVE as a generic approach. In their study, they investigated the relative effects of generic (IMPROVE) and context specific (WWWH) approaches. They found that both approaches had a positive effect on student performance but they did so in differing ways. WWWH led to improved planning and near transfer, however IMPROVE led to enhanced evaluation skills and far transfer. Near transfer tasks required students to apply the algebraic skills they had been taught to items that were similar to what the students had been learning. In contrast, the far transfer condition included number sense and visualisation items that were derived from domains which the students had not been taught. The authors suggest that the more generic IMPROVE programme provided students with a more scaffolded approach to processing abstract information than the context specific WWWH approach. No other study compared generic or context specific SRL approaches. Nor did any study specifically investigate whether the specificity of the programme and transparency of the acronym were more suited to older or younger students.

Programme effectiveness. In their meta-analysis on self-regulation training programmes, Dignath et al. (2008) found SRL programmes had a mean effect size on academic performance of 0.69. However, the mean effect size for mathematics performance was considerably higher, with a mean effect size of 0.97. Not all of the studies reviewed here reported pre- to post-test effect sizes for mathematics performance. Of the studies that did, a number exceeded the mean effect size that Dignath et al. (2008) reported (DiGiacomo, 2014; Kramarski et al., 2010; Leidinger & Perels, 2012; Ramdass & Zimmerman, 2008).

The positive effects attributed to the SRL programmes were not limited to mathematics achievement. The other positive effects can be broadly classified as predominantly motivational, or metacognitive. Many motivational improvements were observed across the studies. The SRL programmes facilitated a reduction in negative emotions, including anxiety (Kramarski et al., 2010) and helplessness (Stoeger & Ziegler, 2008), whilst increasing a number of positive emotions, such as a sense of personal control and improved self-confidence (Lee, Yeo, & Hong, 2014). Many of the motivational effects observed were closely related to academic performance. These included improved goal orientation (Stoeger & Ziegler, 2008; Tzohar-Rozen & Kramarski, 2014), increased on task behaviour (Ness & Middleton, 2012), and increased willingness to exert effort (Stoeger & Ziegler, 2008).

Almost all programmes included metacognitive components. Kramarski et al. (2010) observed that the IMPROVE programme they employed led to improved metacognitive strategy use. Many studies went further than this by identifying which particular metacognitive elements their SRL programmes affected. At this level of analysis, studies reported that SRL programmes led to improved planning (Lee et al., 2014) and time management (Stoeger & Ziegler, 2005, 2008). The studies also reported that the SRL programmes resulted in improved self-reflective behaviour (Stoeger & Ziegler, 2005, 2008). This included improving the accuracy of self-reflections (Kramarski et al., 2013; Ramdass & Zimmerman, 2008), whilst reducing self-reflection bias (Labuhn et al., 2010; Ramdass & Zimmerman, 2008).

Summary. The results from the reviewed studies confirm that SRL programmes can have a large effect on student achievement. This effect seems to be greatest when the programme includes explicit, evidence-based instruction in the mathematics skills being assessed. In addition to enhancing student achievement, the SRL programmes had a positive effect on students' motivational and metacognitive behaviours. Specifically, these factors include goal setting, reflection, and willingness to exert effort. These factors are also associated with effective practice. As a result, SRL programmes may lead to more effective practice behaviour, which in turn, leads to enhanced academic outcomes.

Table 2.3

Self-regulated learner studies

Study (N=16)	Participants; age; design	Programme & Measures	Intervention delivered by	Duration; sessions; period	Results
Camahalan, 2006	N = 60 Age: 9 & 11 Quasi-experimental	Programme: 14 SRL strategies and relationship to maths Measures: Report card grades Mathematics achievement • Self-designed Mathematics SRL • Self-designed	Researcher	Duration: 1 lesson Sessions: 30 Period: 6 weeks	Students in SRL group made a significant improvement in maths achievement. • Significant difference in the mathematics achievement between treatment and no treatment groups, $F(1,56) = 15.51$, $p<.01$ • Significant difference in the mathematics self-regulated learning between treatment and no treatment groups, $F(1,56) = 132.99$, $p<.01$
DiGiacomo, 2014	N = 360 Age: 11 & 12 Mixed methods experimental design	Programme: Self-monitoring and self-reflection Measures: Math performance • 5 self-developed questions for each session Predictive confidence judgments • 10-point self-developed scale Postdictive confidence judgements • 10-point self-developed scale Calibration accuracy Prior math achievement • Math section of Iowa Test of basic Skills	Researcher	Duration: 45 min Sessions: 5 Period: 3 weeks	Students in the intervention had significantly higher math performance and calibration than the control. • Accuracy of calibration: $F(1,26) = 8.314$, $p = .008$, $\eta2 = .242$ • Treatment effect on maths performance: $F(1,26) = 5.750$, $p = .024$, $\eta2 = .181$
Kramarski, Itzhak, & Sarit, 2013	N = 61 Age: 12 Random control study	Programme: IMPROVE and WWWH Measures: Self-regulation • 20-item pre/post self-reported Metacognitive Awareness Inventory (MAI; Schraw & Dennison, 1994) Mathematical measures Short-term effect: Algebraic procedural knowledge • 13-item scale based on the curriculum Long-term transfer to novel task: verbal problems solving • 7-item follow-up test (based on Presmeg, 1986)	Teacher	Duration: Maths lesson Sessions: 9 Period: 6 weeks	WWWH lead to improved planning and near transfer, IMPROVE lead to improved evaluation skills and far transfer. Planning improvement over time • WWWH: (d = .87) • IMPROVE: (d = .48) Monitoring improvement over time • WWWH: (d = .54) • IMPROVE: (d = .38) Evaluation improvement over time • WWWH: (d = .71) • IMPROVE: (d = .9) Mathematics (long term transfer)

					• WWWH outperformed IMPROVE on algebraic skills: (*d* = .44) • IMPROVE outperformed WWWH on number sense (*d* = .56), and visualisation skills (*d* = .34)
Kramarski, Weisse, & Kololshi-Minsker, 2010	N = 140 Age: 8 Quasi-experimental	Programme: IMPROVE Measures: Mathematical problem solving performance • Basic task (+, -, ×, ÷) • Complex task (problem solving) • Transfer task (unfamiliar problem solving) Metacognitive strategy use • 23 item questionnaire (adapted from Kramarski & Mevarech, 2003) Mathematics anxiety • 39 item questionnaire using 4-point Likert scale (adapted from Sarason,1980a, and Midgley et al., 2000)	Teachers	Duration: 4 hours per week Sessions: 4 Period: 4 weeks	The MS group made greater gains in math problem solving. They used metacognitive strategies more often and showed a greater reduction in anxiety than the control. Problem solving: • MS (low achievers): basic task (*d* = 0.86), complex task (*d* = 0.75), transfer task (*d* = 1.2) • MS (high achievers): basic task (*d* = .28), complex task (*d* = 0.57), transfer task (*d* = 1.46) • No MS: complex (*d* = .4) only significant finding for this group Metacognitive strategy: • MS (low achievers): pre-action (*d* = .29), action (*d* = .39) • MS (high achievers): pre-action (*d* = .13), action (*d* = .27) • No MS: no significant findings Anxiety • MS (low achievers): negative thoughts (*d* = -.45), positive thoughts (*d* = .22) • MS (high achievers): negative thoughts (*d* = -.72), positive thoughts (*d* = .42) • No MS: negative thoughts (no change) positive thoughts (low *d* = -.32), (high *d* = -.28)
Kramarski & Mizrachi, 2006	N = 86 Age: 13 Quasi-experimental	Programme: IMPROVE with or without online discussion Measures: Mathematical literacy • Multiple choice and open-ended computation tasks. Self-developed Real life tasks • Based on qualities described by PISA (OECD, 2003) SRL questionnaire • 23 general items and 23 specific items scored on a 5-point scale.	Teacher	Duration: 45min Sessions: 1 Period: 4 weeks	Online meta students significantly outperformed other groups on math task and SRL measures. Mathematical literacy • Online + Meta outperform Ftf + Meta: (*d* = .5 • Ftf + Meta outperform online students (*d* = .81) • Online students outperformed Ftf students (*d* = .25) SRL improvement • Online + Meta (*ES* = 1.82) • Ftf + Meta = (*ES* = 1.68) • No other significant results
Labuhn, Zimmerman, & Hasselhorn, 2010	N = 90 Age: 10	Programme: Differing types of evaluative standards and feedback Measures:	Researcher	Duration: 40min Sessions: 1 Period: Np	No main effect on problem solving for feedback or standards. The students who received more feedback were more accurate in their self-judgements.

	Random control study	Mathematical problem solving performance • 8 questions, self-developed Predictions • Measures how confident students were that they could answer the above questions. 9-point scale Self-evaluation • Perceived effectiveness of solutions. 9-point scale Self-judgment • Based on Kitsantas and Zimmerman (2002) Self-satisfaction • 9-point self-developed scale Calibration of math performance prediction and self-evaluation • Based on Pajares and Graham (1999)			• Significant main effect of feedback for both self-evaluative accuracy F(2, 81) = 5.310, p<.01, eta2 = .116 • Significant main effect of self-evaluation bias F(2, 81) = 5.032, p<.01, eta2 = .111 • Significant main effect of feedback F(2, 81) = 3.270, p<.05, eta2 = .075
Lee, Yeo, & Hong, 2014	N = 63 Age: 9 Quasi-experimental	Programme: Po'lya's problem solving approach and STARtUP Measures: Understanding planning and problem solving success • Problem solving test, comprising 5 non-routine problems. Scored on a rubric adapted from Charles et al. (1987). Confidence and personal control • adapted version of the Problem-solving Inventory (PSI; Heppner and Peterson 1982)	Np	Duration: 1 hour Sessions: 6 Period: 1 week	Metacognitive training had a positive impact on problem understanding, planning, confidence, emotion, perseverance and achievement. Difference between experiment class and control class • Level of understanding: (*d* = .64) • Level of planning: (*d* = .46) • Personal control: (*d* = .26) • Problem solving confidence: (*d* = .2) • Problem solving success: (*d* = .53)
Leidinger & Perels, 2012	N = 135 Age: 9 Longitudinal design	Programme: Metacognitive and motivational strategies Measures: SRL questionnaire • 4-point Likert scale designed by researcher Diary • 4-point Likert scale designed by researcher Mathematics test • 8 practical problems (arithmetic and geometry)	Teachers	Duration: 45 min Sessions: 6 Period: 6	SRL group made slightly more math progress (not significant). SRL • Experimental group: goal setting (*d* = .28) Pre/post-analysis of maths test • Experimental group: (*d* = .68) • Control: (*d* = .31)

		Teacher Register • Assessment of learning material (6-point scale) • Student motivation (4-point scale)			
Ness & Middleton, 2012	N = 1 Age: 11 Case study	Programme: MARS (materials, anticipate, ready to learn, stay on task) Measures: On-task behaviour • Every minute for 50 minutes using Stahr, Cushing, Lane, & Fox, (2006) on-task criteria Classroom preparation • 4 criteria	Researcher, special education teacher, classroom teacher	Duration: Np Sessions: 2 days per letter Period: Measured over 1 month	Intervention led to improved classroom preparation, on-task behaviour, grade, teacher perception of engagement during maths. • On task behaviour: Pre-intervention (48%), post-intervention (67%) • Classroom preparation behaviours: Pre-intervention (48%), post-intervention (82.5%)
Núñez, Rosário, Vallejo, & González-Pienda, 2013	N = 94 Age: 12 Longitudinal randomised trial	Programme: Goal setting, self-monitoring, self-reflection, strategic planning, organisational strategies Measures: SRL strategies • Assesses 9 SRL strategies on a 5-point scale (based on Rosario and Nunez, et al., 2010) Self-efficacy for SRL • 10 items on a 5-point scale (based on Zimmerman, Bandura, & Martinez-Pons, 1992) Perceived usefulness • 10 items on a 5-point scale (based on Rosario et al., 2012) Student study time • Study time logs for 7 days (based on Plant, Ericsson, Hill, 7 Asberg, 2005) Academic achievement • School grades for maths	Teacher	Duration: 1 hour Sessions: 36 Period: @36 weeks	Participation in treatment group led to improvements in SRL strategy use, self-efficacy for SRL, perceived usefulness for SRL and math achievement. More study time was not associated with greater improvements in outcomes for either group. Between group difference at time period 4 • SRL strategies: (d = .98) • Self-efficacy for SRL: (d = .73) • Perceived usefulness of SRL: (d = .9) • Language achievement: (d = -.03) • Mathematics achievement: (d = .34)
Özcan & Erktin, 2015	N = 44 Age: 13 Quasi-experimental	Programme: Homework was enriched with questions from IMPROVE Measures: Mathematics homework behaviour scale • Student and parent forms (based on Özcan and Erktin, 2013) Mathematics achievement Report card scores for maths	Researcher	Duration: Np Sessions: 12 Period: 12 weeks	Significant difference between math scores for children who had been given homework enriched with metacognitive questions than those who had not. • Significant main effect on mathematics performance $F(1,3) = 4.41$, $p < 0.05$ • No significant main effect on the students' homework behaviours scores (parent form) $F(1,17) = 0.03$, $p > 0.05$

Perels, Otto, Landmann, Hertel, Schmitz, 2007	N = 249 Age: 13 Time series analysis and experimental control	Programme: Goal setting, motivation and reflection, strategy training Measures: Problem solving test SRL questionnaire • 4-point scale Learning diary • 5 min each day for 49 days (based on Schmitz and Wiese, 2006)	Researcher	Duration: 90min Sessions: 6 Period: 49 days	Positive result for both self-regulation and problem-solving groups on post-test performance.
Ramdass & Zimmerman, 2008	N = 42 Age: 10 & 11 Random control study	Programme: Strategy, self-correction, self-correction checklist Measures: Mathematical performance • Self-developed Self-efficacy • Ratings 10-100 based on Bandura's (2006) guidelines Self-evaluation • Ratings from 10-100. Adapted from Chen's (2003) self-evaluative scale. Self-evaluation calibration bias • Based on Pajares and Miller's (1997) method of calculating accuracy and bias scores Self-efficacy calibration accuracy • Based on Pajares and Miller's (1997) method of calculating accuracy and bias scores Self-evaluation calibration scores • Based on Pajares and Miller's (1997) method of calculating accuracy and bias scores	Researcher	Duration: 45 Sessions: 1 Period: Np	Experimental group performed significantly better on math performance, self-efficacy, accuracy, self-evaluation and had less bias. • Significant main effect for training group: Wilks' lambda $F(5, 42) = 6.07$, $p < .05$, $\eta 2 = .51$ • Self-efficacy correlated positively with math performance ($r = .49$) • Self-evaluation correlated positively with math performance ($r = .60$) • Self-efficacy accuracy correlated positively with math performance ($r = .75$) • Self-evaluation accuracy correlated positively with math performance ($r = .49$) • Self-efficacy bias was negatively correlated with maths performance ($r = -.75$) • Self-evaluation bias was negatively correlated with maths performance ($r = -.44$)
Stoeger & Ziegler, 2005	N = 36 Age: 9 Quasi-experimental	Programme: Goal setting, strategy choice, self-reflection, self-assessment, time management Measures: Time management and self-reflective approach • 6-point scale (adapted from Gold and Souvignier, 2000) Self-efficacy • 6-point scale (adapted from Ziegler & Stoeger, 2002)	Teacher	Duration: "within regular classroom instruction" Sessions: During regular classroom instruction Period: 6 weeks	No significant training effect on math grades but improved time management and self-reflective learning behaviours. Time management • Treatment: ($\Delta = .2$) • Control: ($\Delta = -.4$) Self-efficacy • Treatment: ($\Delta = .31$) Self-reflective behaviour • Treatment: ($\Delta = .15$) • Control: ($\Delta = -.37$)

		Willingness to exert effort • Self-developed 8 item scale Helplessness • Used 4 items form Helplessness Scale (Breitkopf, 1985) Aspiration level for the subject of mathematics • One self-developed question Scholastic achievement • Developed by participating teachers Ability level Raven test			No significant training effect on achievement or other variables.
Stoeger & Ziegler, 2008	N = 219 Age: 10 Quasi-experimental	Programme: Self-evaluation, self-monitoring, goal setting, strategic planning, effective and ineffective learning strategies Measures: Time management and self-reflective approach • 6-point scale (adapted from Gold and Souvignier, 2000) Self-efficacy • 6-point scale (adapted from Ziegler & Stoeger, 2002) Willingness to exert effort • Self-developed 8 item scale Motivational orientation • One scale from the Manual for the Patterns of Adaptive Learning Scales by Midgley et al. (1998) Interest • 6-item scale developed by Ziegler, Dresel and Schober (1998) Scholastic achievement • Developed by participating teachers Daily maths exercises • Self-developed Homework handouts • Self-developed	Teachers	Duration: "during normal classroom instruction and homework activities" Sessions: See above Period: 5 weeks	Training group showed no increase in performance but increase in self-reflection, self-efficacy, motivation, willingness to exert effort, learning goal orientation Time management. • Treatment: (Δ = .25) Perception of self-efficacy • Treatment: (Δ = .25) • Control: (Δ = -.13) Self-reflection of own learning • Treatment: (Δ = .35) Willingness to exert effort • Treatment: (Δ = .22) Interest • Treatment: (Δ = .17) • Control: (Δ = -.22) Learning goal orientation • Treatment: (Δ = .41) Avoidance orientation • Treatment: (Δ = .25) • Control: (Δ = .2) Helplessness • Treatment: (Δ = -.43) Grade on class exam • Control: (Δ = .34) Only significant effects are reported (<.01)
Tzohar-Rozen & Kramarski, 2014	N = 118 Age: 10 Random control study	Programme: Metacognitive regulation and motivational and emotional regulation Measures: Math problems	Teacher	Duration: 1 hour Sessions: 10 Period: 5 weeks	No difference between MC and ME at post-test but MC showed improved metacognitive regulation and ME showed improved motivational-emotional aspects of SRL. MC group: improved cognition monitoring • $F(1,62) = .418$, $p < .05$, $\eta 2 = .06$

• Numerical form of problem (developed by the Israeli Ministry of Education (2004, Version A) • Verbal form of problems (Karmarski, Weiss, & Kololshi-Minsker, 2010) • Novel transfer problem (Kramarski & Mizrachi, 2006) Metacognitive regulation questionnaire • 24 items using 5-point Likert scale (based on the Junior Metacognitive Awareness Inventory developed by Sperling, Howard, Miller, and Murphy, 2002) Motivation questionnaire based on achievement goal theory • 19 statements using 5-point Likert scale (developed by Midgley et al., 2000) Positive and negative emotions questionnaire • 20 item 5-point scale Moos Affect Scale (Moos, Cronkite, Billings, & Finney, 1987)	Difference in performance approach goals • $F(1,109) = .3.84$, $p < .05$, $\eta2 = .03$ Difference in performance-avoidance goals • $F(3,109) = 7.89$, $p < .01$, $\eta2 = .07$

Note: Np = not provided, MC = metacognitive regulation, ME = motivational-emotional regulation, MS = metacognitive support

2.4 Basic Facts

Two studies (Knowles, 2010; Wong & Evans, 2007) observed that there is little research that has focussed on what strategies are most effective for teaching basic facts to normally achieving students. Of the 45 studies reviewed here, 26 (58%) focussed on normally achieving students. However, the search criteria used for this review was broader than that used by Knowles (2010), who restricted her search to written timed practice drills, implemented with normally achieving middle grade students. An overview of all the basic facts studies is provided in Table 2.4. This table is organised into seven columns. Column two identifies the number of students who participated in each study and the age of the participants. This column also identifies whether the studies included all students, participants with learning difficulties (LD), participants with emotional behavioural disorders (EBD), or a combination of LD and EBD. Column three describes the programme and column four describes the design of the study. Both column five and six describe aspects of the programme implementations. Column five identifies whether the programme was primarily delivered by a teacher or researcher and column six describes the programme in terms of the duration of each lesson, the number of sessions which were administered and the time frame over which the programme ran. The final column identifies the main results from each study.

Study design. As previously mentioned, a large number of studies focussed on students with LD and/or EBD (19 studies, 42%). This influenced both the number of participants included in the reviewed studies and the design of these studies. In New Zealand, a ratio of one teacher to 29 students, in Year 4 to 8, is used to calculate curriculum staffing (Ministry of Education, 2016a). Of the reviewed studies, only 22 (49%) included more than 29 participants. This resulted in many studies adopting a form of single case design. Of the remaining studies, 19 (42%) used a random control design and a further four studies (9%) used a quasi-experimental design.

Delivery. Twenty-five (56%) of the studies reviewed here were primarily delivered by researchers. It is interesting to note that this is substantially more than the percentage of SRL studies that were administered by researchers (38%). This difference may again be attributed to the large number of studies that included students with learning difficulties. In many cases, this involved students being taught separately from the class. This raises questions about the sustainability of these programmes post intervention. Firstly, continued programme implementation would require schools to find additional teachers, and therefore funding. Secondly, schools would also need to provide training for these teachers to ensure programme fidelity is maintained.

Hulac, Dejong, and Benson (2012) and Hulac, Wickerd, and Vining (2013) took an alternative approach. They aimed to position students as the primary interventionists through the self-administered folding-in technique (SAFI). This strategy involved integrating seven known facts with three unknown facts. These facts were then rehearsed, individually, using a *cover, copy, compare* procedure. This procedure was repeated with all ten facts a total of three times. If students completed the procedure within the allocated time, they replaced three of the practiced facts with three new unknown facts and repeated the procedure. Whilst students in the SAFI conditions in these studies completed most of the SAFI procedure independently the researchers still controlled progress monitoring. It was interesting to see that these studies did not involve students in this part of the process as the PT studies by Chiesa and Robertson (2000) and Gallagher (2006) taught students, of the same age, to score, plot, and understand their own data. In fact, self-graphing procedures were successfully used with students as young as six in two of the studies reviewed here (Gross et al., 2014; Gross et al., 2016). Self-graphing procedures play a key role in effective basic facts programmes.

They have been linked to both increased on-task behaviour and academic performance (Schutte et al., 2015).

There was considerable variation between the studies in both the length of session and duration of the programmes. The average session lasted for nearly 15 minutes, although there were substantial differences in the length of sessions between the studies (*SD* = 9.3). A similar pattern was found when comparing the duration of the studies, with the average programme running for just over eight weeks (*SD* = 5.4). Much of this variation can be attributed to the programme design, which is described below.

Programme design. The prevailing view in basic facts instruction is that the teaching of basic facts requires the use of both direct and indirect approaches (Ministry of Education, 2009). In the studies reviewed here, 14 incorporated indirect instruction into their programmes. Whilst this represented only 31% of studies, this is probably not a reflection on the relative importance of direct or indirect instruction. There is a wealth of evidence that suggests that once students have a good understanding of strategies and can complete the skills somewhat accurately, students should move to memorisation (Burns et al., 2012; Dennis et al., 2016; Hopkins & Egeberg, 2009). This is commonly achieved through a direct approach. It seems likely that most studies chose participants who had at least a basic understanding of the relevant indirect approaches so focussed their studies more towards the direct approach.

One technique commonly used in the direct approach is the use of explicit timing. Explicit timing involves the presentation of a task and specifying an amount of time within which the task should be completed. Gross et al. (2014) believe that explicit timing procedures should be applied to all fluency practices. This belief was also wide spread in the studies reviewed here, with nearly 80% of studies including some form of explicit timing procedures. Three procedures that used explicit timing procedures, and that can be successfully integrated into the classroom, are *cover, copy, compare*; *detect, practice, repair*, and *taped problems* (Codding, Hilt-Panahon, et al., 2009; Poncy et al., 2013). Participants in studies which employed one of these three programmes made substantial progress over the course of their respective interventions.

Cover, copy, compare is based on three stages. During the *cover* stage, students look at the basic fact and its answer, then they cover the fact so that it cannot be seen. In the *copy* stage students write the fact from memory. The third stage involves *comparing* the fact that they have written to the original fact. If the fact was written incorrectly an error drill is often implemented. This may involve looking at the target fact and writing the fact correctly a small number of times. After this final stage is completed students engage in one minute of timed practice (Becker, McLaughlin, Weber, & Gower, 2009; Codding, Chan-Iannetta, et al., 2009). The *cover, copy, compare* procedure is also used within *detect, practice, repair* programmes. During the *detect* phase, of *detect, practice, repair* programmes, students are administered a pre-test in order to identify what problems a student needs to work on. Students must answer each question within 1.5 to 2 seconds. If a student does not answer within this timeframe they are prompted to move onto the next question. The *practice* stage is based on *cover, copy compare*. During this stage students practise the first five items that were not answered in time, or answered incorrectly, during the *detect* phase. In the *repair* phase students are presented with the five practiced facts, within a larger pool of facts. This stage uses explicit timing procedures. At the end of this stage answers are totalled and students graph their performance (Poncy et al., 2013).

Taped procedures take an alternative approach. Because of the way the facts are presented, it is more difficult to administer this programme at the tier one level whilst individualising the programme according to student needs. *Taped problem* procedures start by providing students with a printed copy of the selected basic facts questions. The students are then instructed to try to answer the problems before the answer is provided by the tape. Taped problems can use two types of time delay, constant and progressive. Constant time delay involves providing a uniform delay (e.g. 3 seconds) between the target stimulus and response prompt. With progressive time delay, the intervals between the target stimulus and response are gradually increased. When the intervals are brief, students are less likely to make an error because the response prompt is often provided before the student has had a chance to answer. Alternatively, the delay between the target stimulus and response can initially be large and then gradually decreased. This can lead to increased initial error rates but may also provide more opportunities to respond to the target facts (McCallum et al., 2006).

In contrast to PT, taped problems are not based on free operant conditioning. Free operant conditioning means the student is free to respond repeatedly without restrictions (McSweeney & Murphy, 2014). One of the advantages of free operant conditioning is that it, more easily, enables the researcher to observe any changes in the student's behaviour. In addition to facilitating observation and measurement, frequent opportunities to respond are also associated with increased learning (Burns, 2005). The session length in all but one of these programmes was less than the average basic facts lesson length of 15 minutes. Despite this, Codding, Hilt-Panahon, et al. (2009) did observe that additional instruction time was seen as a barrier to implementation in classrooms.

Direct instruction literature classifies basic facts as *simple facts*. This term means facts for which there is only one answer (Kameenui & Simmons, 1990). According to Kameenui and Simmons (1990), the primary practice considerations for *simple facts* include scheduling how many facts should be taught and how frequently these should be rehearsed. Both of these questions were addressed in the basic facts studies reviewed here. Schutte et al.

(2015) investigated whether massed or distributed practice led to the greatest gains in performance. In this study, Schutte et al. (2015) found that the group of students who engaged in a 1-minute explicit timing procedure four times per day demonstrated better growth than those who engaged in two 2-minute practice session each day, who in turn outperformed the group who completed one 4-minute session per day. This study raises two interesting implications. First, the average practice session in the reviewed studies was far longer than the optimal practice time found by Schutte et al. (2015) and in almost all studies the practice occurred during one session throughout the day. Second, if distributed practice is the optimal form of practice, continued practice outside of school hours should lead to additional gains.

Kameenui and Simmons (1990) suggest that up to six new simple facts should be learnt at a time. The optimal number of new facts presented in each session was investigated by Burns et al. (2016). Using incremental rehearsal procedures, Burns et al. (2016) found that presenting problems at a student's acquisition rate was the most effective form of delivery. Students in this condition outperformed conditions in which students were taught either two or eight new facts per session. The average acquisition rate was 4.05 facts. A number of the programmes, including *detect, practice, repair* (Poncy et al., 2013), SAFI (Hulac et al., 2012), and direct instruction procedures (Bjordahl, Talboy, Neyman, McLaughlin, & Hoenike, 2014), used presentation rates close to four facts per session. However, the finding by Burns et al. (2016) does highlight, that where possible, presentation rates should be individualised. This could be practically achieved by using programmes where students are the primary interventionists.

Stein et al. (1997) advocate, that effective basic facts programmes should also include record keeping systems and motivational systems. As mentioned earlier, a number of the studies reviewed here showed that students could be taught to accurately graph their own performances. Schutte et al. (2015) observed how this feature alone can lead to an increase in on task behaviour and academic performance. The fact that both teachers (Gross et al., 2016) and students (Bryant et al., 2015) have reported favourably on the use of self-graphing procedures increases the likelihood that these measures, when included within studies, will be implemented with fidelity.

Programme effectiveness. There were a number of factors that made direct comparisons between the studies challenging. The main limitations were the basic facts focus of the various programmes and the way that the studies reported their results. Of the 45 studies reviewed here, 14 studies focussed on all the basic multiplication facts. The remaining studies focussed on other basic fact areas, such as addition, subtraction, and division, or a limited range of times tables. Whilst fluency is commonly expressed as rate per minute in PT literature (Johnson & Street, 2013), many of the basic facts studies reviewed here used differing time periods. Some also expressed results as correct digits per minute, rather than correct answers per minute (CAPM). Despite these limitations, some interesting comparisons can still be made.

Three studies, with participants aged from 9 to 11 years, provided pre- and post-test data which included all the basic multiplication facts (Knowles, 2010; Wong & Evans, 2007; Woodward, 2006). Both Wong and Evans (2007) and Woodward (2006) administered two programmes. Participants in the study by Wong and Evans (2007) engaged in repeated practice with multiplication facts. One of the groups took part in paper and pencil practice whilst the other group engaged in computer based practice. In contrast, Woodward (2006) focussed on the content of the programmes, rather than the method of delivery. He explored whether a strategy based programme with timed drill practice, or timed drill practice alone, resulted in the greatest improvement with multiplication facts. Knowles (2010) also investigated two versions of one programme, however this study also included a control condition. The two programme conditions were based on timed drill practice. One group engaged in practice on a weekly basis and the other group engaged in daily practice. Unlike Wong and Evans (2007) and Knowles (2010), Woodward (2006) did not include all multiplication facts within the one dependent measure. Instead he created a *common facts* version and a *hard facts* version. The *common facts* version included many facts the students already knew and the *hard facts* version included facts that students had difficulty answering during the pre-test phase. In order to compare these studies, the results from Woodward (2006) and Knowles (2010) were first converted to CAPM. This data showed that the participants in Wong and Evans (2007) and Knowles (2010) were of comparable ability prior to their respective interventions. The average pre-test scores for the students in Wong and Evans (2007) paper and pencil condition was 22.63 CAPM. The average pre-test score for the students who received daily timed practice in the Knowle's (2010) study was 23.4 CAPM. After completing their respective programmes, the students in these studies had made similar progress. The average post-test score in Wong and Evans (2007) was 36.89 CAPM and the average post test score in the Knowle's study (2010) was 34.19 CAPM. This represented a statistically significant improvement for both groups of students. The pre-test scores in the study by Woodward (2006) were substantially lower, although this study did include younger participants. The pre-test scores for *common facts* was 13.51 CAPM for the strategy based instruction group and 13.59 CAPM for the timed drill practice condition. These groups made similar progress over the course of their respective programmes. The average post-test score for the strategy based instruction group was 18.79 CAPM and the average post test score for the timed group was 17.09 CAPM. Whilst there was not a large difference between the groups (d = .27), the difference was significant. These students also made substantial improvements with the *hard facts*. The pre-test scores for the strategy based instruction and timed drill practice group were respectively 5.99 CAPM and 8.16 CAPM. Both groups had improved to nearly 13 CAPM by post-test. This did not represent a significant difference between these groups.

The only PT study to investigate basic facts fluency with all multiplication facts was conducted by McTiernan et al. (2016). Compared to the participants in the three basic facts studies, the participants in this study made far greater gains. The average pre-test score in this study was 12.9 CAPM but by post-test this had increased to 33.1 CAPM. This represented a large effect (d = 1.91). The average post-test score reported by McTiernan et al. (2016) is even more impressive given their participant selection criteria. Unlike the other basic facts studies, this study only included students who were performing below their peers. Whilst the magnitude of this change is impressive it should be noted that the programmes implemented by Knowles (2010) and Woodward (2006) also had a large effect on student performance (Knowles (2010), d = 1.1; Woodward (2006), strategy based: *common facts d* = 2.2, *hard facts d* = 1.4; timed drill practice: *common facts d* = .98, *hard facts d* = .83).

Unfortunately, only Wong and Evans (2007) and Woodward (2006) administered maintenance measures. Of these two studies, only Woodward (2006) provided sufficient information for the calculation of effect sizes. Whilst these effect sizes ranged from medium to large (strategy based: *common facts d* = 1.7, *hard facts d* = 1.4; timed drill practice: *common facts d* = .69, *hard facts d* = .75) it should be noted that the maintenance test was conducted only ten days after the post-test. Wong and Evans (2007) administered their maintenance measure four weeks after the end of the programme. They reported that the small decrement in performance from post-test to maintenance test (-1.63 CAPM) was not statistically significant, however they did not report results in sufficient detail to allow the calculation of effect sizes from the pre-test to maintenance test.

Care must be taken when interpreting the results from these studies. As noted previously, some of these studies used dependent measures that ran for more than one minute (Knowles, 2010; Woodward, 2006). This means that participant fatigue may have affected these results. Endurance is associated with fluent performance (Johnson & Street, 2013), however as these students were not yet fluent it is possible the rate of responding slowed over the time period. It is also difficult to ascertain what lasting effect these programmes had on student achievement. Only one of these studies (Wong & Evans, 2007) provided maintenance results with a sufficient delay between the administration of this measure and the programme completion. In two of the studies (Wong & Evans, 2007; Woodward, 2006) it was not possible to quantify exactly what effect the programme had on student performance as these studies failed to include a treatment as usual control. Without a treatment as usual control it is not possible to rule out a maturation effect. Whilst the results from all of these studies suggest that these programmes had a relatively large effect on student performance, in most cases, this analysis was only provided at the group level. Without sufficient analysis at the idiographic level, it was not possible to ascertain which students did, or did not, benefit from these programmes. McTiernan et al. (2016) did identify the number of fluency aims that were completed by each participant, however they did not provide the same level of analysis for the dependent variables.

Summary. The basic facts studies employed a wide range of programmes, administered to diverse groups of participants, using various study designs. Notwithstanding these differences, a number of common themes were identified. The results showed that basic facts programmes can have a large effect on students’ fluency. Unfortunately, it was difficult to compare studies due to the varied, and often limited, ways the studies reported their results. Despite these challenges a number of key programme elements were identified. These included carefully considering the number of new facts that students were exposed to, the order in which these facts were learned, how these facts were integrated with already known facts, and how frequently these facts should be rehearsed. Other programme components, including the use of explicit timing and student graphing of results, were also associated with developing improved basic facts fluency. Many of these programme elements were employed in the current study. In addition, this study also addressed the design limitations observed in these studies.

Table 2.4

Basic facts studies

Study (N= 45)	Participants; age; description	Programme description (Math focus)	Design	Intervention delivered by	Duration; sessions; period	Results
Baroody, Eiland, Purpura, & Reid, 2013	N = 64 Age = 6 LD	Computer assisted learning (addition)	Training experiment with multiple baselines	Researcher	Duration: 30 min Sessions: 20 Period: 10 weeks	• Students in add-one intervention made significantly greater gains in fluency on practiced items $F(3.61, 11.10) = 5.20$, $p < 0.01$ and marginally better progress on unpracticed items $F(4, 122) = 1.64$, $p < 0.085$ than the active control. Add-one compared to comparison condition: • Immediate post-test: $d = .34$ • Delayed post-test: $d = .5$
Baroody, Purpura, Eiland, & Reid, 2014	N = 164 Age = 6 AS	Computer assisted instruction (addition and subtraction)	Training experiment with multiple baselines	Researcher	Duration: varied Sessions: 39 Period: 16 weeks	Unpracticed subtraction combinations: • Guided-subtraction groups significantly outperformed use-a-10 group: $F(1, 46) = 31.68$, $p < .001$, Hedges' g = 1.46 Add with 8 or 9 combinations: • Guided use-a-10 group significantly outperformed the guided subtraction group, $F(1, 46) = 9.03$, $p = .004$, Hedges' g = 0.78
Baroody, Purpura, Michael, Reid, & Paliwal, 2016	N = 81 Age = 7.9 AS	Strategy and timed practice (addition & subtraction to 20)	Randomised control trial	Teacher	Duration: 30 min Sessions: 24 Period: 12 weeks	Significant findings for fluency rate (effect size = Hedges *g*). • Practiced sub: SUB>U10 = .65; DRL>U10 = .63 • Unpracticed sub: SUB>U10 = .69; SUB>DRL = .67 • Practiced add with 8 or 9: U10>SUB = 1.09; DRL>SUB = 1.35 • Unpracticed add with 8 or 9: U10>SUB = .57
Becker, McLaughlin, Weber, & Gower, 2009	N = 1 Age = 10 LD	Cover, copy, compare & cover, copy, compare + error drill (multiplication facts 2, 3, 4)	ABD single case design	Researcher	Duration: 10 min Sessions: @17 Period: @17 days	Answers correct per minute: • Baseline = 34 digits correct • Cover, copy, compare = 54.5 digits correct • Cover, copy, compare + error drill = 83.4 digits correct

Bjordahl, Talboy, Neyman, McLaughlin, & Hoenike, 2014	N = 1 Age = 13 EBD	Timed practice with direct instruction (division facts)	Non-concurrent baseline single case design	Researcher	Duration: Np Sessions: 24 Period: 7 weeks	Change from baseline to intervention by set: • Set 1: (20%)- (90%) • Set 2: (28%)- (84%) • Set 3: (20%)- (85%) • Set 4: (0%)- (94%)
Brosvic, Dihoff, Epstein, & Cook, 2006	N = 80 Age = 8 AS	Timed practice with feedback (addition, subtraction, multiplication, & division)	Random control design	Researcher	Duration: Np Sessions: 30 Period: @20 days	Mean accuracy was highest for the NA group and higher within the MLD and NA groups for participants provided with immediate rather than with delayed feedback or a Scantron form (p < .005.).
Bryant et al., 2015	N = 4 Age = 10 LD	Strategy (multiplication facts 4, 8)	Single-case multiple probe	Researcher	Duration: 10 min Sessions: 15 Period: 3 weeks	Range of mean digits correct per two minutes (for students) by condition. • Teacher directed instruction: 10.6-50.75 • App based instruction: 8.4-49.5 • Combined instruction: 9.4-55.2
Burns, 2005	N = 8 Age = 8 LD	Incremental rehearsal (multiplication facts)	Multiple baseline single-subject design	Researcher	Duration: 10-15 min Sessions: 30 Period: 15 weeks	Median digits correct per minute by participant: • Participant 1: Baseline = 3, from final 3 data points in intervention = 15 • Participant 2: Baseline = 8, from final 3 data points in intervention = 25 • Participant 3: Baseline = 11, from final 3 data points in intervention = 27
Burns, Kanive, & DeGrande, 2012	N = 216 Age = 9 LD	Maths Facts in a Flash (individualised)	Randomised control design	Teacher	Duration: 5-15 min Sessions: 45 Period: 15 weeks	Mean (and standard deviation) pre-test, post-test and normal curve equivalent scores: Third grade • Computer based math fluency: Pre-test = 13.84 (7.6), post-test = 23.71 (15.03) • Control: Pre-test = 12.93 (7.69), post-test = 18.6 (13.39) Fourth grade • Computer based math fluency: Pre-test 12.99 = (8.1), post-test = 24.42 (18.24) • Control: Pre-test = 10.95 (7.86), post-test = 16.69 (13.15)
Burns, Zaslofsky, Maki, & Kwong, 2016	N = 55 Age = 8-9 AS	Incremental rehearsal & acquisition rate (multiplication facts 6, 7, 8)	Random control design	Researcher	Duration: @3, 7 & 14 min Sessions: 1 Period: 2 weeks	Efficiency = number of facts retained/ intervention length in minutes: • 2 facts: .31 • Acquisition rate: .51 • 8 facts: .25

Carr, Taasoobshirazi, Stroud, & Royer, 2011	N= 178 Age = 7.48 AS	Strategy and timed practice (addition & subtraction to 20)	Random control design	Teacher	Duration: 30 min Sessions: 40 Period: 20 weeks	Mean (and standard deviation) fluency response speed in seconds by condition: • Cognitive instruction: Pre-test = 5.47 (1.77, post-test = 4.29 (1.59) • Fluency instruction: Pre-test = 5.55 (1.58), post-test = 4.24 (1.36) • Combined instruction: Pre-test = 5.67 (2.09), post-test = 4.23 (1.53) • Control: Pre-test = 5.54 (1.98), post-test = 4.52 (1.48) No significant difference between treatment groups: $F(3, 169) = .65$, $p > .05$
Codding, Archer, & Connell, 2010	N = 1 Age = 12 LD	Incremental rehearsal (multiplication facts 3, 4, 5, 6, 7, 8, 9)	Multiple probe design	Researcher	Duration: 20 min Sessions: 24 Period: 12 weeks	Digits correct per minute by set: • Set A: Baseline = 3.8, post = 30 • Set B: Baseline = 21.1, post = 48.7 • Set C: Baseline = 22.8, post = 44.6
Dennis, Sorrells, & Falcomata, 2016	N= 6 Age = 7 AS	Strategy and timed practice (addition & subtraction to 20)	Multiple probe across participants	Researcher	Duration: 30 min Sessions: 16 Period: 4 weeks	• Number sense intervention (number sense 1st): Tau-*U* = .63 • Extensive practice intervention (number sense 1st: TAU-*U* = .87 • Extensive practice (extensive practice 1st): TAU-*U* = .83 • Number sense intervention (extensive practice 1st): TAU-*U* = .61
Doabler et al., 2017	N = 228 Age = 5.5 LD	ROOTS (varied)	Radom control design	School employed paraprofessionals	Duration: 20 min Sessions: 54 Period: 18 weeks	TEMA-3 (standardised norm-referenced test), Early Numeracy Curriculum Based Measurement & Classroom Observations of Student-Teacher Interactions–Mathematics instrument. • Rates of teacher models, feedback, group responses, and individual responses within the intervention condition were not associated with gains in the TEMA-3 and EN-CBM. • Rates of teacher models, and group and individual responses were not associated with students' pre-test TEMA-3 and EN-CBM scores
Duhon, House, & Stinnett, 2012	N = 32 Age = 7.4-8.3 AS (above 80% accuracy)	Timed practice (subtraction facts)	Two group pre-test-post-test with random assignment	Teacher	Duration: 2 min Sessions: 20 Period: 4 weeks	Digits correct per two minutes by modality. Mean and (standard deviation) Paper and pencil:

						• Computer (unmatched): Pre-test = 31 (11), post-test = 34.5 (10.7) • Paper/pencil (matched: Pre-test = 30.6 (13.9), post-test = 42.6 (17.2) Computer: • Paper/pencil (unmatched): Pre-test = 21.6 (7.1), post-test = 32.7 (12.5) • Computer (matched): Pre-test 20.6 (10.6), post-test = 33.9 (9.4) Effect size range: *d* = .32-1.33
Duhon, House, Hastings, Poncy, & Solomon, 2015	N = 48 Age = 7-8 AS (above 80% accuracy)	Timed practice with feedback (subtraction problems)	Three group pre-test-post-test design with random assignment	Researcher	Duration: 2 min Sessions: 20 Period: 20 days	Mean (and standard deviation) digits correct per 2 minutes. • Control: Pre-test = 20.06 (10.06), post-test = 19.75 (8.82) • No immediate feedback: Pre-test = 20.69 (10.64), post-test = 32.85 (11.08) • Immediate feedback: Pre-test = 21.56 (9.74), post-test = 44.25 (9.95) • Growth for the without feedback group was superior to the control group: $t = 8.35$, $p < .01$ (Glass's D = 2.44) • Growth for feedback group was superior to the control group: $t = 15.40$, $p < .01$ (Glass's D = 4.49) • Feedback group had significantly higher growth rate than without feedback group: $t = 7.05$, $p < .01$ (Glass's D = 3.52)
Fuchs et al., 2010	N= 4 Age = 8 LD	Strategy and timed practice (addition and subtraction)	Randomised control study	Researcher	Duration: 20-30 min Sessions: 48 Period: 16 weeks	Questions correct on 4 one-minute tests. Mean and (standard deviation). • Strategic counting with practice: Pre-test = 28.18 (17.2), post-test = 48.82 (15.8) • Strategic counting without practice: Pre-test = 29.69 (13.7), post-test = 45.29 (17) • Control: Pre-test = 28.92 (17.2), post-test = 37.8 (16.9)
Gross et al., 2014	N = 47 Age = 6 AS	Timed practice with goal conditions (subtraction from 0-10)	Random control design	Researcher	Duration: 2 min Sessions: 30 Period: 6 weeks	Mean (and standard deviation) digits correct per minute by group: • Researcher selected goals: Pre-test = 5.31 (2.36), post-test = 6.81 (3.7), *d* = .48 • Researcher selected goals with goal lines: Pre = 6 (2.96), post-test = 12 (6.3), *d* = 1.22

						• Self-selected goals with goal lines: Pre = 7.63 (3.95), post-test = 10.93 (5.92), *d* = .66
Gross, Duhon, Shutte, & Rowland, 2016	N = 53 Age = 6 AS	Timed practice with contingencies (addition sums to 9)	Quasi-experimental	Teacher	Duration: 2 min Sessions: 40 Period: 8 weeks	Mean (and standard deviation) digits correct per minute by group: • Independent group-oriented contingency: Pre-test = 8.4 (3.52), post-test = 21.9 (7.56), *d* = 2.34 • Dependent group-oriented contingency: Pre-test = 11.4 (6.5), post-test = 20.1 (8.84), *d* = 1.11 • ET and goal setting: Pre-test = 10.6 (6.42), post-test = 18.9 (8.36), *d* = 1.12
Hawkins, Musti-Rao, Hughes, Berry, & McGuire, 2009	N = 11 Age = 10 AS	Classwide peer tutoring (multiplication facts 2-9)	Multiple design probe	Teacher	Duration: 15 min Sessions: 30 Period: 15 weeks	Mean (and standard deviation) digits correct per minute by problem set: • Set 1: Baseline = 27.97 (7.26), intervention = 47.72 (8.8) • Set 2: Baseline = 26.42 (5.95), intervention = 48.03 (7.61) • Set 3: Baseline = 28.51 (5.65), intervention = 47.89 (6.98)
Hopkins & Egeberg, 2009	N = 8 Age = 12 LD	Strategy (addition facts)	Multiple baseline and interrupted time series analysis	Researcher	Duration: 15 min Sessions: 20 Period: 4 weeks	• With central executive difficulties: No significant improvements (*p* = .392, .061, .551) • Without central executive difficulties: Effective for one student (*p* = .031) but not others (*p* = .133, .438, .07)
Hulac, Dejong, & Benson, 2012	N = 11 Age = 9 LD	SAFI - Self-administered folding in technique (multiplication facts)	Multiple baseline design across students	Researcher	Duration: 20 min Sessions: @10 Period: 4-6 weeks	Average digits correct per two minutes: • Baseline = 49.9, Intervention = 74.2
Hulac, Wickerd, & Vining, 2013	N = 5 Age = 9 LD	SAFI -self-administered folding in technique (multiplication facts)	Multiple baseline design across students	Teacher	Duration: 20 min Sessions: @20 Period: 10 weeks	Non-overlapping points between baseline and intervention by phase (Phi statistic from the PAND data was transformed to Cohen's *d*): • Baseline to phase 1: 40%-100% (effect size range) -.4 – 3.1 • Baseline to phase 2: 100% (effect size range 2.7-4.4)

Kanive, Nelson, Burns, & Ysseldyke, 2014	N = 90 Age = 10 AS	Strategy and timed practice (multiplication facts)	Randomised pre-test-post-test control group design	Researcher	Duration: 15 min Sessions: 2 Period: 2 weeks	Change in digits correct per minute by condition. Mean and (standard deviation). • Control: 1.39 (5.27) • Computer based practice: 7.3 (12.94) • Conceptual: 3.38 (13.16) • Only CBP had a mean score significantly larger than the control (*p* <.017), *d* = .6
Knowles, 2010	N = 240 Age = 11 AS	Timed practice (multiplication facts)	Quasi-experimental	Teacher	Duration: 3 min Sessions: 0, 8 or 24 Period: 8 weeks	Mean and (standard deviation) for 3-minute test: • No treatment: Pre-test = 73.41 (28.72), post-test = 76.17 (29.27) • Weekly timed practice: Pre-test = 66.56 (25.79), post-test = 83.79 (24.95) • Daily timed practice: Pre-test = 70.22 (26.78), post-test = 102.57 (31.86)
Main & O'Rourke, 2011	N = 59 Age = 9-10 AS	Dr Kawashima's brain training software (addition, subtraction, multiplication, and division)	Quasi-experimental	Teacher	Duration: 20 min Sessions: 50 Period: 10 weeks	Mean (and standard deviation) questions correct on 4 one-minute tests (+,-,×,÷): • HGC software: Pre-test = 48.66 (15.67), post-test = 76.07 (36.46), *d* = .69, significant • No treatment: Pre-test = 57.96 (27.67), post-test = 59.93 (33.47), *d* = 13, not significant
McCallum, Skinner, Turner, & Saecker, 2006	N = 18 Age = 8 AS	Taped practice (multiplication facts 2-9)	Multiple probes across tasks	Researcher	Duration: 20 min Sessions: @23 Period: @10 weeks	Mean (and standard deviation) digits correct per minute: • Set A: Baseline = 6.5 (1.3), intervention (delayed) = 13.3 (3.3) • Set B: Baseline = 7.5 (.7), intervention (delayed) = 14.6 (2.2) • Set C: Baseline = 9.1 (.6), intervention (delayed) = 14.2 (3.7)
Miller, Skinner, Gibby, Galyon, & Meadows-Allen, 2011	N = 19 Age = 7 AS	Taped practice (addition facts with digits 2-9)	Multiple baseline	Teacher	Duration: 8-12 min Sessions: 15 Period: 3 weeks	Mean (and standard deviation) digits correct per minute: • Addition facts: Baseline = 17.41 (4.89), Taped problem mean = 26.87 (5.84) • Inverse facts: Baseline = 15.16 (4.74), Taped problem mean = 23.63 (5.07)
Musti-Rao & Plati, 2015	N = 12 Age = 8 AS	*Detect, practice repair* & self-mediated iPad	Alternating treatments design	Teacher	Duration: 10 min Sessions: 8 Period: 3 weeks	Average responses per minute: • *Detect, practice, repair*: 18.5 responses per minute by session 8

		instruction (multiplication facts 2-9)				• iPad: 8.5 responses per minute by session 8
Nelson, Burns, Kanive, & Ysseldyke, 2013	N = 90 Age = 8-9 LD	Mnemonic strategy & computer delivered practice (multiplication facts 6 & 7 times tables, or 8 & 9 times tables)	Random control design	Researcher	Duration: 15-20 min Sessions: 4 Period: 6 days	Mean (and standard deviation) digits correct per minute: • Computer delivered practice: Post-test = 7.1 (4.21) • Mnemonic strategy: Post-test = 6.51 (4.12) • Control group: Post-test = 5.13 (2.51) Only the computer delivered practice had a mean score significantly larger than the control.
Ok & Bryant, 2016	N = 4 Age = 10 LD	Strategy and timed practice (some multiplication facts)	Single-case multiple probe	Researcher	Duration: 30 min Sessions: 15 Period: 3 weeks	• Change in DCM from pre-test to post-test by participant: • (10.06-25.87), (18.2-29.13), (11.75-26.5), 18.29-32.5) • TAU-*U* = .98-1.0 across participants
Pierce, McLaughlin, Neyman, & King, 2012	N = 2 Age = 11 & 12 EBD & LD	Timed practice with direct instruction (multiplication facts 2, 3, 4, 5)	Multiple baseline design	Teacher	Duration: 30 min Sessions: 12-25 Period: 6 weeks	Digits correct per minute: • X2: Participant 1 – Baseline = 34, intervention = 45.3; Participant 2 – Baseline = 10-15, intervention = 27 • X5: Participant 1 – Baseline = 29.5, intervention = 42.5; Participant 2 – Baseline = 10-15, intervention = 65 • X3: Participant 1 – Baseline = 26, intervention = 69
Poncy, Duhon, Lee, & Key, 2010	N = 3 Age = 9 LD	Timed practice (12 addition and subtraction facts)	Multiple baseline design	Researcher	Duration: 4 min Sessions: 32 Period: @6 weeks	Results not provided in sufficient detail.
Poncy, Fontenelle Iv, & Skinner, 2013	N = 11 Age = 9 AS	*Detect practice repair* (subtraction, multiplication and division)	Multiple baseline design	Researcher	Duration: 12 min Sessions: 11 Period: 11 days	Digits correct per minute: • Aggregated baseline average = 18.5 DCPM • Intervention phase average: 30.9 DCPM • Maintenance phase: 30.2 DCPM
Poncy, Skinner, & McCallum, 2012	N = 20 Age = 8 AS	Cover, copy, compare & taped problems (subtraction facts)	Alternating treatments design	Researcher	Duration: 2 x 6 min Sessions: 18 Period: 9 days	1-digit minus 1-digit and 2-digits minus 1-digit. • Taped problems: baseline phase average = 15.1; median for final 3 intervention data points = 28.6 • Cover, copy, compare: baseline phase average = 13.4; median for final 3 intervention data points = 20.0

						• Control: baseline phase average = 14.4; median for final 3 intervention data points = 19.7
Rave & Golightly, 2014	N = 44 Age = 10 AS	Rocket maths (multiplication facts)	Pre-test-post-test non-experimental design	Teacher	Duration: 2 min Sessions: 28 Period: 9 weeks	Total percentages correct increase on 2-minute probe ((number of correct responses/ goal for individual student (*100)): • Overall: 22.98 (14.23), *d* = 1.61 • Regular education: 23.61 (15.4), *d* = 1.53 • Special education: 21.09 (10.35, *d* = 2.04
Reed, Gemmink, Broens-Paffen, Kirschner, & Jolles, 2015	N = 258 Age = 9-10 AS	Timed practice with recall or choice (multiplication facts)	Random assignment	Teacher	Duration: 10 min Sessions: 10 Period: 2 weeks	• Large effect for practice time $F(1,273) = 147.73$, $p < .001$, $d = 1.47$ • Large effect for week $F(1,237) = 56.86$, $p < .001$, $d = .98$ • Medium effect of practice condition $F(1,249) = 25.37$, $p < .001$, $d = .64$ (favouring choice condition)
Rich, Duhon, & Reynolds, 2016	N = 57 Age = 7 AS	Computer based math fluency building (subtraction facts)	Three-group pre-test–post-test experimental design	Researchers	Duration: 2 min Sessions: 20 Period: 4 weeks	Subtraction problems with minuends up to 18. Modality measure, treatment group, post-test score and effect over intervention (Digits correct per minute). Mean (standard deviation). Paper pencil • Computer: 28.3 (12.3); *d* = .17 • Paper-pencil: 33 (9.8); *d* = 1.33 • Computer with weekly paper: 34.3 (11.1); *d* = 1.02 Computer • Computer: 33.1 (10.6); *d* = 1.2 • Paper-pencil: 26.3 (6.9); *d* = .95 • Computer with weekly paper: 32.1 (12.9); *d* = .85
Schutte et al., 2015	N= 53 Age = 8 AS	Timed practice with massed vs distributed practice (addition sums to 18)	Longitudinal stratified randomised design	Teachers	Duration: 4 min Sessions: 19 Period: 19 days	Mean (and standard deviation) digits correct per minute by condition: • 1 X per day: Pre-test = 25.03 (9.44), post-test = 35.38 (12.84) • 2 X per day: Pre-test = 23.86 (8.41), post-test = 38.92, 12.32 • 4 X per day: 26.95 (9.75), post-test = 44.98 (13.81)

Skarr et al., 2014	N = 3 Age = 8, 10 & 11 LD	Timed practice with direct instruction (multiplication facts)	Single subject multiple baseline design	Researcher	Duration: 20-30 min Sessions: 23 Period: 11 weeks	100 written multiplication facts in 5 minutes • Participant 1: Pre-test = 29, post-test = 71 • Participant 2: Pre-test = 55, post-test = 100 • Participant 3: Pre-test = 38, post-test = 62
Smith, Marchand-Martella, & Martella, 2011	N = 1 Age = 6 LD	Rocket maths (addition facts)	Single case pre-test-post-test non-experimental design	Researcher	Duration: 15 min Sessions: 48 Period: 16 weeks	Problems correct in one minute: • Pre-test = 10, post-test = 21
Whitney, Hirn, & Lingo, 2016	N = 3 Age = 9, 10, & 11 LD & EBD	Great Leaps Maths (addition facts)	Multiple probes across subjects design	Special education teacher	Duration: 5-7 minutes Sessions: varied @20 Period: 6 weeks	Addition maths facts 0-9 (correct questions per minute): • George: Baseline = 22; oral fluency = 37.7 • Gregory: Baseline = 26.5; oral fluency = 38.4 • Jarrett: Baseline = 22; oral fluency = 38.5
Windingstad, Skinner, Rowland, Cardin, & Fearrington, 2009	N = 19 Age = 7 AS	Taped practice (addition facts)	Multiple baseline across tasks	Teacher	Duration: 8-15 Sessions: 20 Period: @10 weeks	Mean (and standard deviation) digits correct per minute: • Set A: Baseline = 21.86 (3.18), taped problem mean = 33.87 (8.71) • Set B: Baseline = 23.92 (6.05), taped problem mean = 37.08 (7.49) • Set C: Baseline = 26.47 (7.82), taped problem mean = 38.08 (6.86)
Wong & Evans, 2007	N = 64 Age = 10 AS	Timed practice (multiplication facts)	Quasi-experimental	Researcher and teacher	Duration: 15 min Sessions: 11 Period: 4 weeks	Average number of correct responses in 1 minute (60 question test): • Computer based instruction: Pre-test = 22.27, post-test = 29.86 • $t(36) = -8.107$, $p = 0.001$ • Paper and pencil instruction: Pre-test = 22.63, post-test = 36.89 • $t(26) = -8.501$, $p = 0.001$ Regression model: For the same pre-test score, at post-test, on average, a PPI participant answered an additional 6.703 facts per minute compared to a CBI participant
Woodward, 2006	N = 58 Age = 9 AS	Strategy and timed practice (multiplication facts)	Random control study	Teacher	Duration: 25 min Sessions: 20 Period: 4 weeks	Mean scores on 40 question (2 min) tests by condition. Mean and (standard deviation). • Students without LD (common): Pre-test = 27.86 (5.58), post-test = 38.91 (1.79) • Students with LD (common): Pre-test = 21.29 (4.46), post-test = 32.86 (5.61)

					There was a significant interaction for time and group F (2,54) = 3.89, p = .02. • Students without LD (hard): Pre-test = 13 (10.47), post-test = 28.41 (8.68) • Students with LD (hard): Pre-test = 6.57 (3.91), post-test = 15.71 (6.92) There was a nonsignificant difference between groups F (1,55) = .13, p = .72 and near-significant differences within groups F (1,55) = 3.83, p = .06

Note: AS = all students, LD = students with learning difficulties, EBD = students with emotional behavioural disorders, SD = standard deviation, Np = not provided, NA = normally achieving, MLD = maths learning disabilities, DCPM = Digits correct per minute. [a]Not calculated in study, calculated from data provided in results section.

2.5 Present Study

The above literature review highlighted a number of strengths and limitations in the existing research. Many of these strengths were related to elements of the programmes employed within the studies, whilst the limitations were primarily related to study design. Five main limitations were observed. The first of these included the use of small sample sizes (Hawkins, Musti-Rao, Hughes, Berry, & McGuire, 2009; Poncy et al., 2013). Small sample sizes make it difficult to generalise the findings to the larger population. A number of the studies that used a small number of participants did so because they investigated the effectiveness of a programme for students with learning difficulties (Gallagher, 2006; Hulac et al., 2012). In contrast, this study aimed to investigate the effectiveness of a basic facts programme administered at the tier one level. Therefore, this study included students of all mathematics abilities. A second limitation observed in many studies was a failure to include a maintenance measure (Knowles, 2010; McTiernan et al., 2016). An effective programme should result in learning that is retained over time. In fact, learning that is maintained over time is one of the key outcomes associated with fluent performance (Johnson & Street, 2013). In order to ascertain what effect a programme had on students' long-term achievement, maintenance measures must be administered.

While a number of the studies used small sample sizes, a similar number of studies included larger numbers of participants. Two different limitations were observed in these larger studies. The first of these was a failure to randomly assign students. Instead, some studies chose to use a quasi-experimental design (Knowles, 2010; Wong & Evans, 2007). Whilst this is more easily obtained in a school setting, there are limitations associated with this design. Primarily, the researcher cannot be sure that the participants did not vary in some systematic way (Mitchell & Jolley, 2013). The second limitation was associated with the groups themselves. Some studies implemented programmes in two or more conditions but did not include a treatment as usual control (Wong & Evans, 2007; Woodward, 2006). Without a treatment as usual control it is not possible to quantify any maturation effect over the course of the study. The final limitation related to the results and was observed in both the large and small studies. Specifically, a number of studies failed to report results in sufficient detail to enable easy comparison between studies. Very few studies reported results at the nomothetic and idiographic level. In fact, of all the studies reviewed, only one study reported the results clearly at both levels (Strømgren et al., 2014). Whilst this level of analysis was not suitable for all studies, given the design they adopted, many studies would have benefited from adopting this approach. For a tier one study to be considered effective it should meet the needs of approximately 80% of the population (Johnson & Street, 2013). If results are only reported at the group level it is not possible to ascertain which students did or did not respond positively to the programme. This means important information about the efficacy of the programme is not identified.

This study was designed to overcome many of these limitations. Specifically, the study included students of all mathematics abilities. These students were randomly assigned to either the SRL fluency programme or the treatment as usual control. Pre-test, post-test, and maintenance test data was collected and used for nomothetic and idiographic analysis. To facilitate comparisons with other studies, detailed descriptive and inferential statistics were reported. In addition, daily sprints were conducted by the SRL students and this data was used to calculate celeration rates and related analyses. This study aimed to present the findings with a level of transparency that was missing in many of the reviewed studies.

In addition to identifying design limitations, this literature review discerned two main gaps in the literature. Whilst a number of studies implemented basic facts programmes that resulted in improved achievement, no study measured what effect the programmes had on student practice behaviour outside of school hours. Given that basic facts fluency is related to the frequency with which practice occurs (Baroody, 1999; Steel & Funnell, 2001) any programme that results in additional high-quality practice outside of school hours should be of particular interest to educators. It is possible that additional practice outside of school hours may reduce the amount of time teachers need to allocate to basic facts fluency building within the class timetable. The second gap in the literature is related to the use of PT methodology at the tier one level. Two studies used PT to build fluency in basic facts with typically developing children in regular school settings. A key feature in both of these studies involved the random assignment of students in primary schools to either a PT intervention or treatment as usual condition. The term 'typically developing', used by Strømgren et al. (2014), is somewhat misleading. The participant selection in both Strømgren et al. (2014) and McTiernan et al. (2016) was restricted to students performing below their peers. In order to obtain these participants, both studies had to select students from a number of classes across a number of year groups. The present study addressed two limitations associated with these designs. First, this study included students of all abilities. This enabled investigation into what effect the programme had on all ability levels. The second adaption was related to the school setting. Whilst the Strømgren et al. (2014) and McTiernan et al. (2016) studies did occur in regular school settings they do not reflect regular practice within schools. This study chose participants from two classes that regularly interchanged during their mathematics instruction. By mirroring regular school practice, the results from this study can be more confidently generalised to other school settings.

This study brings together many of the key elements identified in the basic facts, SRL, and PT studies reviewed above. On the basis of these elements the SRL fluency programme was designed to overcome many of the barriers associated with traditional basic facts practice. At its core, the programme employed in this study was based on basic facts and direct instruction literature. Traditionally, these programme elements are heavily reliant on teacher, researcher, or paraprofessional support. In contrast, the elements included in this programme were designed so that students could engage in high quality independent practice. In addition, the materials used in this study were selected so that they could be easily transported to and from school to ensure that practice was not limited to the hours a student spent in class. Whilst these features were designed to increase the frequency and duration with which students practised, these changes alone would not have been sufficient to effect large improvements in basic facts performance for all students. To ensure students engaged in high quality practice, PT methodology was employed. This enabled the researcher and teacher to ensure that students were consistently making 'robust' progress. When progress slowed, adaptions to the programme were made. The use of celeration charts, a feature of PT, meant that programme adaptions could be made on a daily basis. This ensured that students were developing fluency with both the type and number of facts that was commensurate to their current level of ability. The researcher was cognizant of the fact that these factors alone would not result in altered practice behaviour outside of school hours. In order to facilitate this change, the programme was embedded within a self-regulated learner framework. Chapter 3.1 provides a more detailed overview of this basic facts fluency programme.

2.5.1 Research questions and hypotheses

This study explored what effect the SRL fluency programme had on students' basic facts fluency. Specifically, it set out to answer two questions. The following section details these questions and the associated hypotheses. The data was collected at three-time points, including; prior to the programme, at the end of the programme (after four weeks), and at a five-week follow-up after the end of the programme. From this point forward, these time periods are referred to as T1, T2, and T3.

Research question 1. To what extent does a basic facts fluency programme, based on *detect, practice, repair*, direct instruction, and PT methodology, implemented within a SRL framework, lead to improved performance on a basic facts (multiplication facts) post-test?

Hypothesis 1. Students in the SRL condition will make significant progress over the course of the intervention. They will also make significantly more progress than their peers in the traditional instruction (Trad) condition.

Research question 2. To what extent does the SRL fluency programme alter students' basic facts practice behaviour outside of school hours?

Hypothesis 2. Students in the SRL condition will practise their basic facts more frequently, and for longer durations, than they did prior to the programme. They will also practise more frequently, and for longer durations, than their peers in the Trad group.

Students in the SRL group will also choose to engage in practice with flash cards over other types of practice. In addition, significantly more students in the SRL group will report engaging in practice with flash cards than their peers in the Trad condition.

Chapter 3: Methods

This chapter describes in greater detail the experimental programme, teacher and student training, ethical considerations, experimental design, participant recruitment, experimental measures, programme equipment, programme procedures, and data analysis.

3.1 Programme overview

This section describes the key elements of the experimental SRL intervention programme. It also provides a brief overview of the research on which this programme was based.

The SRL programme was based on the three-stage model for self-regulation (Zimmerman, 2000). Unlike Zimmerman (2000), who termed these stages forethought, performance/volitional control, and self-reflection, this study employed the commonly used (Schmitz & Wiese, 2006) terms pre-action, action, and post-action. These terms were deemed more appropriate given the age of the students in this study. The basic facts programme was based on PT (Binder & Watkins, 2013; Johnson & Street, 2013), and direct instruction literature (Kameenui & Simmons, 1990), as well as *detect*, *practice*, *repair* procedures (Poncy et al., 2013). The teacher in charge of the SRL group was provided with a script to aid her in her implementation of the SRL programme. This script emphasised the role of modelling and emulation along the pathway to self-control and self-regulation. The original script was modified after the first session to provide a more concise format, which was easier for the teacher to follow.

3.1.1 Pre-action

Self-control. Self-control is essential to the SRL process (Stoeger & Ziegler, 2008; Zimmerman, 1990). To help students develop improved self-control the students were taught the first three strategies from the process model of self-control (Duckworth, Gendler, & Gross, 2014). These strategies included: setting selection, setting modification, and attention deployment. The process model for self-control was specifically designed for use with school aged children.

Goal setting. During the pre-action phase students were taught to set goals. Students' medium-term goal was to reach a set target fluency rate (TFR), expressed as correct answers per minute, for the multiplication facts they were working on. The TFR used in this programme was based on existing literature and data obtained from four fluent performers within the school, as well as three fluent adults. In order to find fluent performers within the school, students were selected from Year 7 and 8 classes. The TFR was set at 45. This was consistent with the TFR used in Gallagher (2006), Chiesa and Robertson (2000), and Strømgren et al. (2014). A TFR of 45 translates to approximately 80 digits correct per minute, which is also the rate advocated for by Kubina and Yurich (2012). Data obtained from the fluent student and adult performers confirmed that this TFR was set at an appropriate level.

During the study, it became apparent that some students lacked the fine motor skills required to achieve this TFR. These students completed a digit writing task to establish the number of digits they could write within a minute. This was then compared to a small group of fluent performers within the SRL group. On the basis of this data, a lower limit TFR, of 40 correct answers per minute, was established. A TFR of 40 was also accepted as the lower limit in Strømgren et al. (2014), Chiesa and Robertson (2000), and Gallagher (2006).

Students also identified daily goals which were based on the celeration line that was drawn on their celeration chart. Prior to the programme, a celeration rate of ×1.6 was set as the benchmark for acceptable growth. According to Kubina and Yurich (2012), celeration rates between ×1.4 and ×1.8 represent 'robust' growth. A celeration rate of ×1.6 equates to weekly growth of 60%. For example, if a student could correctly answer 20 questions per minute at the start of the week they would need to correctly answer 32 questions per minute by the end of the week. This description is a simplification of the calculation process. The calculation of celeration rates is not purely based on the numbers obtained at the start and end of the week. See Kubina and Yurich (2012) for a more detailed description of this process.

The celeration line was drawn using the following procedure. The median data point was identified from the first three days of sprint data. A small dot representing this data point was placed at day three and a ×1.6 celeration line was drawn from this point up to the TFR (45 correct answers per minute). These celeration lines were not continued through the weekends, as no in class practice time was allocated during these days. The line was also re-calculated when a programme change occurred. Students considered their daily progress in relation to this line and used this line to set their goal for the following day's sprint. Two celeration charts are shown in Figure 3.1, at the bottom of this section. The red solid line depicts the TFR (40 and 45), the red dotted lines represent the target celeration rate of ×1.6.

The celeration line was also used to identify any student who was not making adequate progress. In consultation with the teacher, programme adaptions were made for students whose rate of progress fell below the ×1.6 celeration rate, or who met one of the other six change criteria (see section 3.1.3 'Feedback'). The primary considerations when teaching simple facts are identifying how many new facts should be taught and how frequently they should be rehearsed (Kameenui & Simmons, 1990). On this basis, programme adaptions involved reducing the number of new facts a child was exposed to, if their progress fell below the celeration rate of ×1.6.

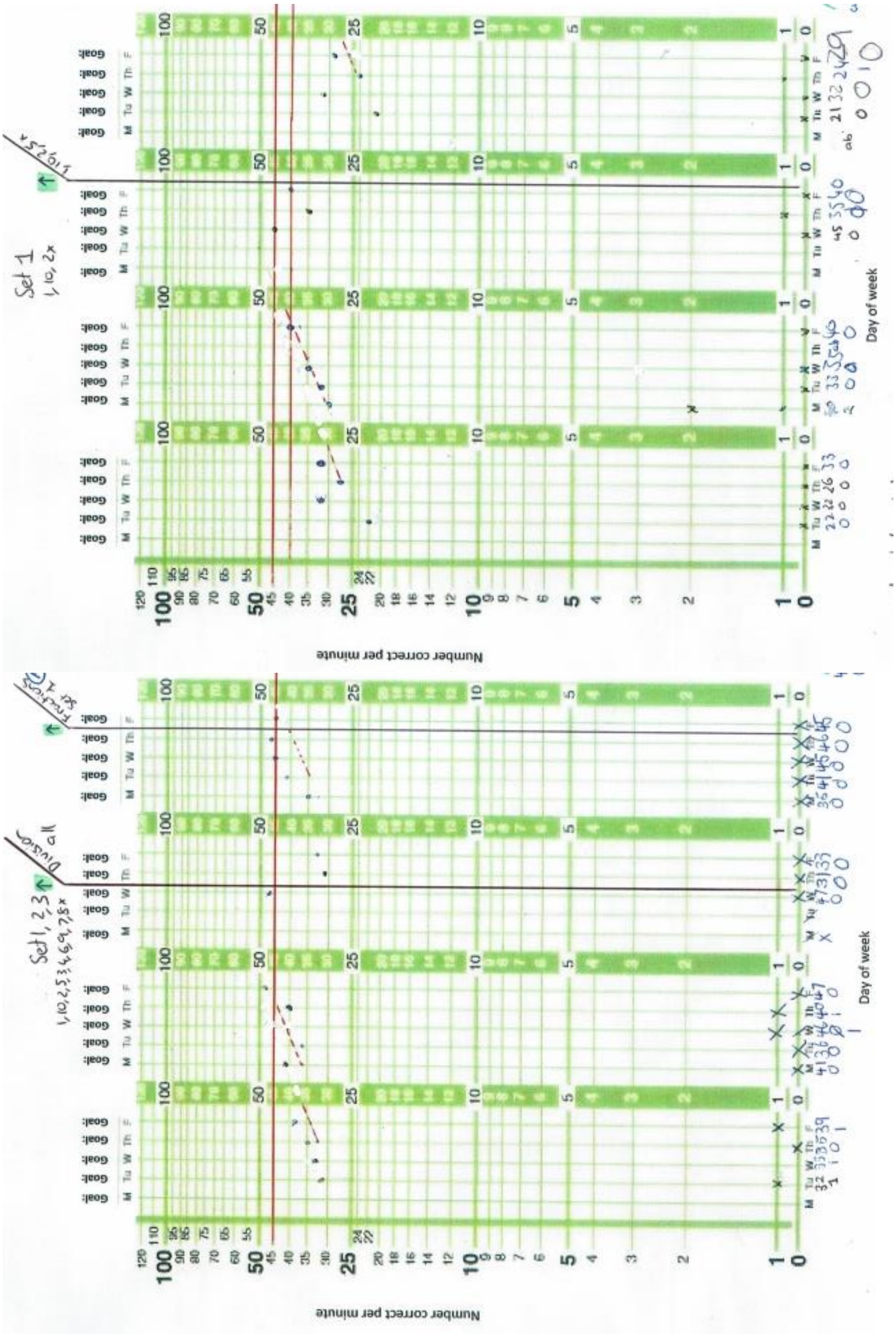

Figure 3.1. Example celeration charts. Solid red lines depict the TFR (45). The celeration chart at the top of this figure also depicts the lower limit TFR (40). The red dotted lines represent the target ×1.6 celeration rate and the black vertical lines represent programme changes, for example the addition of new facts.

3.1.2 Action

Detect. This phase was similar to that used in *detect, practice, repair* procedures by Poncy et al. (2013). Students started the action phase by going through all the cards in their pack. This was referred to as the *detect* stage of the action phase. They read the card out loud, instantly said the answer, and then turned the card over to check that their answer was correct. If the student answered the question correctly they put the card in a pile called the 'got its'. If the student did not answer the question correctly, or could not answer the question instantly, they put the card in a pile called the 'not yets'. Students were required to answer the facts instantly to discourage counting procedures (Miller, Skinner, Gibby, Galyon, & Meadows-Allen, 2011). Instant recall is a key component of PT. The PT literature suggests students should be able to answer at least one fact every second (Binder & Watkins, 2013; Johnson & Street, 2013). Near instant recall periods are used in many other basic facts fluency programmes, including taped problems (Miller et al., 2011), *detect, practice, repair* (Poncy et al., 2013), SAFI (Hulac et al., 2012), and timed drill practice (Bjordahl et al., 2014).

Practice. The second stage of the action phase was called *practice*. In this stage, students selected the top four cards from their 'not yet' pile. Students read the question out loud, checked the answer, said the answer out loud, and wrote the fact three times on the reverse page of their notebook diary. They then read the question from the card again, but this time they said the answer before they turned the card over. If they correctly answered the question they moved onto the next card and followed the same procedure. If they answered the card incorrectly they repeated the procedure with this fact. Students went through all four cards three times, or until they could instantly answer each of the four questions.

The protocol used in the *practice* stage was similar to that used in incremental rehearsal (Burns, 2005), *detect, practice, repair* (Poncy et al., 2013), SAFI (Hulac et al., 2012), and timed drill practice (Bjordahl et al., 2014). In these programmes, students were provided with a number of practice opportunities, although SAFI was the only procedure that involved written practice. The decision to limit practice to four new facts at a time was evidence based. In a New Zealand Council for Educational Research (NZCER) article, Neill (2008) suggests limiting the presentation of new basic facts to between three and seven items. Direct instruction literature also supports the presentation of only a few new items, with Kameenui and Simmons (1990) suggesting a limit of up to six new items per session. Burns et al. (2016) found the learning of basic facts was most efficient when facts were presented at a student's acquisition rate. In this study, Burns et al. (2016) found that the average rate of acquisition was four facts during one intervention session.

Repair. The final stage of the action phase was called *repair*. This stage involved integrating the newly learned facts into a slightly larger pool of problems. This stage required students to discriminate the new facts from the previously known facts and tested the learners recall with a longer delay (Kameenui & Simmons, 1990). The decision to integrate the four new facts with six 'got it' facts was again evidence based. Burns (2004) conducted a meta-analysis on drill ratios. In this study, Burns (2004) found presentation ratios that were composed of at least 50% known facts resulted in a mean effect size of over .85, with an optimal presentation ratio of 70% -85% known facts. Based on these findings, a ratio of four 'not yet' facts to six 'got it' facts was employed. Students randomly selected six facts from their 'got it' pile and mixed them with the four 'not yet' facts they had been practicing. They then went through these ten facts following the same procedure they used for all the cards during the *detect* stage. If, at the end of this stage, students had placed cards in a 'not yet' pile, they repeated the practice stage procedure with these facts. If all ten cards were placed in the ‘got it’ pile they selected four new cards from the original ‘not yet’ pile. In the event that there were no cards left in this pile, students practised answering all the cards in their pack as quickly as they could for the remainder of the five minutes.

3.1.3 Post-action

Sprint. At the end of the 5-minute action phase students took part in a sprint. Sprint sheets contained only the basic facts questions students had been practising in their own flash card packs. Every student collected their own sprint sheet and placed this sheet upside down where they were working. The teacher instructed them to turn the sheets face up, put their finger on the first question and their pencil in the air. She then indicated the start of the one-minute sprint using the phrase “on your marks, get set, go”. Students aimed to answer as many questions as they could within one minute. Once the time period was up, they handed their sheet to their assigned buddy who marked their sheet using the answer sheets provided. Students then graphed their number of correct answers and errors on their own celeration chart.

Sprints have been used in a number of basic facts programmes with students of this age or younger. Poncy et al. (2013) used them as part of a *detect, practice, repair* intervention with nine-year-old students and Windingstad, Skinner, Rowland, Cardin, and Fearrington (2009) and Miller et al. (2011) used them with seven-year-old students in taped problem procedures. All three studies identified the importance of providing additional opportunities to respond though sprint procedures. Daily, brief recording periods are also a critical component of PT (Binder & Watkins, 2013; Johnson & Street, 2013). Sprint data was essential for evidence based decision making.

Graphing. Self-graphing procedures have been used in a number of studies (Bryant et al., 2015; Gross et al., 2014; Schutte et al., 2015). This procedure is a key component of PT

(Binder & Watkins, 2013; Johnson & Street, 2013) and has been found to increase on-task behaviour and academic performance (Schutte et al., 2015). Self-graphing procedures have been used successfully with students as young as six (Gross et al., 2014; Gross et al., 2016), as well as students similar in age to those in this study (Bryant et al., 2015). Both teachers (Gross et al., 2016) and students (Bryant et al., 2015) have reported favourably on the use of self-graphing procedures.

In this study, students graphed their own results on their celeration chart. First, students located the correct day on the x-axis. They then moved vertically up the sheet using the logarithmic y-axis to place a dot that represented the number of questions they answered correctly, and an ‘x’ for the number questions they answered incorrectly. They also wrote the number of questions they answered correctly and incorrectly immediately below the day on the x-axis. Once students had added this information to their graphs they could compare their score to the celeration line on their graphs. Students used this information to set their goal for the following days sprint.

Reflection. The reflection stage, within the post-action phase of this study, encouraged students to reflect on their learning and self-evaluate their performance. The reflection was led by the teacher and occurred after students had graphed their results on their celeration charts. First, the teacher asked students to independently reflect on what facts they had got better at, what challenges they faced, how they overcame them, and what they needed to work on in their next learning session. The teacher then asked the students to share their reflections with a buddy who was sitting next to them on the mat. Finally, the teacher selected a few students to share their reflections with the class. During this stage the teacher encouraged the other students to provide specific praise and, if required, suggest ways the student could overcome the challenges they were experiencing.

Deliberate practice outside of school hours. Students were encouraged to continue using the SRL programme outside of school hours. To facilitate this, students were asked to identify a time that night when they would practise their basic facts. They were also prompted to identify any barriers that may prevent them from engaging in practice. Students were then encouraged to consider how they could use setting selection, setting modification, or attention deployment to overcome these barriers.

Limited access to resources is known to be a barrier to practice (Ericsson et al., 1993). To overcome this barrier students took their packs home each day. This ensured students had the resources they required to continue working on their specific basic facts. Students used five-minute sand timers, which were included in their packs, to ensure they allocated sufficient time to the *detect*, *practice*, and *repair* stages of the programme whilst practising at home.

Feedback. At the end of every lesson, the celeration charts and sprint sheets were collected. Sprint sheets were reviewed to ensure students had marked and graphed the data accurately. A removable sticky label was then applied to every celeration chart. This label provided specific praise related to the student's progress. It also directed the student's attention to a fact, or series of facts, that required extra attention during the following day's programme. Students were encouraged to reflect on this feedback during the subsequent days pre-action phase.

The celeration charts were also used to determine when to make a programme change**.** This study used six change guidelines, proposed by Kubina and Yurich (2012), to determine when to add or remove flash cards from student packs. The change criteria included: (a) The student met the acceleration aim for two out of three days; (b) acceleration data was decelerating; (c) deceleration data was accelerating; (d) there were four days of flat data; (e) the celeration rate fell below the projected aim for three or more data points; (f) additional information pertinent to improving the learner's performance was obtained. The decision to alter student programmes was made by the researcher on the basis of celeration chart data. If a student met the TFR, for two out of three days, additional cards were added to their pack. The number of new cards added to each pack was made on a case by case basis.

3.2 Training

Prior to the commencement of the programme, a half hour training session was run for the teacher in charge of the SRL group. This session focussed on the SRL administration script. This script was based on the three-stage model for self-regulation (Stoeger & Ziegler, 2008), the first three strategies from the process model for self-control (Duckworth et al., 2014), and the basic facts programme, which incorporated PT strategies (Binder & Watkins, 2013) and *detect, practice, repair* procedures (Poncy et al., 2013). This script followed the four-phase model for the development of self-regulation competence (Schunk & Zimmerman, 2007) emphasising the role of modelling and emulation along the pathway to self-control and self-regulation. The teacher had an opportunity to run through the programme and was encouraged to ask questions throughout the training.

Student training occurred during the programme. The programme used both direct instruction and the four-phase model for the development of self-regulation competence (Schunk & Zimmerman, 2007). First the teacher introduced a key component of the programme, such as the *detect* phase of the programme. Students were told to closely observe the teacher as she modelled the programme component. The students were then asked to emulate this behaviour whilst still sitting with the teacher. During this time, the teacher provided specific feedback to students. The teacher also identified students who were accurately exhibiting the target behaviour. These students were then asked to model the behaviour for the rest of the class. The rest of the class were then encouraged to provide specific praise, for aspects of the behaviour that the students were performing fluently, as well as next steps for students to work on. Once all students could accurately exhibit the behaviour they were encouraged to find a place inside the classroom where they could perform the behaviour. This was referred to as the self-control phase of the model. During this stage, the teacher roved around the classroom providing specific feedback to students.

Prior to progressing to the self-control stage of the model, students had also received training in the first three strategies from the process model for the development of self-control (Duckworth et al., 2014). Specifically, students were taught to use setting selection, setting modification, and attention deployment. These strategies facilitated the progression from the emulation stage to the self-control stage. Students were then encouraged to continue using these strategies at home. This represented the self-regulation stage of the model. Whilst this behaviour could not be directly observed, diary data confirmed that students were able to apply the strategies learned at school to practice at home. Students also started every subsequent practice session by reflecting on the practice they had engaged in the previous night. During this time students discussed what challenges they had faced and what strategies they had used to overcome these challenges.

The researcher also met with the teacher in charge of the traditional instruction (Trad) group prior to the programmes commencement. At this meeting the researcher and teacher confirmed which lessons from Book 4 of the Numeracy Project (Ministry of Education, 2008b) would be taught during the programme. Based on the students’ ability, the following activities were selected: Bowl a Fact, In and Out, Multiplication Madness, and Loopy. Some of these activities required the teacher to organise students into groups. As the teacher had taught all of these activities in previous years she was encouraged to group students according to her usual practice, whilst following any specific instructions provided in the lesson's activity description. The researcher also ensured the teacher had the equipment required for each activity and understood the instructions that accompanied each activity. Observations undertaken during the programme confirmed that students in the Trad group were engaged in the activities. The observations also confirmed that the activities were implemented with fidelity.

3.3 Programme fidelity

The programme fidelity check forms were designed to measure both the structural and process validity of the SLR programme. They were based on those used by Odom et al. (2010) in their evaluation of curriculum implementation in preschool classes. A sample programme fidelity form can be found in Appendix G. The purpose of the fidelity checks was to identify whether the intervention was being implemented with the required fidelity, so that additional training could be provided if required. Observations were also carried out in the Trad classroom to ensure that students were adequately engaged and that the agreed upon lessons/activities were being taught.

3.4 Ethics

Ethical Approval was obtained from The University of Canterbury Human Ethics Committee. After approval had been received, the chairman of the participating school's board of trustees was approached by phone. The researcher provided the chairman with a verbal description of the study as well as the information sheet and consent form, that had been approved by the University of Canterbury Human Ethics Committee. After the chairman of the board of trustees had completed the consent form, the school's principal was approached. Again, a verbal description of the study was provided in addition to the approved information sheet and consent form. Once the principal had completed the consent form, the two participating teachers were approached. The teachers were also provided with a verbal description of the programme as well as the approved information sheet and consent form.

Once these consent forms had been obtained the researcher met with all the children in these two classes. The students were provided with the information form. The researcher then read through the information sheet with the students and answered students' questions about the programme. The same process was then followed with the consent form. The students were subsequently provided with an information sheet and consent form for their parent(s)/caregiver(s). Once the students' parent(s)/caregiver(s) had completed the consent form the students returned the consent form to the school, where they were collected by the researcher. To ensure that informed consent was obtained, information and consent forms used language that was appropriate for the various audiences with whom consent was sought. Examples of the information sheets can be found in Appendix A and examples of the consent forms can be found in Appendix B.

A number of ethical issues were considered during the design of this programme. The primary considerations included how to mitigate test anxiety, how to minimise additional work load for teachers, how to minimise disruption to the class timetable, how to develop the programme components to minimise student anxiety. These considerations were explicitly identified on all information and consent forms. In order to ensure students in the Trad group did not miss out on the benefits of the programme, the researcher provided the teachers with all the resources they required to run the programme with the students in the Trad group, after the study had ended. The researcher also offered to provide additional training and support.

3.5 Experimental design

This study employed a repeated measures experimental design with a treatment-as-usual control group. This type of design controls for many threats to validity, including history, maturation, and regression effects (Tuckman & Harper, 2012). In contrast to a post-test-only control group design, a repeated measures experimental design with a treatment-as-usual control group allowed investigation into whether the treatment had a differential effect on the groups within the study. This was an important feature of the study.

The control group (Trad) received traditional classroom instruction. This instruction was based on Book 4 from the New Zealand Numeracy Project (Ministry of Education, 2008b). The SRL condition and the Trad condition received the intervention during the last 15 minutes of their mathematics lesson. The intervention ran five days a week and lasted for four weeks.

3.6 Recruitment of participants

The participants in this study came from one full primary school (Years 1 – 8) in Christchurch, with a Ministry of Education decile ranking of seven. The decile system is used by the Ministry of Education to allocate funding to schools. Schools are allocated a decile from one to ten. Decile one schools are the 10% of schools that have the highest proportion of students from low-socio-economic communities. The lower the school's decile, the more funding it receives. (Ministry of Education, 2016b).

The selected school was of sufficient size to have two separate classes at the Year 5/6-year level (children aged 9 to 10 years). This was an important requirement as it enabled random assignment into either the SRL or Trad group. These groups, and the two teachers, were then allocated to one of the two conditions. The study focussed on Year 5 and 6 students because The New Zealand Curriculum (Ministry of Education, 2007) and Book 1 from the New Zealand Numeracy Project (Ministry of Education, 2008a) identify the importance of multiplication fact recall at this age. These documents are supported by research from Steel and Funnell (2001) who found that students shifted from strategy use to direct retrieval for basic facts at around ten years of age.

3.7 Participants

Selection of students. All students in the two Year 5/6 classes were invited to take part in the study. Of the 50 students and families approached for consent, 47 (94%) agreed to take part in the study. Table 3.1 provides an overview of the participants' demographic information by condition. Gender and ethnicity data was taken from student enrolment information. This form was completed by parents and allowed for recording of more than one option to describe their child's ethnicity

Table 3.1

Participant demographic information by condition

	SRL programme			Traditional instruction		
Ethnicity	NZ European/Pakeha 17 (71%)	NZ European/ Pakeha & Maori 3 (13%)	Other ethnicity[a] 4 (17%)	NZ European/Pakeha 13 (57%)	NZ European/ Pakeha & Maori 6 (26%)	Other ethnicity[a] 4 (17%)
Gender	Male 10 (42%)	Female 14 (58%)		Male 12 (52%)	Female 11 (48%)	
Year group	Year 5 17 (71%)	Year 6 7 (29%)		Year 5 14 (61%)	Year 6 9 (39%)	
Age (5/6/17)	Age 9 8 (33%)	Age 10 16 (67%)		Age 9 9 (39%)	Age 10 14 (61%)	
Total students	24			23		

Note: [a]The other category included children who were classified as part or full ethnicity of any other groups than Maori and European/Pakeha.

Assignment to condition. All students who provided the necessary consents were randomly assigned to either the SRL or Trad group. The random assignment procedure involved printing all student names onto the same sized pieces of paper, stapling the paper in half so that the name could not be seen, and placing this piece of paper into a container. The container was then shaken thoroughly before names were pulled out one by one and assigned to either group. The teachers were also randomly assigned using the same technique. This procedure occurred prior to data collection at T1.

Retention of participants. Data was collected from all 47 students at T1 and again at T2. Data was obtained from 45 students at T3, as two students were absent for medical reasons.

Teacher demographics. The two participating teachers were female, of comparable age, and had in excess of 20 years teaching experience. In both cases, they had spent the majority of their teaching career educating students similar in age to the participants in this study. One teacher identified as New Zealand European and the other teacher identified as American from British decent. Both teachers met the experienced registered teaching criteria and had been teaching at this school for over five-and-a-half years.

3.8 Measures

3.8.1 1-minute multiplication probes

The 1-minute multiplication probes were paper and pencil tests, composed of 90 questions, which came from a pool of 52 multiplication facts. All questions were presented horizontally with a line next to every problem on which students recorded their answers. This pool of facts included all multiplication facts from 2 × 1 to 9 × 10. As no turn-around facts were included (e.g. if 2 x 1 was included then 1 x 2 was not included), this created a pool of 52 problems. The probes were developed in Microsoft Excel. This enabled the presentation order for the 90 problems, from the 52-item pool, to be randomised in all administrations of the 1-minute multiplication probes. The probes were designed so that every question was randomly selected from the 52-item pool. This was facilitated through the use of an Excel formula. As every question in each probe was randomly selected from the 52-item pool, some questions occurred more than once. This procedure was employed to mitigate the possibility that students may have remembered the order of test items across administrations of the 1-minute multiplication probes. It was also necessary as prior testing revealed that some students could complete 52 items within one minute however, no student was able to complete 90 questions within this time. Two versions of the 1-minute multiplication probes were created. These were labelled: Test A and Test B. The main dependent variable for the SRL and Trad groups was their correct answers per minute (CAPM) on the 1-minute multiplication probes. These scores were collected from the tests administered at T1, T2, and T3.

3.8.2 1-minute multiplication probe (Test A)

Test A consisted of all 52 multiplication fact problems (see Appendix C). Variations of Test A were administered at T1, T2, and T3. The only difference between the Test A 1-minute multiplication probes, administered throughout the study, was the order in which the facts were presented.

3.8.3 1-minute multiplication probe (Test B)

Test B contained turn-around facts for all the facts presented in Test A. For example, Test A contained 2×7, and Test B contained 7×2. Variations of Test B were also administered at all three time periods, shortly after Test A. As with Test A, the order the basic facts were presented in differed for all three administrations of Test B. Test B was developed to test whether fluent performance, of the 52 basic facts learned during the programme, generalised to their associated turn-around facts.

3.8.4 Warm-up multiplication probe

A warm-up multiplication probe was also administered however this was not used as a dependent variable. For this reason, these probes were not marked or analysed. The warm-up multiplication probe had the same appearance as the 1-minute multiplication probes. Like the 1-minute multiplication probes, it consisted of 90 multiplication fact questions organised into three columns. The 90 questions were randomly generated to include facts from 2 × 1 to 10 × 10. This meant that the warm-up probe included questions from both Test A and Test B of the 1-minute multiplication probes. Unlike the 1-minute multiplication probes, the warm-up probe did not have to be completed within one minute. The purpose of the warm-up probe was to familiarise students with the layout and procedure associated with the timed probes. This step was taken, in part, to reduce any anxiety students had about completing a timed probe. Providing a practice opportunity prior to Test A also mitigated the chance that any significantly greater score on Test B than Test A was due to a practice effect.

Assessment probes similar to Test A and Test B have been identified as an appropriate method for determining student proficiency in basic facts. One-minute probes have been used with this age group to investigate basic facts programmes using *detect, practice, repair* (Poncy et al., 2013); taped problems (McCallum et al., 2006; Miller et al., 2011); incremental rehearsal (Burns, 2005); *cover, copy, compare* (Poncy, Skinner, & McCallum, 2012); explicit timing (Schutte et al., 2015); direct instruction (Pierce, McLaughlin, Neyman, & King, 2012); and PT (McTiernan et al., 2016). Analysis of Test A and Test B data at T1 showed good reliability for these parallel forms (r =.85).

3.8.5 Self-efficacy

Self-efficacy for multiplication was measured using a ten-point self-efficacy tool at T1 and T2. This tool was based on measures used by Hoffman (2010) with pre-service teachers and by Lopez, Lent, Brown, and Gore (1997) with high school aged students. Analyses of the self-efficacy data confirmed that this measure had good internal consistency (Cronbach's alpha = .87 at T1 and .88 at T2) and test re-test reliability (T1 to T2 r = .83).

Students were presented with ten multiplication questions which were representative of those included in the 1-minute multiplication probes. Students rated these problems on a ten-point scale ranging from *I would not be able to answer this question* (1), to *I am extremely confident I could answer this question instantly* (10). Three additional self-efficacy statements were located between these statements to assist students with their self-efficacy assessments (see Appendix D). These statements were: *I would need to use my fingers* (3-4), *I could work it out from another basic fact I know* (5-6), *I know this answer but it might take me a few seconds to remember it* (7-8). After administration, the self-efficacy ratings were averaged to calculate an overall self-efficacy belief rating. This resulted in a self-efficacy score between 1 and 10, where higher scores represented greater self-efficacy.

3.8.6 Questionnaire

A brief questionnaire was administered at T1 and T2. The questionnaire investigated the type of basic facts practice students engaged in outside of school hours and the frequency and duration with which they engaged in it. Students were asked to reflect on only their basic facts practice behaviour from the last seven days.

The questionnaire administered in the final week of the intervention included two additional questions. It asked students to rate how helpful and enjoyable they found the programme they had been assigned to, on a five-point scale (Appendix E). Similar questionnaires have been used by Bonneville-Roussy and Bouffard (2015), Moore, Burland, and Davidson (2003), Plant et al. (2005), and Rosario et al. (2013).

3.8.7 Sprints and celeration charts. The sprint sheets were composed of 60 multiplication fact questions. These 60 questions consisted of a randomly generated mix of the multiplication facts that the student had been practising. Because every student had their own set of facts, a number of different sprint sheets were created. Different versions of these sheets were generated to ensure that students could not simply memorise the order of the questions from one sprint to the next. A matching answer sheet was also generated for every sprint sheet.

This study also employed self-graphing procedures. All students were taught to record their daily sprint results on celeration charts (Appendix F). The celeration chart used in this study was based on the celeration chart developed by Giroux and Crow (2000). Students used dots to represent correct answers and crosses to represent incorrect answers. The number of correct answers and incorrect answers were also recorded directly underneath each day on the x-axis. These charts were used to monitor every student's progress and identify whether a programme change needed to occur. The results section also includes a detailed analysis of six celeration charts from the study.

3.8.8 Diaries. Two written diaries were developed. One was completed by the students in the SRL group (Appendix H) and the other was completed by the students in the Trad group (Appendix I). The diary recording procedure was based on that used by Plant et al. (2005) and Rosario et al. (2013). However, slight modifications were made to these measures to ensure they were appropriate for the students in this study. Students in the SRL group used the diaries, after every practice session, to record which self-control strategies they used at home and how helpful they found them. They also recorded how confident they felt answering the facts they had been practising after every home-based practice session.

3.9 Equipment

The following section describes the equipment that was used throughout this study. Where appropriate, this section identifies whether the equipment was provided to all students or just one of the two conditions.

Every student in the SRL programme was given a named SRL programme pack. This pack contained flash cards, a timer, a diary, and a pen. These items were stored inside snap-lock bags, which were clearly named. The teacher was provided with spare equipment to add to the bags, in case equipment was lost or broken. The Trad students also received a programme pack. Their zip lock bag contained the traditional instruction diary and a pen. This teacher was also provided with spare equipment which she added to packs when required. Both the SRL and Trad packs were similar in appearance.

3.9.1 Flash cards

Every student in the SRL group was provided with a pack of multiplication fact cards. The multiplication fact questions were presented horizontally in size 36 font with answers provided on the back of the card. All cards were 7.5cm by 4.5cm in size and printed on 250 GSM card. This made the cards more durable than paper copies and also ensured no answer could be seen through the card. The top right-hand corner of all the cards were cut diagonally. These diagonal cuts enabled students to quickly organise their cards into the correct rotation, without having to check each individual card. The cards were held together with a rubber band and kept inside snap-lock bags.

Students were provided with a pack of cards based on analysis of their 1-minute multiplication probe, administered at T1. Initially, these packs contained either the 1, 2, and 10 times tables (referred to as set 1), the 1, 2, 3, 4, 5, and 10 times tables (referred to as set 2), or the 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 times tables (referred to as set 3). As no turn-around facts were included, set three contained a total of 52 facts. These were the same 52 facts that were included in the Test A 1-minute multiplication probe. Students had cards either removed or added to these packs according to the data obtained from the celeration charts.

3.9.2 Timers

Every SRL student pack contained a five-minute sand timer. Students used the five-minute sand timers to ensure they allocated a full five minutes to the action phase of the programme, when practicing outside of school hours. Prior to the programme 60 timers were sourced and given a unique code. The accuracy of every timer was checked. On the basis of these checks, one timer was discarded.

3.9.3 Pen

A blue biro was included in all SRL and Trad packs. Students were provided with a biro rather than a pencil to avoid time lost to pencil sharpening and lead breakages. The teacher was provided with a number of spare biros to replace lost or broken pens.

3.9.4 Diary

The SRL and Trad diaries were spiral bound with dimensions similar to a 3B1 notebook. This enabled the notebook to fit inside the zip lock plastic bags that were provided as part of the programme. Five spare diary pages were included in each diary, in addition to the 28 diary pages which covered every day of the programme. Every diary day started on a new page. The back of every diary page was left blank, as students in the SRL group required this space for the written practice stage of their programme.

3.10 Procedures

The following section describes how, and when, the measures and assessments, used in this study, were administered. Figure 3.2, at the end of this section, provides an overview of the study timeframe.

3.10.1 Prior knowledge and demographic information. Prior to the study, the school provided student demographic information for all students who consented to participate in the study. This data was retrieved from the school's student management system and provided to the researcher. At this time, the two classroom teachers were also asked to review their assessment records to identify which students understood all lessons up to and including 'Turn Abouts', in Book 6 of the Numeracy Project (Ministry of Education, 2008c). Students working at this level can skip count, understand the relationship between repeated addition and multiplication, and have a basic understanding of the distributive and commutative properties of multiplication. The teachers provided the researcher with this information and the Mathematics Progressive Achievement Test (PAT) data after the study had commenced. The Mathematics PAT is a standardised test developed for use in New Zealand schools. This test is aligned with the New Zealand curriculum and enables students' achievement to be compared against national norms (NZCER, n.d.).

3.10.2 1-minute multiplication probes.

The warm-up multiplication probe and Test A and Test B of the 1-minute multiplication probes were completed by all students in the SRL and Trad instruction groups. These three probes were administered to all students at T1, T2, and T3. All probes were administered by the researcher, who followed a scripted administration procedure. The researcher then took away all probes for marking and analysis.

3.10.3 Sprints

At the end of every session, students in the SRL group completed a sprint. Students collected their named sprint sheet from the teacher and placed the sheet upside down at their desk. Once seated, the teacher instructed students to turn the sheets face up, put their finger on the first question and their pencil in the air. She then indicated the start of the one-minute sprint using the phrase “on your marks, get set, go”. After one minute had expired the teacher instructed students to put their pencil down. Students then swapped their test sheet with their buddy and marked their buddy's sprint using the answer sheet provided. Students then recorded their own results on their celeration chart.

3.10.4 Self-efficacy

All students in the SRL group and Trad group completed the self-efficacy measure at T1 and T2. The self-efficacy measure was administered by the researcher. Students were asked to look at all ten basic facts questions in turn. They were asked to consider which number, on the scale provided, best represented how confident they felt answering that question. Students were encouraged to use the written descriptions at the top of the scale to aid their judgments. These descriptions were also read aloud to the students.

3.10.5 Questionnaire

The questionnaire was administered to all students in the SRL and Trad groups at T1 and T2. The questionnaire administered at T2 contained the two additional questions described in section 3.8.6. The researcher emphasised to students that they were only to reflect on the basic facts practice they had engaged in over the previous seven days. To support students with the questionnaire, the researcher read all instructions, and possible answers, out loud. The researcher also supported any student who was unable to complete the written response to question three, which required students to describe the type of practice they engaged in if they selected the option ‘other’.

3.10.6 Diary

Students in both groups were instructed to complete a recording page in their diaries whenever they engaged in basic facts practice outside of school hours. They were encouraged to record their practice as soon as they finished their practice session. The action phase of the SRL programme lasted for five minutes. To ensure students allocated this amount of time to the action phase at home, students in the SRL group were provided with a five-minute sand timer to measure their sessions. Students in the Trad instruction group were encouraged to use regular household timers, such as timers on computers, cell-phones, and clocks. Students could engage in more than one session of practice, outside of school hours, during any day. In these instances, students were told to neatly record this information next to the information recorded from earlier sessions that day.

T1: Prior to programme (12/5/17)

All participants

- All consent forms obtained
- Student data collected (name, age, year, ethnicity, gender, learning difficulty status, PAT mathematics data)
- Students and teachers randomly assigned

SRL condition

T1: Immediately prior to programme (12/5/17)

Measures administered:

- Self-efficacy measure
- Questionnaire
- Warm-up multiplication probe
- 1-minute multiplication probe (Test A)
- 1-minute multiplication probe (Test B)

SRL programme (4 weeks)

T2: Immediately after programme (21/6/17)

Measures administered:

- Self-efficacy measure
- Questionnaire
- Warm-up multiplication probe
- 1-minute multiplication probe (Test A)
- 1-minute multiplication probe (Test B)

Maintenance – five weeks after end of programme (26/7/17)

Measures administered:

- Warm-up multiplication probe
- 1-minute multiplication probe (Test A)
- 1-minute multiplication probe (Test B)

Traditional classroom instruction

T1: Immediately prior to programme (12/5/17)

Measures administered:

- Self-efficacy measure
- Questionnaire
- Warm-up multiplication probe
- 1-minute multiplication probe (Test A)
- 1-minute multiplication probe (Test B)

Traditional instruction (4 weeks)

T2: Immediately after programme (21/6/17)

Measures administered:

- Self-efficacy measure
- Questionnaire
- Warm-up multiplication probe
- 1-minute multiplication probe (Test A)
- 1-minute multiplication probe (Test B)

Maintenance – five weeks after end of programme (21/7/17)

Measures administered:

- Warm-up multiplication probe
- 1-minute multiplication probe (Test A)
- 1-minute multiplication probe (Test B)

Figure 3.2. Study time frame

3.11 Data analysis

The following section describes the statistical analyses that were performed in order to answer the research questions. All data in this study was analysed using Microsoft Excel and SPSS. The alpha level used in these analyses was set at .05.

3.11.1 Analysis prior to programme implementation

A number of analyses were undertaken to confirm that the students did not differ significantly on any of the variables prior to the study. Independent samples *t*-tests were used to investigate whether students' basic facts ability, reported practice duration, and reported practice frequency differed significantly by condition. In addition, an exact significance test for Pearson's chi-square was conducted to investigate whether the type of practice students reported engaging in differed by condition. In order to investigate whether self-efficacy ratings differed by condition, analysis of variance (ANOVA) and Mann-Whitney Tests were conducted. A further independent samples *t*-test was also undertaken to investigate whether students' basic facts ability differed by gender.

3.11.2 Research question one

Basic facts fluency. An analysis of covariance (ANCOVA) was used to investigate what effect the SRL programme had on basic facts fluency. Group was entered as the independent variable, 1-minute multiplication probe results at T1 were entered as the covariate, and the 1-minute multiplication probe results at T2 were entered as the dependent variable. This analysis was conducted with both Test A and Test B data. To investigate the size of this effect, Cohen's *d* was calculated for both within group and between group differences for Test A and Test B. The same analyses were also undertaken to investigate whether the gains in basic facts fluency were maintained at T3. Group was again entered as the independent variable, multiplication probe results at T1 were entered as the covariate, and the 1-minute multiplication probe results at T3 were entered as the dependent variable. A hierarchical multiple regression was also employed to investigate if the SRL programme continued to be associated with Test A performance at T2 after controlling for children's pre-existing mathematics ability (assessed prior to group assignment and the start of the basic multiplication facts instruction).

Prior to the programme, the two teachers were asked to review their records and identify which students had mastered all the lessons up to and including 'Turn Abouts' in Book 6 of the Numeracy Project (Ministry of Education, 2008c). Students working at this level can skip count, understand the relationship between repeated addition and multiplication, and have a basic understanding of the distributive property of multiplication. It was hypothesised that students who had mastered these skills would make better progress than students who had not mastered these skills, especially with the turn-around facts used in Test B. Unfortunately, the information provided was not sufficiently accurate to be used for this purpose.

Basic facts self-efficacy. The self-efficacy data was treated as an ordinal variable. A Mann-Whitney test was conducted to explore whether students in the SRL group reported higher self-efficacy scores than those in the Trad group. Two Wilcoxcon Tests were also conducted to explore whether the self-efficacy scores, for the SRL and Trad groups, changed over the course of the programme. To explore the relationship between self-efficacy and the 1-minute multiplication probe performance a correlation matrix was also generated.

Reliable Change Index (RCI). Idiographic analysis was also undertaken. Idiographic analysis focuses on individual cases. The main advantage of idiographic analysis is that, unlike nomothetic analysis, it does not infer within-individual effect from between person data (Rorer & Widiger, 1983). The within-individual effect was investigated using the reliable change index (RCI). The RCI was calculated from the 1-minute multiplication probe scores, collected at T1, T2, and T3, for all students in the SRL and Trad groups, using the method described in Jacobson and Truax (1991). Calculation of the RCI allowed the identification of 1-minute multiplication probe scores which showed a statistically significant improvement or decrement from T1 to T2 and T3.

Celeration Chart Data. Celeration chart data from two low, average, and high ability students, from the SRL group, was analysed. This analysis included calculating celeration and bounce rates as well as providing a brief description of the learning displayed on the celeration charts. Celeration chart data was also used to calculate the number of SRL students who met the TFR by type of times table and to investigate how long it took students, who had met the TFR for all times tables, to meet the TFR for division facts.

Time to division fact TFR. Six students met the TFR for multiplication facts and division facts. Daily celeration data was used to plot a multiple line graph to investigate the rate of progress to division facts fluency. This graph followed the PT convention of using a logarithmic y-axis to display celeration data.

3.11.3 Research question two

Practice. Three separate analyses were undertaken to investigate to what extent the SRL programme altered students' basic facts practice behaviour outside of school hours. First, an ANCOVA was performed to investigate whether the SRL group engaged in more frequent practice, at T2, than the Trad group. In this analysis, group was entered as the independent variable, frequency of practice at T1 was entered as the covariate, and frequency of practice at T2 was entered as the dependent variable. The second analysis investigated whether the SRL group practised for longer durations than the Trad group. In this analysis, group was entered as the independent variable, practice duration at T1 was entered as the covariate, and practice duration at T2 was entered as the dependent variable. Finally, an exact significance test for Pearson's chi-square was used to investigate whether the SRL and Trad groups chose to engage in different forms of basic facts practice at T2.

3.11.4 Supplemental analysis

Social validity. Data investigating how enjoyable and useful students in the SRL and Trad groups found their programmes were collected from the final questionnaire. An independent samples *t*-test was used to compare how enjoyable the students in the SRL group and Trad groups rated their respective programmes. An independent-samples *t*-test was also used to investigate whether there was any significant difference between how helpful the students in the SRL and Trad groups found their respective programmes.

Chapter 4: Results

4.1 Examining pre-programme group differences (T1)

Although children were randomly assigned to experimental conditions (SRL or Trad), the first set of analyses examined the possibility of significant differences between the two groups in terms of their basic facts, basic facts practice characteristics, and self-efficacy. In summary, these analyses confirmed that the SRL group and Trad group did not differ significantly on any measure prior to the programme commencing.

Table 4.1 reports the descriptive statistics for Test A, Test B, self-efficacy, practice frequency, and practice duration, by condition. The following analyses were undertaken to explore whether The SRL and Trad groups differed significantly on any of these five variables at T1. Independent samples *t*-tests confirmed that there was no statistically significant difference between the conditions on Test A (t = -.499, df = 45, p = .620, two-tailed) or test B (t = -.121, df = 45, p = .904, two tailed) at T1. Analysis of the data also confirmed that male and female scores on Test A (t = .128, df = 45, p = .899, two-tailed) and Test B (t = -.096, df = 45, p = .924, two-tailed) at T1 did not differ significantly. Independent samples *t*-tests were also used to confirm that the SRL and Trad groups did not differ significantly in either the reported number of practice days (t = .282, df = 45, p = .779) or practice duration (t = .513, df = 45, p = .611).

Two separate analyses were conducted to explore whether the SRL and Trad groups differed in their self-efficacy ratings at T1. First, a one-way between-subjects analysis of variance (ANOVA) was conducted. This analysis confirmed that the SRL and Trad groups did not differ significantly in their self-efficacy ratings at T1 (F(1, 45) = .003, p = .954). Because the self-efficacy data was not normally distributed a Mann-Whitney Test was also conducted. This test also confirmed that there was no significant difference between the two groups (U = 266.500, N_1 = 24, N_2 = 23, p = .840, two-tailed).

Table 4.1

Dependent variables by condition at T1

	Test A CAPM *M (SD)*	Test B CAPM *M (SD)*	Self-efficacy *Median*	Practice frequency *M (SD)*	Practice duration *M (SD)*
SRL	19.8 (8.2)	20.8 (9.7)	8.6[a]	4.1 (1.4)	15.4 (8.8)
Trad	21.0 (8.4)	21.1 (9.4)	8.5[a]	4.0 (1.7)	14.1 (8.3)

Notes: *M* = mean. *SD* = standard deviation, CAPM = correct answers per minute.

[a]Median provided as self-efficacy data was treated as an ordinal scale.

The questionnaire, at T1, also queried the type of mathematics activity students most commonly engaged in, outside of school hours. A clear preference for mathematics games (48.9%) was observed. Table 4.2 details the type of activity students engaged in, by condition. A multi-dimensional chi-square test was conducted to investigate whether the SRL group and Trad group differed significantly in their response to this question. Eight cells had expected counts of less than five, so an exact significance test was selected for Pearson's chi-square. This analysis confirmed that there was no relationship between the conditions and the type of basic facts practice students engaged in, outside of school hours: χ^2 (4, N = 45) = .671, exact p = .961.

Table 4.2

Type of practice by condition at T1

	Maths games	Testing	Flash cards	Activity sheets	Other
SRL	45.5%	18.2%	13.6%	13.6%	9.1%
Trad	52.2%	21.7%	8.7%	8.7%	8.7%

4.2 Differences between conditions at time period 2 (T2)

Nomothetic analysis for basic facts (Test A). A one-way between-subjects analysis of covariance (ANCOVA) was conducted to assess the impact the SRL programme had on Test A performance at T2. Checks were carried out to confirm homogeneity of regression and linear relationship between the covariate and dependent variable. The between-subjects factor comprised two groups, the SRL and Trad conditions. Test A performance at T1 was entered as the covariate. Test A performance at T1 was significantly related to Test A performance at T2: $F(1,44) = 80.52$, $p < .05$, partial $\eta^2 = .65$. After adjusting for this covariate, the between-subjects factor group showed a statistically significant difference between the two groups: $F(1,44) = 49.58$, $p < .05$, partial $\eta^2 = .53$. The adjusted mean score for the SRL group was 34.4 CAPM compared to 22.1 CAPM for the Trad group (see Table 4.3). The within group and between group effect sizes were calculated using Cohen's *d*. The effect size for the SRL group from T1 to T2 ($d = 1.42$) and the effect size between the SRL group and the Trad group ($d = 1.14$) at T2 were both found to exceed Cohen's (1988) convention for a large effect size. In contrast, the effect size for the Trad group from T1 to T2 was small ($d = .2$). Thus, the children in the SRL group showed much greater improvement in their CAPM scores on Test A from T1 to T2, even after controlling for T1 performance.

Table 4.3

One-Way Between-Subjects ANCOVA for Test A (Means)

			95% Confidence Interval	
Group	Mean CAPM	Std. Error	Lower Bound	Upper Bound
SRL	34.402a*	1.220	31.943	36.861
Trad	22.102a	1.247	19.590	24.615

a. Covariates appearing in the model are evaluated at the following values: T1(Test A) = 20.43.

Hierarchical multiple regression was employed to investigate if the SRL programme continued to be associated with Test A performance at T2 after controlling for children's pre-existing mathematics ability (assessed prior to group assignment and the start of the basic multiplication facts instruction). Mathematics ability was measured using the PAT percentile data, which was provided by teachers. As can be seen in Table 4.4 below, in the first step of the analysis, PAT percentile data was entered as the only predictor variable and was moderately associated with performance on Test A multiplication facts at T2 (R^2 = 14.7%). The second step of the analysis added group assignment as a predictor variable, and both variables showed moderately strong significant independent associations with Test A at T2. Children who had higher PAT scores and were in the experimental group performed significantly better on multiplication facts at T2. Model 2 explained significantly more of the variance in Test A performance at T2 (48.3%, R^2 change F (1, 44) = 27.03, p <.05). In the final step, Test A performance at T1 was added as a predictor variable. This full model explained significantly more of the variance in Test A performance at T2 (75.4%, R^2 change F(1,43) = 47.39, p < .05). The full model showed that the association between PAT percentile and Test A at Time 2 was substantially reduced and no longer significantly contributed to the predictive utility of the model.

Table 4.4

Hierarchical multiple regression predicting Test A performance at Time 2

Variable	B(SE)	Beta;(p)	ANOVA
Model 1			8.923
PAT percentile	.437 (.146)	.407 (.005)	
Model 2			20.558
PAT percentile	.527 (.118)	.491 (.000)	
Group	-12.766 (2.455)	-.570 (.000)	
Model 3			43.954
PAT percentile	.181 (.096)	.168 (.067)	
Group	-12.713 (1.713)	-5.67 (.000)	
Test A T1	.841 (.122)	.612 (.000)	

Nomothetic analysis for basic facts (Test B). A one-way between subjects ANCOVA was conducted to assess the impact the SRL programme had on Test B (Test B was composed of the turn-around facts) performance at T2. The same checks, described previously, were again performed. Group was entered as the between-subjects independent variable. Test B at T1 was entered as the covariate and Test B at T2 was entered as the dependent variable. Test B performance at T1 was significantly related to Test B performance at T2: $F(1,44) = 103.56$, $p < .05$, partial $\eta^2 = .70$. After adjusting for this covariate, the between-subjects factor group showed a statistically significant difference between the two groups $F(1,44) = 9.04$, $p < .05$, partial $\eta^2 = .17$. The adjusted mean score for the SRL group was 29.8 compared to 24.6 for the Trad group (see Table 4.5). The within group and between group effect sizes were calculated using Cohen's *d*. These calculations confirmed that the effect size for the SRL group, from T1 to T2 ($d = .85$), exceeded Cohen's (1988) convention for a large effect size. The effect size between the SRL group and the Trad group ($d = .46$), at T2, fell just short of Cohen's convention for a medium effect size. The effect size for the Trad group, from T1 to T2 was $d = .37$. These analyses confirm that the SRL students also made far greater gains in CAPM on Test B from T1 to T2, than their peers in the Trad condition.

Table 4.5

One-Way Between-Subjects ANCOVA for Test B (Means)

			95% Confidence Interval	
Group	Mean CAPM	Std. Error	Lower Bound	Upper Bound
SRL	29.823a	1.221	27.363	32.284
Trad	24.576a	1.247	22.063	27.089

a. Covariates appearing in the model are evaluated at the following values: T1(Test B) = 20.91.

Idiographic analysis for basic facts (Test A & B) at T2. Idiographic analysis was also undertaken for Test A and B. Calculation of the reliable change index (RCI) indicated that 21 (87.5%) students in the SRL group showed a reliable improvement from T1 to T2 on Test A. Of the 23 students in the Trad group, two students (8.7%) showed a reliable improvement and one student (4%) showed a reliable decrement in performance during this time period. The same analysis on Test B data showed that 12 (50%) students in the SRL group and six students in the Trad group (26.1%) showed a reliable improvement from T1 to T2 (see Figure 4.1 and 4.2).

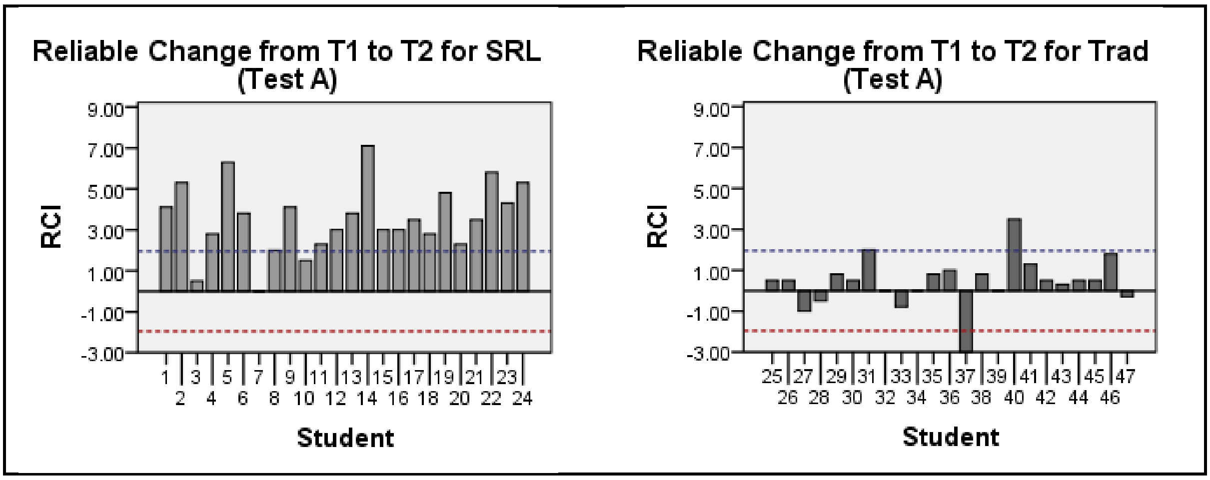

Figure 4.1. Reliable Change scores from T1 to T2 for the SRL and Trad groups on Test A.

The blue dotted line represents the threshold for reliable increase and the red dotted line represents the threshold for reliable decrease.

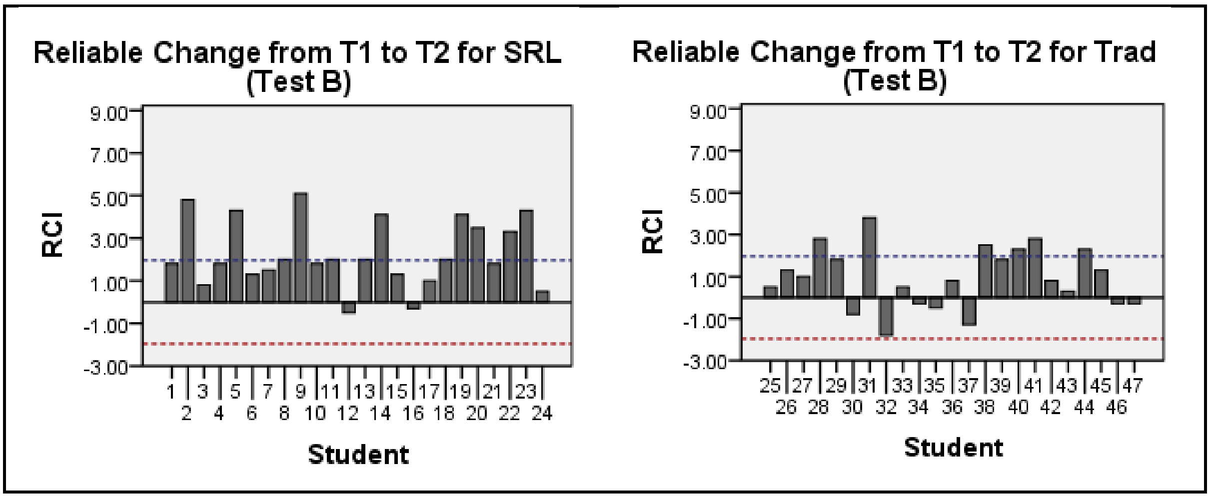

Figure 4.2. Reliable Change scores from T1 to T2 for the SRL and Trad groups on Test B.

The blue dotted line represents the threshold for reliable increase and the red dotted line represents the threshold for reliable decrease.

The SRL group completed daily sprints as part of their programme. This data was used to identify the number of SRL students who met the TFR by type of times table (see Table 4.6). For example, 100% of students in the SRL group met the TFR for 1, 2, and 10 times tables. This translates to having met the fluency goal for 24 facts, which is 46% of all facts, excluding turn around facts. In fact, over half of all students in the SRL group met the fluency goal for just over 80% of all the times table facts.

Table 4.6

Percentage of SRL Students Who Met TFR by Times Table Type

Times table	Total number of facts (% of all facts)	Number of students who met TFR (% of all students)
1, 2, 10	24 (46%)	24 (100%)
5	31 (60%)	21 (88%)
3	37 (71%)	17 (71%)
4	42 (81%)	13 (54%)
6, 9	47 (90%)	10 (42%)
7, 8	52 (100%)	9 (38%)

Over the course of the programme eight students in the SRL condition reached the multiplication TFR (45 correct answers per minute). These students then moved to fluency building with division facts. The sprint data showed that once students had reached the TFR for multiplication facts they reached the division TFR within seven days. Figure 4.3 shows the individual rate of progress for six students. Two students did not begin fluency building with division facts as they did not reach the multiplication TFR until the final two days of the programme.

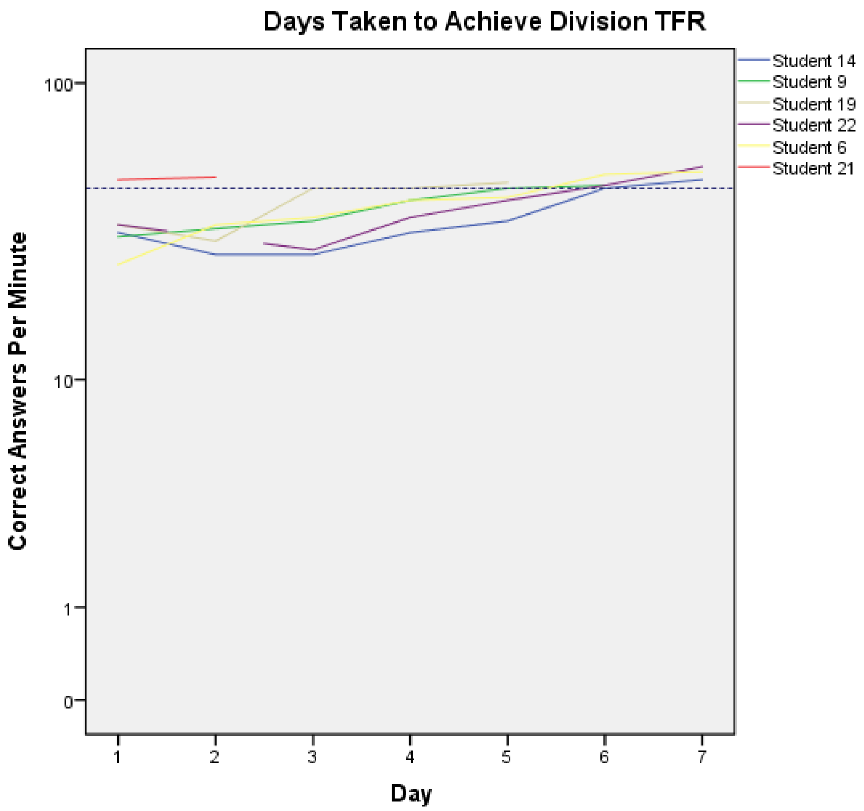

Figure 4.3. Days taken to achieve division TFR for six students in the SRL condition

Practice frequency and duration. Two separate one-way between-subjects ANCOVAs were run to investigate whether the SRL and Trad groups differed in their reported frequency and duration of practice at T2. The adjusted means for these variables are displayed in Table 4.7. In the first analysis, group was entered as the independent variable, frequency of practice at T1 was entered as the covariate, and practice frequency at T2 was entered as the dependent variable. Frequency of practice at T1 was not significantly related to frequency of practice at T2: $F(1,43) = 2.108$, $p = .154$. There was no significant difference between groups ($F(1,43) = .467$, $p = .498$) after adjusting for this covariate.

In the second analysis, group was entered as the independent variable, duration of practice at T1 was entered as the covariate, and practice duration at T2 was entered as the dependent variable. Duration of practice at T1 was significantly related to frequency of practice at T2: $F(1,44) = 10.174$, $p < .05$, $\eta^2 = .188$. However, there was no significant difference between groups ($F(1,44) = .875$, $p = .019$) after adjusting for this covariate.

Table 4.7

Adjusted Mean Practice Frequency and Duration at T2

	Practice Frequency				Practice Duration			
			95% Confidence Interval	95% Confidence Interval			95% Confidence Interval	95% Confidence Interval
Group	Mean (days)	Std. Error	Lower Bound	Upper Bound	Mean (mins)	Std. Error	Lower Bound	Upper Bound
SRL	4.376a	.346	3.678	5.075	13.288b	2.223	8.809	17.767
Trad	4.711a	.346	4.012	5.409	16.264b	2.270	11.689	20.840

a. Covariates appearing in the model are evaluated at the following values: Q(T1Days) = 4.02.

b. Covariates appearing in the model are evaluated at the following values: Q(T1Duration) = 14.79.

Type of practice. At T2, the type of mathematics practice students engaged in was again compared across the two groups, which can be seen in Table 4.8 below. A multi-dimensional chi-square test was conducted to investigate whether the SRL group and Trad groups differed significantly in the type of practice they reported engaging in at T2. Six cells had expected counts of less than five, so an exact significance test was selected for Pearson's chi-square. This analysis confirmed that there was a significant relationship between the conditions and the type of basic facts practice students engaged in outside of school hours: χ^2 $(4, N = 47) = 28.560$, exact $p < .05$. The main change observed at T2 was the number of SRL students who reported using flash cards as their most common form of basic facts practice.

At T2, 79.2% of SRL students reported using flash cards. This was substantially larger than the number of SRL students who reported using flash cards as their primary practice method at T1 (13.6%). It was also substantially larger than the number of students in the Trad group who reported using flash cards as their primary practice method at T2 (4.3%). The preferred method of practice for the Trad students at T2 remained unchanged from T1, with 65.2% of Trad students selecting mathematics games as their preferred method of practice.

Table 4.8

Type of Practice by Condition at T2

Group		Maths games	Testing	Flash cards	Activity sheets	Other	Total
SRL	Count	4	0	19	0	1	24
	% within Group	16.7%	0.0%	79.2%	0.0%	4.2%	100.0%
Trad	Count	15	3	1	3	1	23
	% within Group	65.2%	13.0%	4.3%	13.0%	4.3%	100.0%

Use of self-control strategies. Students in the SRL group recorded how confident they felt answering the basic facts questions they were working on, at the end of every practice session (see Table 4.9). At this time, they also recorded how helpful they found the setting selection, setting modification, and attention deployment strategies (see Table 4.10). The frequencies in Tables 4.9 and 4.10 were calculated by summing all student responses across all the SRL participants. For example, students in the SRL group reported their level of confidence on 260 occasions over the course of the study. On 99 (38%) of these occasions students were extremely confident they could instantly answer the facts they had learned in that session.

The analysis, depicted in Table 4.9, shows that after 72% of all the SRL group's home-practice sessions, students felt either 'very' or 'extremely' confident answering the basic facts they had been practising. These findings suggest that students believed the practice sessions they completed helped them to become more fluent with their multiplication fact recall. Table 4.10 shows that students did choose to use the self-control strategies at home. Environmental strategies were the most popular self-control strategies that students chose to employ. Of all the at-home practice sessions, *setting selection* was employed during

92% of all sessions and *setting modification* was employed on 88% of all occasions. Whilst *attention deployment*, a cognitive strategy, was still frequently employed (74% of all occasions), it was less commonly used than the two environmental strategies. The students also reported finding the environmental self-control strategies more helpful than the cognitive strategy. On 72% of practice sessions the SRL students considered the use of *attention deployment* to be either 'somewhat' or 'very' helpful. In contrast, they rated *setting selection* 'somewhat' or 'very' helpful on 91% of sessions and *setting modification* 'somewhat' or 'very' helpful on 85% of practice sessions. The analysis suggests that SRL students found the environmental strategies more useful than the cognitive strategy. This may have influenced their decision to use these strategies more frequently than *attention deployment.*

Table 4.9

Reported Confidence (SRL Group) with Basic Facts During Practice Sessions Outside of School Hours

	Not at all	A little	Fairly	Very	Extremely	
Confidence	2	9	62	88	99	260
	1%	3%	24%	34%	38%	100%

Table 4.10

SRL Group's Reported Use of Self-Control Strategies During Sessions Outside of School Hours

		Did not use strategy	Used strategy but not helpful	Strategy was somewhat helpful	Strategy was very helpful	Strategy was extremely helpful	Total
Setting Selection	n	20	2	99	138	1	259
	%	8%	1%	38%	53%	0%	100%
Setting	n	32	7	91	129	1	259
Modification	%	12%	3%	35%	50%	0%	100%
Attention	n	67	4	91	96	0	258
Deployment	%	26%	2%	35%	37%	0%	100%

Self-efficacy. Self-efficacy data was collected at T1 and T2, for the SRL and Trad groups. Analysis of this data found that it was not normally distributed. A number of data transformations were tested, however no transformation normalised the data collected for both groups at T1 and T2. On this basis, two separate approaches were taken to analyse whether the SRL and Trad groups differed in their self-efficacy ratings at T2. Initially an ANCOVA was conducted. Group was entered as the independent variable, self-efficacy at T1 was entered as the covariate, and self-efficacy at T2 was entered as the dependent variable. Self-efficacy at T1 was significantly related to self-efficacy at T2 $F(2,44) = 96.974$, $p < .05$, $\eta^2 = .688$, however there was no significant difference between groups after adjusting for this covariate $F(2,44) = .011$, $p = .918$.

In addition to this analysis, two nonparametric analyses were conducted. A Mann-Whitney Test was conducted to investigate whether the SRL and Trad groups differed in their self-efficacy ratings at T2. This analysis confirmed that there was no significant difference between the two groups ($U = 259.000$, $N_1 = 24$, $N_2 = 23$, $p = .717$, two-tailed). In order to explore whether the SRL or Trad groups' self-efficacy ratings changed from T1 to T2 two Wilcoxon Tests were conducted. These analyses revealed that neither the SRL ($z = 1.750$, N – Ties = 23, $p = .080$, two-tailed) nor the Trad groups' ($z = 1.271$, N – Ties = 21, $p = .204$, two-tailed) self-efficacy ratings varied significantly over time.

Two correlational analyses were undertaken to investigate the relationship between self-efficacy and performance. These analyses revealed that there was a significant positive relationship between self-efficacy and basic facts performance for the SRL group at T1 ($r_s = .722$, $N = 24$, $p < .05$) and T2 ($r_s = .657$, $N = 24$, $p < .05$). A significant positive relationship between self-efficacy and basic facts performance was also observed for the Trad group at T1 ($r_s = .418$, $N = 23$, $p < .05$) and T2 ($r_s = .754$, $N = 21$, $p < .05$). These results show that there was a moderate to strong relationship between self-efficacy and basic facts performance across the two time periods for both conditions.

Enjoyment. The T2 questionnaire asked students in the SRL and Trad groups to rate how enjoyable they found their respective basic facts programmes. Analysis of this question revealed that 83.3% of SRL students rated the SRL programme as being either very enjoyable or extremely enjoyable. This is contrasted by the Trad group where only 56.5% of students rated their programme as very enjoyable or extremely enjoyable. In fact, 21.7% of students in the Trad group selected one of the lowest two categories to depict their level of enjoyment, compared to only 8.3% of students in the SRL group (see table 4.11). A Mann-Whitney U Test confirmed that students' enjoyment ratings differed significantly by condition (U = 168.500, N_1 = 24, N_2 = 23, p < .05, two-tailed).

Table 4.11

Programme Enjoyment by Condition

			Enjoyment					
			1	2	3	4	5	Total
Group	SRL	Count	0	2	2	9	11	24
		% within Group	0.0%	8.3%	8.3%	37.5%	45.8%	100.0%
	Trad	Count	2	3	5	9	4	23
		% within Group	8.7%	13.0%	21.7%	39.1%	17.4%	100.0%

Note. 1 = not enjoyable, 2 = a little bit enjoyable, 3 = fairly enjoyable, 4 = very enjoyable, 5 = extremely enjoyable.

Helpfulness. The T2 questionnaire also asked students in the SRL and Trad groups to rate how helpful they found their basic facts programme. A substantial difference in perceived helpfulness by condition was observed. 100% of SRL students rated their programme as either very helpful or extremely helpful. In contrast, only 26.1% of students in the Trad group perceived their programme to be either very helpful or extremely helpful (see table 4.12). In fact, 19.2% of students in the Trad group selected one of the two lowest categories: a little bit helpful or not helpful. A Mann-Whitney Test confirmed that students' enjoyment ratings differed significantly by condition (U = 66.000, N_1 = 24, N_2 = 23, p < .05, two-tailed).

Table 4.12

Programme Helpfulness by Condition

			Helpfulness					
			1	2	3	4	5	Total
Group	SRL	Count	0	0	0	6	18	24
		% within Group	0.0%	0.0%	0.0%	25.0%	75.0%	100.0%
	Trad	Count	2	7	8	2	4	23
		% within Group	8.7%	30.4%	34.8%	8.7%	17.4%	100.0%

Note. 1 = not helpful, 2 = a little bit helpful, 3 = fairly helpful, 4 = very helpful, 5 = extremely helpful.

Celeration chart analyses. The following section examines the celeration charts from two low, average, and high ability students who were assigned to the SRL group (this data was not collected for those in the Trad group). In this instance, students were classed as low, average, or high ability students, based on the PAT data provided by the school and the students' Test A performance at T1. These particular students were chosen as their celeration charts were representative of the progress made by the low, average, and high ability students within the SRL programme.

Prior to the intervention a celeration goal of ×1.6 was set. An acceptable celeration rate is one of the seven change criteria, described by Kubina and Yurich (2012), which were adhered to in this study. Kubina and Yurich (2012) define 'robust' growth celerations as a celeration rate between ×1.4 and ×1.8. Variability in performance was measured using bounce rates. Bounce rates describe the variation in data points from the celeration rate. A bounce rate between ×1.0-×3.0 is considered smooth and consistent. Smooth and consistent progress is a feature of efficient learning.

The celeration charts and celeration chart analysis for two low ability students are shown in Figure 4.4 and Table 4.13 respectively. Both student 10 and student 3 achieved the lower TFR (40) for their one, ten and two times tables, within eleven days. The celeration rates for student 10 and student 3, during their respective phases, represented ‘robust’ growth. They achieved this with bounce rates of ×3 or less. Student three was able to increase their rate of progress when additional basic facts were added to their programme. No celeration and bounce rate could be calculated for student ten in phase two, as at least five data points are required for these calculations.

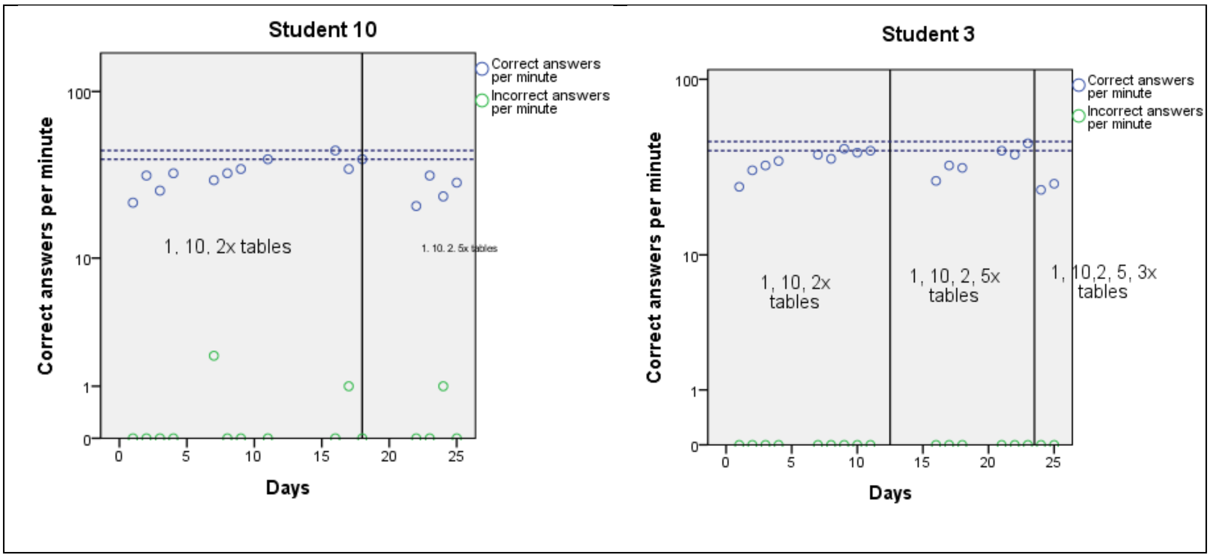

Figure 4.4. Celeration chart for low ability students. The upper dotted blue line represents a TFR of 45 and the lower dotted line represents a TFR of 40. These charts use a logarithmic y-axis. A logarithmic y-axis is one of the key features of a celeration chart.

Table 4.13

Celeration Analysis (Low Ability Students)

Student		Phase 1	Phase 2
Student 10	Celeration rate	×1.6 (11 days)	IDP
	Bounce	×2 (11 days)	IDP
Student 3	Celeration rate	×1.5(11 days)	×1.7 (8 days)
	Bounce	×3 (11 days)	×3 (11 days)

Note: IDP = Insufficient data points.

Figure 4.5 displays the celeration charts for two average ability students. Both celeration charts show a phase where sufficient progress was not being made. In phase 1 for student 24, progress had plateaued (celeration rate = ×1.2 [8 days] and bounce rate = ×2 [8 days]). In phase 2 for student 17 the CAPM was decelerating. This data necessitated a programme change. For both students, this involved reducing the number of new facts. Once the students had achieved the TFR, with the reduced number of facts, additional facts were added to their packs (see text box). Students were then able to rapidly meet TFR in all successive phases. As students accelerated to the TFR within 5 data points, celeration and bounce rates for each phase could not be calculated.

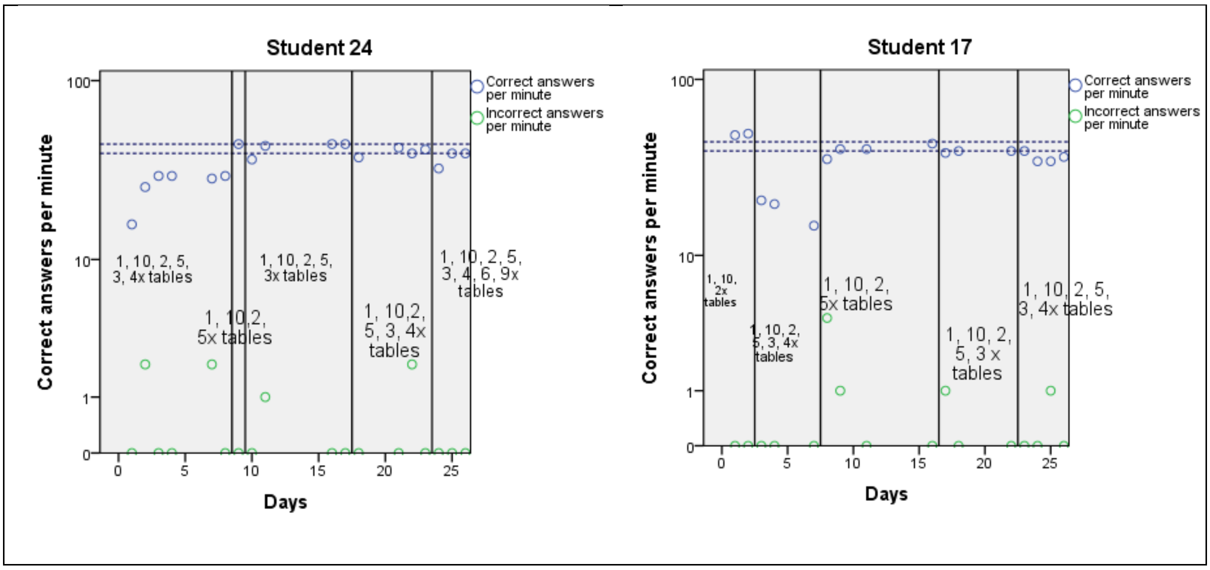

Figure 4.5. Celeration chart for average ability students. The upper dotted blue line represents a TFR of 45 and the lower dotted line represents a TFR of 40. These charts use a logarithmic y-axis. A logarithmic y-axis is one of the key features of a celeration chart.

Figure 4.6 and table 4.14 displays the celeration charts and celeration chart analyses for two high ability students. Student 9 and student 19 made 'robust' growth during the first phase reaching TFR (45) within 11 days. Both students then progressed at steeper celeration rates towards their division TFR. In all phases students maintained a bounce rate that was smooth and consistent.

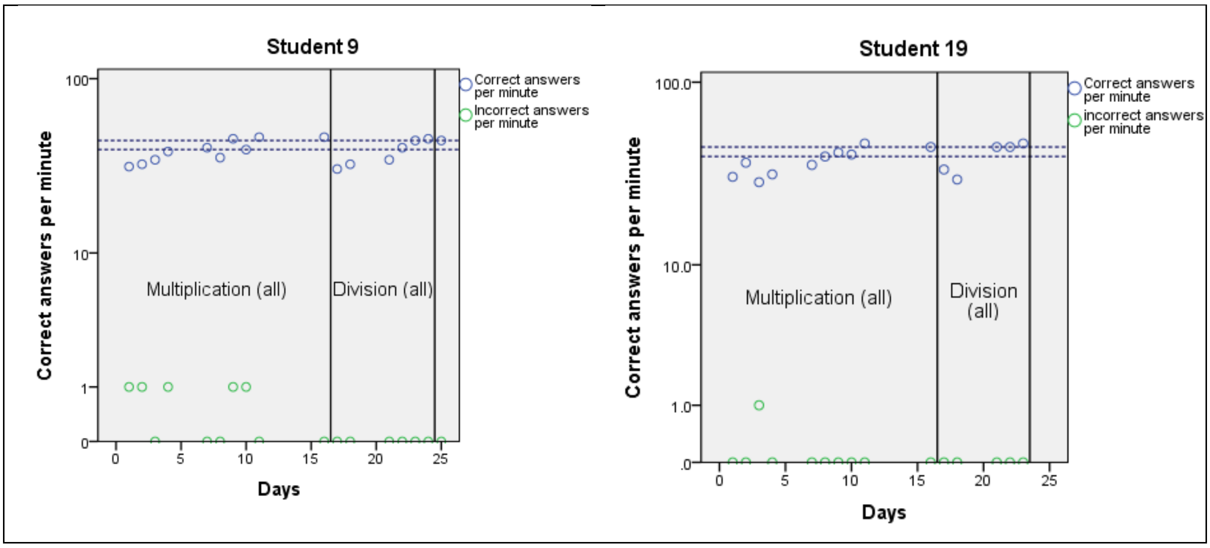

Figure 4.6. Celeration chart for high ability students. The upper dotted blue line represents a TFR of 45 and the lower dotted line represents a TFR of 40. These charts use a logarithmic y-axis. A logarithmic y-axis is one of the key features of a celeration chart.

Table 4.14

Celeration Analysis (High Ability Students)

		Phase 1	Phase 2
Student 9	Celeration rate	×1.35 (11 days)	×1.5 (9 days)
	Bounce	×3 (11 days)	×2 (9 days)
Student 19	Celeration rate	×1.6 (11 days)	×1.8 (7 days)
	Bounce	×2 (11 days)	×2 (7 days)

Social validity. The teacher in the SRL class completed the social validity questionnaire at T2. Through her responses, the teacher indicated that she thought the programme was ‘extremely helpful’ for improving students’ basic facts. She identified the flash cards, self-control strategies, diaries, and graphs as the most beneficial aspects of the programme. The teacher indicated that she would feel ‘very confident’ implementing this programme again, without researcher support, and believed she was ‘very likely’ to implement this programme again in the future. She also indicated that she was interested in applying both the self-control strategies and graphing to other curriculum areas. The teacher noted that the students involved in the SRL programme developed a “very positive attitude to learning their basic facts". She also observed that the students enjoyed the "dialogue and competitiveness". The teacher was asked if there were any aspects of the programme that made the programme challenging to implement. She identified allocating sufficient time, within a busy school programme, as the greatest challenge. Whilst programme feedback was not sought from parents, one question on the teacher validity form did inquire into whether the teacher had received any feedback from parents regarding the programme. The teacher confirmed that she had not received any feedback. In summary, the teacher of the SRL programme had a positive perception of the programme and the effect it had on student learning. She is likely to use the programme again and elements of the programme in other curriculum areas.

Fidelity checks. Ten fidelity checks were completed during the programme. Seven checks were undertaken in the SRL room and three were undertaken in the Trad room. The SRL room fidelity checks indicated that the programme was being implemented with fidelity. Where appropriate, feedback was provided to the teacher to enhance the fidelity with which the programme was implemented. The Trad room fidelity checks confirmed the teacher was teaching the agreed upon basic facts activities and that students were adequately engaged in the activities. The fidelity checks confirmed that both the SRL and Trad group instruction was reliably implemented and that both teachers were able to engage students in their respective learning tasks.

4.3 Differences between conditions at time period 3 (T3)

Nomothetic analysis for basic facts. Data from the 1-minute multiplication probes, administered at T3, was used to explore whether the SRL group's gains in multiplication fluency were maintained five weeks after the end of the programme. A one-way between-subjects analysis of covariance (ANCOVA) was conducted to investigate this question.

Group was entered as the independent variable, Test A performance at T1 was entered as the covariate, and Test A performance at T3 was entered as the dependent variable. The analysis confirmed that Test A performance at T1 was significantly related to Test A performance at T3: $F(1,42) = 84.34$, $p < .05$, partial $\eta^2 = .67$. After adjusting for this covariate, the between-subjects factor group showed a statistically significant difference between the two groups: $F(1,42) = 29.53$, $p < .05$, partial $\eta^2 = .41$. The adjusted mean score for the SRL group was 32.6 compared to 21.7 for the Trad group (see table 4.15). The within group and between group effect sizes were calculated using Cohen's *d*. The effect size for the SRL group from T1 to T3 ($d = 1.13$) and the effect size between the SRL group and the Trad group ($d = .97$) at T3 were both found to exceed Cohen's (1988) convention for a large effect size. In contrast, the effect size for the Trad group from T1 to T3 was very small ($d = .16$). These results confirm that the students in the SRL group showed much greater improvement from T1 to T3, even after controlling for T1 performance. They also confirm that the progress made by students in the SRL group, during the SRL programme, was largely maintained five weeks after the end of the programme.

Table 4.15

One-Way Between-Subjects ANCOVA for Test A (Means)

			95% Confidence Interval	
Group	Mean CAPM	Std. Error	Lower Bound	Upper Bound
SRL	32.609[a]	1.366	29.853	35.365
Trad	21.733[a]	1.460	18.786	24.679

a. Covariates appearing in the model are evaluated at the following values: T1(Test A) = 20.33.

A second one-way between-subjects analysis of covariance (ANCOVA) was conducted using the Test B data. Group was again entered as the independent variable, Test B performance at T1 was entered as the covariate, and Test B performance at T3 was entered as the dependent variable. Test B performance at T1 was significantly related to Test B performance at T3: $F(1,42) = 96.581$, $p < .05$, partial $\eta^2 = .70$. After adjusting for this covariate, the between-subjects factor group showed a statistically significant difference between the two groups: $F(1,42) = 14.96$, $p < .05$, partial $\eta^2 = .26$. The adjusted mean score for the SRL group was 29.98 compared to 23.45 for the Trad group (see table 4.16). The within group and between group effect sizes were calculated using Cohen's *d*. The effect size for the SRL group, from T1 to T3 ($d = 91$), exceeded Cohen's (1988) convention for a large effect size. However, the effect size for the Trad group from T1 to T3 on Test B was small ($d = .27$). The effect size between the SRL group and the Trad group ($d = .77$) at T3, fell just short of Cohen's convention for a large effect size. These results again confirm that the SRL group showed much greater improvement in CAPM, for Test B, from T1 to T3, even after controlling for T1 performance. They also confirm that the progress made, during the SRL programme, was maintained five weeks after the end of the programme.

Table 4.16

One-Way Between-Subjects ANCOVA for Test B (Means)

			95% Confidence Interval	
Group	Mean CAPM	Std. Error	Lower Bound	Upper Bound
SRL	29.980[a]	1.153	27.653	32.307
Trad	23.452[a]	1.233	20.964	25.939

a. Covariates appearing in the model are evaluated at the following values: T1(Test B) = 20.82.

Idiographic analysis for basic facts (Test A & B) at T3. Idiographic analysis was again undertaken for Test A and B at T3. Calculation of the reliable change index (RCI) indicated that 17 (71%) students in the SRL group showed a reliable improvement from T1 to T3 on Test A and 13 (54%) showed a reliable improvement on Test B. Of the 21 students assessed in the Trad group, three students (14%) showed a reliable improvement on Test A and three (14%) students showed a reliable improvement of Test B. This analysis confirms that substantially more SRL students made significant progress than students in the Trad condition. These results are similar to those obtained at T2. Whilst there were slightly less students who made a significant improvement on Test A at T3 (71%) compared to Test A at T2 (87.5%) the results confirm that the progress made by T2 was largely maintained over time. This is also evidenced by the Test B results where there was a slight increase in the number of SRL students who recorded a significant improvement from T2 (50%) to T3 (54%). In contrast, the results show that very few (three) students appeared to benefit significantly from Trad instruction (see Figure 4.7 and 4.8).

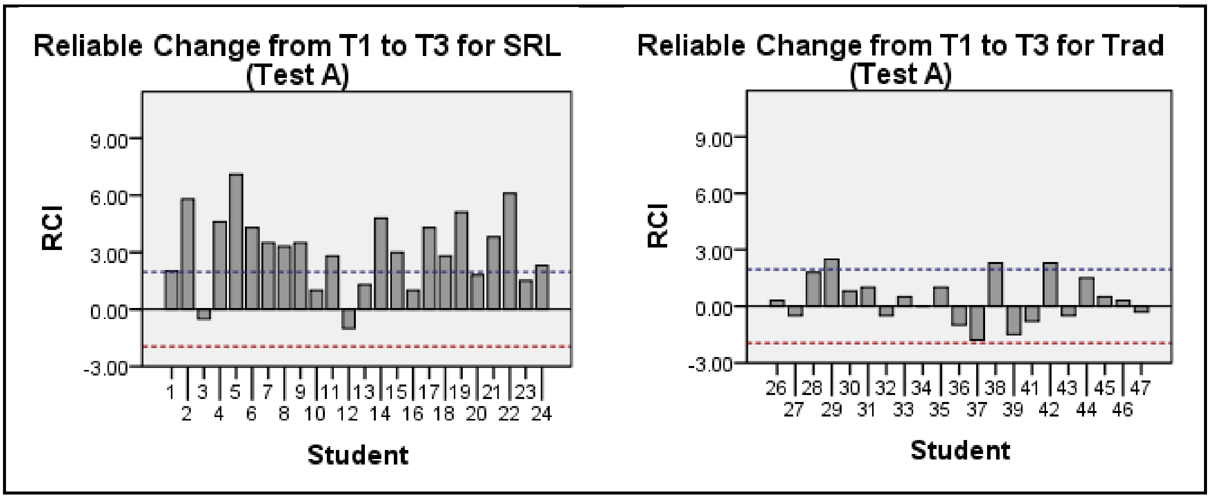

Figure 4.7. Reliable Change scores from T1 to T3 for the SRL and Trad groups on Test A.

The blue dotted line represents the threshold for reliable increase and the red dotted line represents the threshold for reliable decrease.

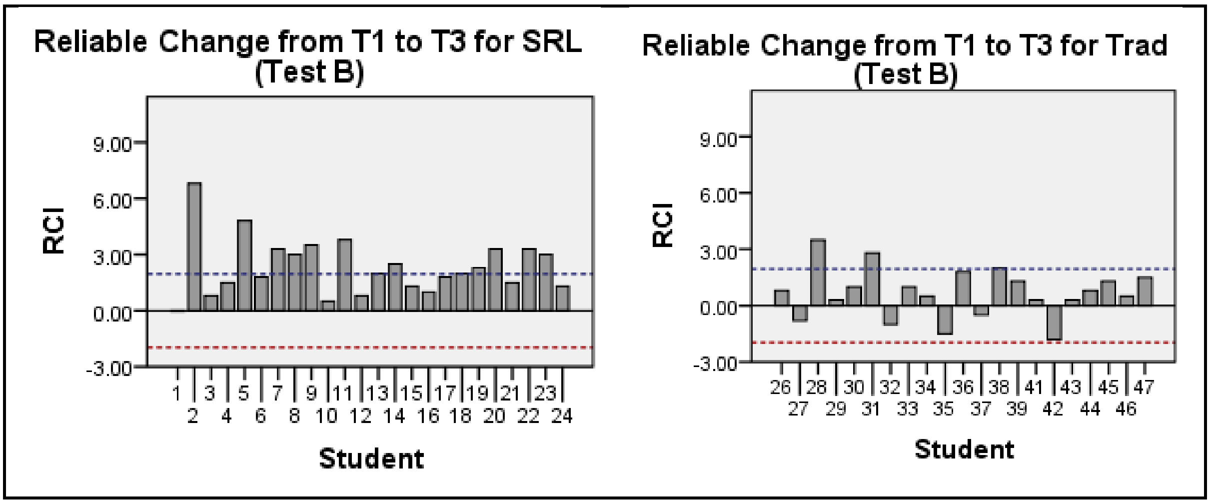

Figure 4.8. Reliable Change scores from T1 to T3 for the SRL and Trad groups on Test B.

The blue dotted line represents the threshold for reliable increase and the red dotted line represents the threshold for reliable decrease.

Chapter 5: Discussion

This study used an experimental design to investigate the effects of a SRL basic facts fluency programme. Specifically, it set out to answer two questions: (a) to what extent did the programme lead to improved multiplication fact performance, and (b) to what extent did students modify their practice behaviour outside of school, as a result of the programme. The following section discusses the findings in relation to these two questions.

5.1 Multiplication fact performance

The results from this study support the contention, expressed in hypothesis one, that the SRL group would make significant basic facts progress over the course of the intervention. The analysis confirmed that not only did the students in the SRL group make significant progress over the course of the programme, they also made significantly more progress than their peers in the Trad group. In fact, the Trad group made no significant progress over the course of the study.

These results can also be considered in relation to the PT and basic facts studies that were reviewed in section two. As previously noted, not all basic facts studies focussed on multiplication facts, or presented their results in a way that enabled comparison. Despite this fact, some meaningful comparisons can be made. In this study, the SRL group recorded a mean of 34 CAPM for Test A, at the end of intervention assessment (T2). This mean was comparable to the highest end of intervention mean CAPM reported in the reviewed studies (Knowles, 2010 (34 CAPM); McTiernan et al., 2016 (33 CAPM); Wong & Evans, 2007 (37 CAPM). This programme can also be evaluated in terms of its effect size. From T1 to T2 the SRL fluency programme had a large effect ($d = 1.42$) on students' basic facts performance. This exceeds the effect sizes obtained by both Gallagher (2006, d = 1.16) and Knowles (2010, d = 1.1), who obtained two of the largest effect sizes in the reviewed studies. In fact, of studies which were similar in design, only McTiernan et al. (2016, *d* = 1.91) and Woodward (2006, d = 1.4) reported larger effect sizes. The larger effect sizes observed in these studies may however be a product of their design. McTiernan et al. (2016) only included students who were struggling mathematicians. This may have resulted in a larger effect size as these students had more room for growth. Whilst Woodward (2006) did include typically developing students, he did not include all basic facts in one measure. Again, this may have contributed to the larger effect sizes observed here.

The effect sizes calculated in this study can also be considered in relation to the average effect size obtained in SRL studies. According to Dignath et al. (2008), SRL programmes have a mean effect of 0.97 on mathematics performance. The SRL group's improvement in performance from both T1 to T2 and T1 to T3, on Test A, exceeded this effect size. Hattie (2012) proposes a lower threshold when evaluating programme effectiveness. He suggests, that to be considered effective a programme should exceed an effect size of 0.4. This may be a more appropriate threshold to consider when determining the practical importance of these findings. Clearly, the effect sizes obtained in this study far exceed this threshold. In fact, compared to the 150 influences on achievement rank ordered by Hattie (2012), the effect sizes obtained in this study are comparable to the effect sizes obtained by the top two influences of achievement on this list. Whilst Cohen (1988) classifies an effect size of 0.8 as large, this effect size also has specific implications when evaluating the efficacy of a programme within an educational context. It has been suggested (Hudson, 2011) that an effect size of 0.5 to 0.8 is of sufficient magnitude to enable poor performing students to catch up to their peers. Teachers must consider a number of factors when determining whether a programme is suitable for implementation within the classroom. One of these considerations is a programme's effectiveness. In summary, the effect sizes obtained in this study show that this programme had a large effect on student achievement and that the magnitude of this effect may be sufficient to close the achievement gap between poorly achieving and typically achieving students. This is an important issue for future research to address. The results also show that this programme compares favourably to other basic facts programmes and the average effect size obtained in SRL studies.

As well as investigating the effect of the programme at the group level, this study also investigated what effect the SRL programme had on basic facts performance at an individual level. One criticism of studies that solely compare group means is that between-persons data is used to make an inference of a within-individual effect. A second criticism is that a group effect is used to infer a causal effect within an individual (Rorer & Widiger, 1983). To overcome these criticisms, data obtained at T1, T2, and T3 was used to calculate the RCI. This data again confirmed the efficacy of the SRL programme, as nearly 90% of SRL students made a reliable improvement on Test A from T1 to T2. In contrast, less than 10% of students in the Trad group made a reliable improvement during this time. The results from this study also compare favourably to the results reported by Strømgren et al. (2014), which was the only study to calculate the RCI. Strømgren et al. (2014) found that 37% of students made a reliable increase in performance over the course of their study. These findings again emphasise the efficacy of the programme employed in this study. Not only did a far greater proportion of students make a reliable increase in performance, they also did so over a period of only four weeks. In contrast, the Strømgren et al. (2014) programme ran for eight weeks.

This finding is particularly important, as the SRL programme was designed as a tier one programme. A tier one programme should result in adequate progress for at least 80% of all students (Johnson & Street, 2013). This finding supports the utility of the SRL programme for use within tier one of a RTI framework. Effective tier one programmes are an essential component of the RTI framework. Without effective tier one programmes students may be over identified for more intensive support, which puts pressure on resources, or under identified, which reduces the preventative effect of the model (Tunmer & Greaney, 2010).

Individual data was also monitored on a daily basis through the use of celeration charts. The importance of this level of analysis is evidenced by the discrepancy between three students' RCI scores and their celeration chart data. According to the RCI data, students 3, 7, and 10 did not make a reliable improvement from T1 to T2 on Test A. However, their celeration data (see figure 4.4 and table 4.13 for student 3 and 10's celeration data) actually showed 'robust' growth throughout the intervention. 'Robust' growth is defined as celeration rates of between ×1.4-×1.8, which represents weekly growth of 41-79% (Kubina & Yurich, 2012). It is likely that the 1-minute multiplication probes, which were composed of all the basic facts, did not capture the progress made by these students. Whilst these students made 'robust' growth throughout the programme, they only met the TFR for the one, two, and ten times tables. If analysis was conducted only at the RCI level it may be incorrectly assumed that these students were not responding to the programme. Celeration charts provided valuable information on how students of all abilities responded to the intervention. Unlike the PT studies reviewed here, this study included students of all abilities. This meant it was possible to quantify what effect this programme had on students who were already relatively fluent with most basic facts. In fact, eight students (33%) were able to achieve the multiplication facts TFR before the end of the intervention. Six of these students then transitioned to fluency building with division facts. These students were all able to reach the TFR for division facts within seven days. This finding highlights the importance of implementing the SRL fluency programme at the tier one level. Whilst it is likely that these six students would have obtained fluency with basic facts through normal class instruction, this programme facilitated rapid progress towards the TFR. In a typical classroom programme this would then free up additional instruction time for more complex mathematics strategies.

This study also investigated whether fluency with some or all of the 52 multiplication facts generalised to their respective turn-around facts. Analysis confirmed that whilst students made slightly less progress with the turn-around facts, presented in Test B, they still made substantial growth over the course of the programme. According to Cohen's (1988) criteria, the SRL group's growth from T1 to T2 could be described as a 'large' effect. Whilst the average CAPM for Test B at T2 (30) was relatively similar to the CAPM for Test A at T2 (34), the RCI data indicated that the students were less fluent with the turn-around facts than with the facts in their original presentation configuration. The RCI data showed that 50% of the SRL students made a reliable increase in performance from T1 to T2 on Test B. In contrast, nearly 90% of SRL students made a reliable increase in performance on Test A during the same time period. It should be noted that whilst the SRL students made less progress with the Test B facts than the Test A facts, they still made substantially more progress with the Test B facts than their peers in the Trad group. It is possible that students' progress with the turn-around facts was mediated by their understanding of the commutative property of multiplication. Unfortunately, this hypothesis could not be investigated due to inconsistencies in the screening data that was obtained from teachers.

The results confirmed that the progress made by students in the SRL group, during the programme, was generally maintained through to T3. A small reduction in Test A performance from T2 (34 CAPM) to T3 (33 CAPM) was observed, however no decrement in performance was observed for the Test B data from T2 (30 CAMP) to T3 (30 CAPM). Using Cohen's (1988) criteria, the SRL group's improvement on Test A and Test B, from T1 to T3, is considered 'large'. Analysis of the RCI data confirmed 71% of SRL students made a reliable improvement from T1 to T3 on Test A. This is slightly less than the 90% of SRL students who made a reliable improvement from T1 to T2 on Test A. Conversely, a slightly higher percentage of students demonstrated a reliable improvement on Test B at T3 (54%) than at T2 (50%).

Maintaining improvements over time is one of the features associated with fluent performance (Johnson & Street, 2013). Within a RTI framework, only programmes which result in learning that is maintained over time should be employed at the tier one level (Johnson & Street, 2013). Despite the importance of children being able to perform a skill in the future, without additional practice, only a small number of the reviewed studies included maintenance assessments. However, the few studies that did report maintenance data showed a similar pattern to that observed in this study. Both Strømgren et al. (2014) and Wong and Evans (2007) reported maintenance data, recorded four weeks after the end of their respective programmes. Strømgren et al. (2014) expressed this data using the RCI, finding that 42% of the students in their study made a reliable improvement from their T1 to T3 assessment. Inspection of the data showed that this percentage represented the same seven students who made a reliable improvement at T2, plus one additional student. The maintenance scores in Wong and Evans (2007) were again expressed as average CAPM. Like our own data, only a small drop from T2 (37 CAPM) to T3 (35 CAPM) was observed. A similar finding was also observed in the study by Woodward (2006), who found little change between the strategy based student scores on either the *common facts* (T2 = 18.79 CAPM, T3 = 18.07 CAPM) or *hard facts* (T2 = 12.88 CAPM, T3 = 12.62 CAPM). This pattern was also observed in the timed drill practice condition for both *common facts* (T2 = 17.09 CAPM, T3 = 16.18 CAPM) and *hard facts* (T2 = 12.73 CAPM, T3 = 12.31 CAPM). However, in contrast to this study, the maintenance measure was administered after only ten days.

This study was able to effect change within the relatively short time period of four weeks. In contrast, the reviewed PT programmes ran for between 8 and 36 weeks and the average basic facts programme ran for 8 weeks. The efficiency of a programme plays a key role in determining whether a programme can be successfully implemented within classroom practice (Carson, Gillon, & Boustead, 2013). Teachers often identify limited instruction time as a barrier to programme implementation (Codding, Hilt-Panahon, et al., 2009). It is therefore important that a programme delivers ‘robust’ growth within relatively short time frames and that this growth is observable for both teachers and students. This study used celeration charts to provide a visual representation of learning for teachers and students. It is possible that by making the learning process more visible teachers may feel less reticent about allocating class time to effective tier one interventions. The following observation supports this contention. This study obtained ethical consent to run for four weeks. The data obtained during this period suggested that, as the students continued to make ‘robust’ growth throughout the study, the programme should have been continued for longer than four weeks. After observing the fluency gains made by the SRL group, the participating teachers decided to continue with the SRL programme and extend the SRL programme to other classes within the school. This finding is of particular importance. On the social validity questionnaire, the teacher in charge of the SRL group identified allocating sufficient time within a busy school programme as the greatest challenge to programme implementation. This suggests that whilst limited instructional time is indeed a barrier to programme implementation, teachers are prepared to allocate time to evidence based tier one interventions when they can observe students making ‘robust’ and enduring progress.

In summary, on the basis of the data obtained, the first hypothesis was supported. The SRL students made significant and meaningful progress over the course of the programme. The programme was beneficial for low, average, and high ability students and the gains in fluency were maintained five weeks after the end of the programme. The SRL students’ progress is contrasted with their peers in the Trad group, whose mean score did not increase during this time. The evidence also suggests that developing fluency with some, or all, of the 52 multiplication facts generalised to their respective turn-around facts. Analysis at a group and individual level confirmed the SRL students made substantially more progress with the turn-around facts than the students in the Trad group. However, the percentage of students in the SRL group who showed a reliable improvement with turn-around facts was slightly less than the percentage of SRL students who showed a reliable increase in performance with the multiplication facts in their original configuration. Future research should investigate whether students' knowledge of commutativity mediated this effect.

5.2 Practice behaviour outside of school hours

The second hypothesis predicted that students in the SRL group would practise their basic facts more frequently, and for longer durations, than they did prior to the programme and in comparison to their peers in the Trad group. The second part of this hypothesis predicted that, unlike students in the Trad group, SRL students would choose to engage in practice with flash cards over other types of practice. The data obtained during this study confirmed that whilst students in the SRL group did choose to engage in practice with flash cards over other types of practice, they did not practice more frequently, or for longer durations, than their peers in the Trad condition.

Given how enjoyable and helpful students in the SRL group rated the programme, it seems somewhat counterintuitive that these students did not then choose to engage in any additional practice outside of school hours. One possible explanation for this is that students did not find the programme as enjoyable as the myriad of other activities they could engage in, outside of school hours. Research by Duckworth et al. (2011) provides support for this explanation. This study investigated what role deliberate practice played in determining performance in the Scripps National Spelling Bee. Whilst the participants in this study considered deliberate practice to be more effective than other types of preparation, they also found deliberate practice more effortful and less enjoyable than other types of practice. Ericsson et al. (1993) also observed that deliberate practice is more effortful than other types of practice. In addition to a lack of resources and motivation, Ericsson et al. (1993) identified 'effort' as one of three factors that inhibit an individual's engagement in deliberate practice. Whilst students did not choose to practice more frequently, or for longer durations, they did alter the type of practice they engaged in. Prior to the programme, the SRL group's preferred method of practice was engaging in mathematics games (45.5%), with only a small percentage (13.6%) preferring to use flash cards. However, at T2 nearly 80% of SRL students selected practice with flash cards as their preferred method of basic facts practice. In contrast, the Trad group's preferred method of basic facts practice at T2 remained mathematics games (65.2%). This finding is of particular interest, as quality of practice is a better predictor of performance than quantity of practice in some studies (Plant et al., 2005; Rosario et al., 2013).

The SRL programme was specifically designed to overcome barriers associated with engaging in deliberate practice. In order to overcome limited time and resources, students were encouraged to take their SRL packs home every day. This ensured students always had the resources they required to continue practicing outside of school hours. In addition, the programme was designed so that students could complete the programme phases without adult support or supervision. Because self-control is essential to independent performance (Duckworth et al., 2014; Schunk & Zimmerman, 2007) students were taught how to use, and practised using, the first three strategies from the process model of self-control. The programme also incorporated a number of features designed to increase and maintain student motivation. Examples of these included the use of student self-graphing (Bryant et al., 2015; Schutte et al., 2015) and goal setting (Duckworth, Kirby, Gollwitzer, & Oettingen, 2013;

Gross et al., 2014) procedures. Paradoxically, the use of self-graphing procedures may also explain why SRL students did not choose to engage in additional practice outside of school hours. The celeration charts provided a visual representation of a student's learning. Through these charts, students were able to monitor their progress towards the TFR. They were also able to compare their rate of progress to the celeration line that represented 'robust' growth. It is possible that students did not choose to engage in additional practice outside of school hours as almost all students were able to maintain 'robust' progress throughout the programme. Thus, students may have considered additional practice outside of school hours unnecessary, as they were satisfied with their growth through in-class practice alone.

Duckworth et al. (2014) note that there is little research on situation selection strategies. Whilst this study did not attempt to specifically investigate situation selection strategies, it does go some way to addressing two of the questions posed by Duckworth et al. (2014). Specifically, "What is the best way to instruct children in self-control strategies?" and "Should instruction be didactic and direct, or should children simply be provided with models to emulate?" (p212). It is not possible to conclude whether the strategies employed in this study were more effective than other strategies, but this study does confirm that the strategies employed in this programme were effective and did generalise to use outside the classroom. Initially, direct instruction was used to introduce the first three components of the process model for the development of self-control. Schunk and Zimmerman's (2007) social-cognitive model for the development of self-regulation was then used to transition through the stages *observation* to *emulation* to *self-control* to *self-regulation*. The results confirmed that students did engage in these strategies at home and they did find them helpful. In addition, the results also confirmed the proposition, expressed by Duckworth et al. (2014), that students found altering their physical or social setting more helpful than selectively deploying their attention.

In summary, of the three parts of hypothesis two that investigated how the SRL programme altered students' basic facts practice behaviour outside of school hours, only the third part of this hypothesis was supported. As quality of practice is more closely related to improved performance than quantity of performance, this finding represents an important change in student behaviour.

5.3 Integrating self-regulated learning with precision teaching

The findings from this study suggest that, despite developing from different philosophical positions, elements of self-regulated learning and PT can be successfully combined to enhance student achievement. Most models of self-regulated learning include cognitive, metacognitive, and motivational components (Dignath et al., 2008). It appears PT may enhance this framework by ensuring decisions are based on accurate data obtained on a daily basis. Metacognition is simply defined as "cognition about cognition" (Dignath et al., 2008, p107). In education, it is concerned with an individual's ability to monitor, control, and regulate their learning. In order to engage in these processes, students require accurate information on their current level of performance and rate of progress. Applied behavioural analysis emphasises continuous and direct measurement of observable behaviour (Sugai et al., 2012). This is reflected in PT's guiding principles which emphasise measuring the frequency of observable behaviour and displaying this data on celeration charts (Kubina & Yurich, 2012).

In this study, the application of PT meant that students had access to easily interpretable, accurate information, which was obtained on a daily basis. It is likely that this real-time data enabled students to reflect more accurately on their performance and set goals accordingly. It is possible that the celeration charts also fostered improved motivation and affect. Self-graphing has been found to increase on-task behaviour and academic performance

(Schutte et al., 2015). In addition to enhancing the motivational and metacognitive aspects of the SRL model, it is likely that PT also affected students' cognition. Cognitive strategies refer to the type of strategy that students use to enhance their learning. The selection and use of these strategies is a key component of self-regulated learning (Pintrich, 2000). Whilst the students in this study did not choose which strategy they would use to learn their basic facts, they did have some autonomy within the programme. Through the celeration charts, sprints, and *detect* phase of the programme, students were able to identify what facts they needed to work on. Within this framework students then had the ability to allocate additional practice to these facts. It is likely, that students made enhanced progress in the SRL fluency programme as decisions were based on accurate data obtained on a daily basis. This would not have been possible without implementing PT methodology. The results from this study showed that once students had been taught the cognitive strategy within the classroom, they had the willingness and ability to apply the strategy outside of school hours. In light of these results, it appears that further investigation of programmes implementing both self-regulated learning and PT methodology is warranted.

5.4 Limitations and future research

The results from this study confirm that the SRL programme resulted in a substantial improvement in multiplication fact fluency. Future research should look to replicate the findings from this study. In addition, future research should investigate whether this model can also be applied to other subject areas and more complex types of learning, such as composite skills. The following section discusses this study's limitations and identifies areas for future research.

Programme duration. The SRL programme ran for the relatively brief period of four weeks. As previously noted, this is substantially less time than the average programme duration employed in the reviewed basic facts (8 weeks) and PT studies (8-36 weeks). During the four weeks, 33% of SRL students were able to meet the TFR for all multiplication facts and 87.5% of students showed a reliable change from T1 to T2 on Test A. Future studies should implement the programme for longer time periods. Administration of the programme over longer time periods would enable investigation into whether the 'robust' rates of progress, observed in this study, can be maintained by students until the TFR is met.

Social validity. The data obtained in this study showed that students found the programme to be both enjoyable and helpful. Notwithstanding this finding, future research could investigate reported enjoyment and helpfulness data at a lower level of abstraction. The enjoyment and helpfulness data were obtained from single items within the questionnaire administered at T2. Single item measures are less reliable than measures that include a larger sample of items (Shum, O'Gorman, Myors, & Creed, 2013). Future research could decompose the programme into its key components and ask students to rate how enjoyable and helpful they found each aspect of the programme.

Self-report data. This study used self-report data to investigate student practice behaviour outside of school hours. Self-report data is subject to social desirability bias. Social desirability bias occurs when participants do not respond to the content of the question but instead respond in a way that presents themselves in a favourable light (Shum et al., 2013). It seems unlikely that social desirability bias affected the results obtained in this study for two reasons. First, neither group reported increasing the duration or frequency with which they practised over the course of the study. This suggests students were not attempting to present themselves in a favourable light. Second, of the three practice behaviours investigated, the only significant change from T1 to T2 was observed in the type of practice behaviour the SRL group engaged in. It seems improbable that social desirability bias would only affect the type of practice students reported engaging in. If the findings were subject to social desirability bias it is likely that self-reports for practice duration and frequency of practice would also have been inflated. As this pattern was not observed, it appears unlikely that the data was affected by social desirability bias. Self-reports are also subject to other forms of bias. Some of these, such as acquiescence and nay-saying bias, were mitigated through the design of the questionnaire. The accuracy of self-report data and other forms of bias, such as self-deceptive optimism, extreme responding, and demand characteristics were mitigated through the study design. Specifically, by randomly assigning students to a condition it is unlikely that differences in self-report data between the groups varied in any systematic way that did not represent an actual shift in the behaviour being measured. Whilst the study design mitigated some of the issues associated with self-report data, this study was still subject to the limitations connected with this form of data collection. It is possible that the self-report data obtained in this study was influenced by this type of response format. Future studies could supplement this data with direct observations or parent reports.

Commutativity knowledge. Prior to the study, teachers were asked to use their own records to identify which students had mastered the lessons up to and including ‘Turn Abouts’, from Book 6 of the Numeracy Project (Ministry of Education, 2008c). Students who had mastered these lessons should have had a basic understanding of the commutative property of multiplication. As previously noted, examination of this data found that it was not sufficiently accurate to allow investigation into whether students fluency with turn-around facts was mediated by their understanding of the commutative property. Future studies should assess students understanding of the commutative property of multiplication, separately from teacher records, to allow investigation of this question.

Self-efficacy. Prior studies have found that self-efficacy is positively related to mathematics achievement (Yurt, 2014), as well as problem solving accuracy and problem solving efficiency (Hoffman, 2010). This study also found a positive relationship between self-efficacy scores and test achievement. After participating in the programme for four weeks it was anticipated that SRL students' self-efficacy scores would be more accurately calibrated at T2, resulting in a more positive correlation with Test A performance at T2, however the data did not support this contention. Future research, using this programme, should again investigate this question. In this study, the self-efficacy questionnaires were administered before the 1-minute multiplication probes. It is possible that administering the self-efficacy measure after the 1-minute multiplication probes may improve the calibration of student self-efficacy assessments. The students would then have a clear understanding of the task demands which may help improve the accuracy of students' self-efficacy judgments at T1.

Contingent reinforcement. It was somewhat surprising that whilst students changed the type of practice behaviour they engaged in, they did not change the frequency or duration with which they practised. Future research should investigate whether contingent reinforcement can be used to modify the amount, and frequency, of practice students engage in, outside of school hours. In the reviewed studies, Gross et al. (2016) used contingent reinforcement to improve addition fluency, but contingent reinforcement was not employed in any of the studies to facilitate additional practice outside of school hours. If contingent reinforcement does lead to increased practice frequency and duration, future research should also explore the relationship between these factors and basic facts fluency.

Sample size. The sample size employed in this study was similar in size to the largest PT study and larger than the sample size employed in 57% of all the reviewed maths studies. Notwithstanding this finding, a relatively small number of students participated in this study. As the students all came from one school, in one geographical location, they also represent a relatively homogeneous group of participants. It is possible that programme changes may be required in different cultural contexts. This means care must be taken when attempting to generalise the results from this study. It is also one of the reasons why replication studies are recommended. Whilst the sample size was small it did allow the study to capture normal school practice. As previously noted, in order to obtain sufficiently large sample sizes some studies chose to select students from a wide range of year groups (Strømgren et al., 2014; McTiernan et al., 2016). This method of selecting students does not reflect typical school practice. An alternative approach could involve conducting a number of replication studies in different schools throughout the country.

5.5 Conclusion

The results from this study confirm that the SRL programme led to a large improvement in basic facts fluency. As a result of this programme, students also adopted more beneficial basic facts practice behaviours outside of school hours. These findings, in addition to the programmes high social validity, emphasise the utility of this programme for use at the tier one level. A number of features should appeal to educators. First, this programme was able to facilitate 'robust' and enduring basic facts progress. This means educators should be able to allocate additional time to more complex mathematics behaviour. Second, this programme was effective for students of all abilities. In the RTI framework, tier one programmes should be effective for approximately 80% of all students (Johnson & Street, 2013). The SRL programme exceeded this threshold. The use of PT methodology enabled personalisation of the SRL programme so that both the both the type and number of facts presented were commensurate to each students' current level of ability. Brown and Moore (2011) argue that the ability to personalise learning to meet the needs of all students is not just a characteristic of effective teaching, it is in fact a basic human right. In addition, implementation of this programme within schools is likely to result in less students requiring tier two or tier three support. This should reduce the costs that are typically associated with tier two and tier three interventions.

This study also demonstrated how a fluency programme embedded within a SRL framework can modify students' practice behaviour outside of school hours. This finding has important implications for educators. Specifically, it encourages educators to consider how programmes can be designed to facilitate high quality practice outside of school hours. It is likely that a number of the strategies employed in this programme could be applied to other skills, contexts, and curriculum areas. However, this hypothesis needs to be confirmed through future studies. This study also has implications for researchers. The magnitude of the findings observed here warrant replication studies. It is hoped that future research may adopt the level of analysis provided in this study. As previously noted, many of the reviewed studies did not analyse results in sufficient detail. It is only through detailed idiographic and nomothetic analysis that the utility of a tier one programme can be sufficiently evaluated.

New Zealand's comparatively poor performance in mathematics (Ministry of Education, 2016c, 2016d) has been attributed to a relative weakness in basic facts knowledge (Ministry of Education, 2016c). In order to overcome this challenge, New Zealand schools require efficient and effective tier one programmes. Whilst additional research is required, the results from this study have demonstrated the efficacy of this programme within tier one of the RTI framework.

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APPENDICES

Appendix A

Board of Trustees' Information Sheet

College of Education, Health and Human Development

Telephone: 021908040

Email: mike.sleeman@pg.canterbury.ac.nz

Date to be confirmed

The Effects of a Self-Regulated Learner Framework on the Fluency of Single-Digit Multiplication Facts with Year 5 & 6 Students.

Information Sheet for the School Board of Trustees (Chair)

My name is Mike Sleeman. I am a teacher completing a thesis for the Masters of Education at the University of Canterbury. This research project will investigate whether a self-regulated learner programme leads to improved multiplication fact fluency compared to traditional classroom instruction. The study will also explore whether the basic fact programme affects the quantity and quality of basic fact practice that students engage in outside of school hours. I am seeking permission to approach your principal for permission to use their school in my study.

The study is voluntary. It will require one of the Year 5 and 6 teachers to allocate, during their maths lesson, 15 minutes of class time each day for 20 consecutive school days to provide the SRL programme. The teacher in the other class, the traditional class, will carry on as usual.

The researcher will train both of the teachers in the SRL programme. One teacher will be trained prior to the SRL programme starting and the other teacher will be trained after the maintenance 1-minute maths assessment probes have been administered. The teachers will have a script to follow the SRL programme with. Teachers will not be requested to mark or analyse any of the measures administered.

There is a small possibility that some students may experience some anxiety or worry while completing the 1-minute maths assessment probes but this is mitigated by providing 'warm up' exercises which model what is expected in the 1-minute maths assessment probe. Very similar measures have previously been used with this age group, plus the programme encourages self-assessment and learning goals rather than social/peer comparison. There are no other foreseeable risks associated with your schools' participation in this study but please contact me if you have any questions or wish to know more about the study.

Participation is voluntary and your school has the right to withdraw from the project at any time without penalty. If you choose to withdraw, I will use my best endeavours to remove any of the information relating to your school from the project, including any final publication, provided that this remains practically achievable.

A thesis is a public document and will be available through the UC Library. The findings from this study may also be presented at an educational conference, school presentations or published in a journal article which may result from this study. You can be assured of complete confidentiality of data gathered in this investigation: your school, the principal, teachers, students and their parent's identity is confidential and will not be made public. To ensure anonymity and confidentiality, only the researcher and supervisor will have access to the raw data. This data will be kept in locked storage and will be destroyed after five years in accordance with the University of Canterbury's Educational Research Human Ethics Committee Policy. Anonymisation of the data will be used throughout the coding of the data and data analysis.

The project is being carried out as a requirement for the Masters of Education endorsed in Inclusive and Special Education by Mike Sleeman under the supervision of Dr Gaye Tyler-Merrick, who can be contacted at gaye.tyler-merrick@canterbury.ac.nz. She will be pleased to discuss any questions or concerns you may have about participation in my project.

This project has been reviewed and approved by the University of Canterbury Educational Research Human Ethics Committee, and participants should address any complaints to The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

Please indicate to the researcher on the consent form if you would like a copy of the summary of results from my project.

Please complete the consent form if you understand what is expected and agree to take part in the study. Return the consent form to the school office for collection by the researcher Mike Sleeman (7/4/17).

Mike Sleeman

Principal's Information Sheet

College of Education, Health and Human Development

Telephone: 021908040

Email: mike.sleeman@pg.canterbury.ac.nz

Date to be confirmed

The Effects of a Self-Regulated Learner Framework on the Fluency of Single-Digit Multiplication Facts with Year 5 & 6 Students.

Information Sheet for Principals

My name is Mike Sleeman. I am a teacher completing a thesis for the Masters of Education at the University of Canterbury. This research project will investigate whether a self-regulated learner programme leads to improved multiplication fact fluency compared to traditional classroom instruction. The study will also explore whether the basic fact programme affects the quantity and quality of basic fact practice that students engage in outside of school hours. Research suggests this approach should help students to more quickly and accurately recall their multiplication facts. Your teachers and students are invited to take part in my research study.

If you choose to take part in this study, the Year 5 and 6 teachers' involvement will include:

- Agreeing to the random assignment of Year 5 and 6 students into one of two groups. Group 1: Self-regulated learner (SRL); Group 2: Traditional classroom instruction. Students in the traditional classroom instruction group will have access to the programme after the maintenance 1-minute maths assessment probes have been administered in the SRL group.

- Providing access to limited student enrolment data (student name, gender, ethnicity, date of birth and maths PAT data).

- Attending a 30-minute training session held at your school at their convenience. The session will provide training in how to provide the programme and administer the measures associated with this programme. The teachers will not be required to mark or analyse any of the measures administered. The teachers may request additional training or support at any time during the programme. The training for the teacher in charge of the SRL group will occur prior to the programme. The other teacher will receive the same programme training after the maintenance 1-minute maths assessment probes have been administered for the SRL group.

- Administering two questionnaires at the start and end of the programme. The questionnaires are designed to investigate how confident students feel attempting a range of multiplication fact problems and their perceptions of the programme. The questionnaires will take approximately five minutes to complete.

- Giving permission for the student administration of a diary. The diary will be completed seven days a week for the duration of the programme by students in the SRL group. The diary takes up to 1 minute to complete. It is designed to record the amount of deliberate basic fact practice students engage in and their use of self-control strategies in their home setting.

- One of the Year 5 and 6 teachers allocating, during their maths lesson, 15 minutes of class time each day for 20 consecutive school days to provide the SRL programme. The teacher in the other class, the traditional class, will carry on as usual.

- Allowing the administration of six 1-minute maths assessment probes for the students in the SRL programme and the students in the traditional instruction class: two assessment probes at the beginning, two at the end of the 20-day programme and two, four school weeks after the programme. The researcher will also provide and model warm-up tasks during these same time periods.

There is a small possibility that some students may experience some anxiety or worry while completing the 1-minute maths assessment probes but this is mitigated by providing 'warm up' exercises which model what is expected in the 1-minute maths assessment probe. Very similar measures have previously been used with this age group, plus the programme encourages self-assessment and learning goals rather than social/peer comparison. There are no other foreseeable risks associated with your schools' participation in this study but please contact me if you have any questions or wish to know more about the study.

Participation is voluntary and you have the right to withdraw your school from the project at any time without penalty. If you choose to withdraw, I will use my best endeavours to remove any of the information relating to your school from the project, including any final publication, provided that this remains practically achievable.

A thesis is a public document and will be available through the UC Library. The findings from this study may also be presented at an educational conference, school presentations or published in a journal article which may result from this study. You can be assured of complete confidentiality of data gathered in this investigation: your school, the principal, teachers, students and their parent's identity is confidential and will not be made public. To ensure anonymity and confidentiality, only the researcher and supervisor will have access to the raw data. This data will be kept in locked storage and will be destroyed after five years in accordance with the University of Canterbury's Educational Research Human Ethics Committee Policy. Anonymisation of the data will be used throughout the coding of the data and data analysis.

The project is being carried out as a requirement for the Masters of Education endorsed in Inclusive and Special Education by Mike Sleeman under the supervision of Dr Gaye Tyler-Merrick, who can be contacted at gaye.tyler-merrick@canterbury.ac.nz. She will be pleased to answer any questions or discuss any concerns you may have about participation in the project.

This project has been reviewed and approved by the University of Canterbury Educational Research Human Ethics Committee, and participants should address any complaints to The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

Please indicate to the researcher on the consent form if you would like a copy of the summary of results from the project.

If you agree to participate in the study, you are asked to complete the consent form and return it to your school office for collection by Mike Sleeman by (11/4/17).

Mike Sleeman

Teachers' Information Sheet

College of Education, Health and Human Development

Telephone: 021908040

Email: mike.sleeman@pg.canterbury.ac.nz

1/5/17

The Effects of a Self-Regulated Learner Framework on the Fluency of Single-Digit Multiplication Facts with Year 5 & 6 Students.

Information Sheet for Teachers

My name is Mike Sleeman. I am a teacher completing a thesis for the Masters of Education at the University of Canterbury. This research project will investigate whether a self-regulated learner programme leads to improved multiplication fact fluency compared to traditional classroom instruction. The study will also explore whether the basic fact programme affects the quantity and quality of basic fact practice that students engage in outside of school hours. You are invited to take part in this research study.

If you choose to take part in this study, your involvement in this project will include:

- Attending a 30-minute training session held at your school at your convenience. The session will provide training in how to provide the SRL programme and administer the measures associated with this programme. You will not be required to mark or analyse any of the measures administered. You may request additional training or support at any time during the programme.

- Screening all students prior to the study. This will involve reviewing your records to identify any student who has not completed the lessons up to and including 'Turn Abouts' in Book 6 of the Numeracy Project.

- Agreeing to the random assignment of Year 5 and 6 students into one of two groups. Group 1: Self-regulated learner (SRL) Group 2: Traditional classroom instruction. Students in the traditional classroom instruction group will have access to the programme after the maintenance 1-minute maths assessment probes have been administered.

- One teacher implementing the SRL programme for 20 consecutive school days (four weeks). The programme runs for 15 minutes each day. The SRL programme procedure will be taught in the training session. The teacher in the other class, the traditional class, will carry on as usual.

- Agreeing to the administration of six 1-minute maths assessment probes for the students in the SRL programme and the students in the traditional instruction class: two assessment probes before the programme, two assessment probes after the programme and two 1-minute maintenance maths assessment probes (four school weeks after the programme). The researcher will also provide and model the warm-up assessment probe at each time period.

- Administering two questionnaires at the beginning and end of the programme. The questionnaires are designed to investigate how confident students feel attempting a range of multiplication fact problems and their perceptions of the programme. The questionnaires will take approximately five minutes to complete.

- Giving permission for the administration of a diary. The diary will be completed seven days a week for the duration of the programme by students in the SRL group. The diary takes up to 1 minute to complete. It is designed to investigate the amount of deliberate basic fact practice students engage in and their use of self-control strategies.

The programme requires teachers to allocate 15 minutes of class time each day for the 20 days of the programme. The expected increase in multiplication fact fluency should offset this impact on teaching time.

There is a small possibility that some students may experience some anxiety or worry while completing the 1-minute maths assessment probes but this is mitigated by providing 'warm up' exercises which model what is expected in the 1-minute maths assessment probe. Very similar measures have previously been used with this age group, plus the programme encourages self-assessment and learning goals rather than social/peer comparison. There are no other foreseeable risks associated with your schools' participation in this study but please contact me if you have any questions or wish to know more about the study.

Participation is voluntary and you have the right to withdraw from the project at any time without penalty. If you choose to withdraw, I will use my best endeavours to remove any of the information relating to you from the project, including any final publication, provided that this remains practically achievable.

A thesis is a public document and will be available through the UC Library. The findings from this study may also be presented at an educational conference, school presentations or published in a journal article which may result from this study. You can be assured of complete confidentiality of data gathered in this investigation: your school, the principal, teachers, students and their parent's identity is confidential and will not be made public. To ensure anonymity and confidentiality, only the researcher and supervisor will have access to the raw data. This data will be kept in locked storage and will be destroyed after five years in accordance with the University of Canterbury's Educational Research Human Ethics Committee Policy. Anonymisation of the data will be used throughout the coding of the data and data analysis.

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Please indicate to the researcher on the consent form if you would like a copy of the summary of results from the project.

If you agree to participate in the study, you are asked to complete the consent form and return it to your school office for collection by Mike Sleeman (11/4/17).

Mike Sleeman

Parents' Information Sheet

College of Education, Health and Human Development

Telephone: 021908040

Email: mike.sleeman@pg.canterbury.ac.nz

1/5/17

The Effects of a Self-Regulated Learner Framework on the Fluency of Single-Digit Multiplication Facts with Year 5 & 6 Students.

Information Sheet for Parents/ Caregivers

My name is Mike Sleeman. I am a teacher completing my thesis for the Masters of Education at the University of Canterbury. My research project will investigate whether a programme, that can be run by students (self-regulated learner programme) leads to improved multiplication fact performance compared to normal classroom instruction. The study will also explore whether the basic fact programme affects the amount and type of basic fact practice that students complete outside of school hours. I am seeking permission for your child to participate in my study. If you give permission for your child to take part in my study, your child's involvement will include:

- Being randomly placed into one of two groups. Group 1: Self-regulated learner (SRL) Group 2: Traditional classroom instruction. If you choose, and your child is placed in the traditional classroom instruction group, your child will have access to the SRL programme after it has finished for group 1.

- Taking part in a SRL programme. Each day, for 20 school days, your child's teacher will allocate 15 minutes of class time to carrying out the programme. All instruction will occur during maths time and no time will be taken from other subject areas.

- Completing six 1-minute maths probes and three warm-up probes over the course of the study.

- Completing two questionnaires designed to investigate basic fact confidence and practice routines. The questionnaires will take up to five minutes to complete.

- Completing a diary. Students will only complete the diary when they engage in basic fact practice outside of school hours. The diary takes up to 1 minute to complete. It is designed to investigate the amount of deliberate basic fact practice the student engages in and their use of self-regulation strategies.

All 1-minutes maths assessment probes and questionnaires will be completed at school. You will not be required to mark or oversee any activity.

There is a small possibility that your child may become worried or anxious about completing the 1-minute maths assessment probes. To reduce the likelihood of them experiencing anxiety, warm-up tasks will be given. These tasks are like the mini probes, but are not timed or marked. The 1-minute maths assessment probe has been previously used with this age group. There are no other foreseeable risks associated with your child's participation in this study but please contact me if you have any questions or wish to know more about the study.

Participation is voluntary and you have the right to withdraw your child from the project at any time without penalty. If you choose to withdraw, I will use my best efforts to remove any of the information relating to your child from the project, including any final publication, provided that this remains possible.

A thesis is a public document and will be available through the UC Library. The findings from this study may also be presented at an educational conference, school presentations or published in a journal article which may result from this study. You can be assured of complete confidentiality of data gathered in this project, your child's identity will not be made public. To ensure anonymity and confidentiality, only the researcher and supervisor will have access to the raw data. This data will be kept in locked storage and will be destroyed after five years in accordance with the University of Canterbury's Human Ethics Policy. Anonymisation of the data will be used throughout the coding of the data and data analysis.

The project is being carried out as a requirement for the Masters of Education endorsed in Inclusive and Special Education by Mike Sleeman under the supervision of Dr Gaye Tyler-Merrick, who can be contacted at gaye.tyler-merrick@canterbury.ac.nz. She will be pleased to answer any questions you may have or discuss any concerns about participation in the project.

This project has been reviewed and approved by the University of Canterbury Education Research Human Ethics Committee, and participants should address any complaints to The Chair, Education Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

Please indicate to the researcher on the consent form if you would like a copy of the summary of results from the project.

If you agree to participate in the study, you are asked to complete the consent form and return it to your school office for collection by Mike Sleeman by 5/5/17.

Mike Sleeman

Students' Information Sheet

College of Education, Health and Human Development

Email: mike.sleeman@pg.canterbury.ac.nz

1/5/17

The Effects of a Self-Regulated Learner Framework on the Fluency of Single-Digit Multiplication Facts with Year 5 & 6 Students.

Information Sheet for Students

My name is Mike Sleeman. I am a teacher completing my thesis for the Masters of Education at the University of Canterbury. My project will investigate whether a self-regulated learner programme (SRL) leads to improved multiplication fact compared to traditional classroom instruction. In my study, I am also interested in whether you practice your multiplication facts outside of school time. You are invited to take part in this research study.

If you take part in my study, your involvement will include:

- Taking part in either trialling my programme or traditional classroom instruction for four weeks. Students in the traditional classroom group will have access to my programme at the end of my study.

- Completing six 1-minute maths probes and three warm-up probes over the course of the study.

- Completing two questionnaires designed to investigate basic fact confidence and practice routines. The questionnaires will take up to five minutes to complete.

- When you practice SRL at home, I will ask you to complete a diary. The diary will be completed for four weeks. The diary will take up to 1 minute per day to complete. It is designed to record the amount of deliberate basic fact practice you complete and your use of self-regulation strategies.

The programme will run for 15 minutes every day, for 20 school days, during part of your normal maths time. There is a small possibility that you may feel anxious or worried when completing the 1-minute maths assessment probes. To reduce the likelihood of you experiencing anxiety we will provide and model warm-up exercises/tasks. This programme is designed to help you to achieve your own personal bests. It does not encourage you to compare your scores to other students in the class. There are no other foreseeable risks associated with you taking part in this study but please contact me if you have any questions or wish to know more about the study.

Participation is voluntary. You can withdraw from the project at any time, without penalty, by contacting your teacher, parent or researcher. If you choose to withdraw, I will use my best efforts to remove any of the information relating to you from the project, including any final publication, provided that this remains possible.

A thesis is a public document and will be available through the UC Library. The findings from this study may also be presented at an educational conference, school presentations or published in a journal article which may result from this study. Your identity will not be made public. Only the researcher and my supervisors will have access to your information and your name will be replaced with a unique code. Your information will be kept in locked storage and will be destroyed after five years in accordance with the University of Canterbury's Educational Research Human Ethics Committee Policy. Your name will be replaced with a code during the data analysis.

The project is being carried out as a requirement for the Masters of Education endorsed in Inclusive and Special Education by Mike Sleeman under the supervision of Dr Gaye Tyler-Merrick, who can be contacted at gaye.tyler-merrick@canterbury.ac.nz. She will be pleased to answer your questions and discuss any concerns you may have about participation in the project.

This project has been reviewed and approved by the University of Canterbury Educational Research Human Ethics Committee, and participants should address any complaints to The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

Please indicate to the researcher on the consent form if you would like a copy of the summary of results from the project.

If you agree to participate in the study, you are asked to complete the consent form and return it to your school office for collection by Mike Sleeman by 5/5/17.

Mike Sleeman

Appendix B

Board of Trustees' Consent Form

College of Education, Health and Human Development

Telephone: 021908040

Email: mike.sleeman@pg.canterbury.ac.nz

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

The Effects of a Self-Regulated Learner Framework on the Fluency of Single-Digit Multiplication Facts with Year 5 & 6 Students.

Consent Form for the Board of Trustees (Chair)

Please tick all the check boxes below to indicate you understand and agree with the following statements.

- ☐ I have been provided with a full explanation of this project and have been given the opportunity to ask questions.
- ☐ I understand what is required of the Board of Trustees if I agree to the school's participation in this research.
- ☐ I understand that the participants' involvement is voluntary and that they may withdraw at any stage without penalty.
- ☐ I understand that any information or opinions that I provide will be kept confidential to the researcher and his supervisor and that any published or reported results will not identify the principal, students, parents, teachers, the school or me.
- ☐ I understand that all data collected for the study will be kept in locked and secured facilities and/or in password protected electronic form and will be destroyed after five years.
- ☐ I understand the risks associated with taking part and how they will be managed.
- ☐ I understand that I will be able to receive a report on the findings of the study.
- ☐ I understand that I can contact the researcher or supervisor for further information.
- ☐ I understand that I can contact the Chair of the University of Canterbury Educational Research Human Ethics Committee if I have any complaints.

Name (first and last): ____

Signature: ____ Date: __________________

Please provide your e-mail address if you would like a copy of the research findings.

e-mail: ____

Please return this form to the school office for collection by Mike Sleeman prior to (7/4/17).

Mike Sleeman

Principal's Consent Form

College of Education, Health and Human Development

Telephone: 021908040

Email: mike.sleeman@pg.canterbury.ac.nz

The Effects of a Self-Regulated Learner Framework on the Fluency of Single-Digit Multiplication Facts with Year 5 & 6 Students.

Consent Form for Principals

Please tick all the check boxes below to indicate you understand and agree with the following statements.

☐ I have been provided with a full explanation of this project and have been given the opportunity to ask questions.

☐ I understand what is required of me and the school if I agree to the school's participation in this research.

☐ I understand that the participants' involvement is voluntary and that they may withdraw at any stage without penalty.

☐ I understand that any information or opinions that I provide will be kept confidential to the researcher and his supervisor and that any published or reported results will not identify students, parents, teachers, the school or me.

☐ I understand that all data collected for the study will be kept in locked and secured facilities and/or in password protected electronic form and will be destroyed after five years.

☐ I understand the risks associated with taking part and how they will be managed.

☐ I understand that I will be able to receive a report on the findings of the study.

☐ I understand that I can contact the researcher or supervisor for further information.

☐ I understand that I can contact the Chair of the University of Canterbury Educational Research Human Ethics Committee if I have any complaints.

Name (first and last): ____

Signature: ____ Date: __________________

Please provide your e-mail address if you would like a copy of the research findings.

e-mail: ____

Please return this form to the school office for collection by Mike Sleeman prior to (11/4/17).

Mike Sleeman

Teachers' Consent Form

College of Education, Health and Human Development

Telephone: 021908040

Email: mike.sleeman@pg.canterbury.ac.nz

The Effects of a Self-Regulated Learner Framework on the Fluency of Single-Digit Multiplication Facts with Year 5 & 6 Students.

Consent Form for Teachers

Please tick all the check boxes below to indicate you understand and agree with the following statements.

☐ I have been provided with a full explanation of this project and have been given the opportunity to ask questions.

☐ I understand what is required of my students and me if I agree to take part in this research.

☐ I understand that my participation is voluntary and that I may withdraw at any stage without penalty.

☐ I understand that any information or opinions that I provide will be kept confidential to the researcher and his supervisor and that any published or reported results will not identify students, parents, teachers, the principal, school or me.

☐ I understand that all data collected for the study will be kept in locked and secured facilities and/or in password protected electronic form and will be destroyed after five years.

☐ I understand the risks associated with taking part and how they will be managed.

☐ I understand that I will be able to receive a report on the findings of the study.

☐ I understand that I can contact the researcher or supervisor for further information.

☐ I understand that I can contact the Chair of the University of Canterbury Educational Research Human Ethics Committee if I have any complaints.

Name (first and last): ____

Signature: ____ Date: __________________

Please provide your e-mail address if you would like a copy of the research findings.

e-mail: ____

Please return this form to the school office for collection by Mike Sleeman prior to (11/4/17).

Mike Sleeman

Parents' Consent Form

College of Education, Health and Human Development

Telephone: 021908040

Email: mike.sleeman@pg.canterbury.ac.nz

The Effects of a Self-Regulated Learner Framework on the Fluency of Single-Digit Multiplication Facts with Year 5 & 6 Students.

Consent Form for Parents/ Caregivers

Please tick all the check boxes below to indicate you understand and agree with the following statements.

☐ I have been provided with a full explanation of this project and have been given the opportunity to ask questions.

☐ I understand what is required of my child and me if we agree to take part in this research.

☐ I understand that my participation is voluntary and that my child or I may withdraw at any stage without penalty.

☐ I understand that any information or opinions that I provide will be kept confidential to the researcher and his supervisor and that any published or reported results will not identify the principal, teachers, school, our family, or my child.

☐ I understand that all data collected for the study will be kept in locked and secured facilities and/or in password protected electronic form and will be destroyed after five years.

☐ I understand the risks associated with taking part and how they will be managed.

☐ I understand that I will be able to receive a report on the findings of the study.

☐ I understand that I can contact the researcher or supervisor for further information.

☐ I understand that I can contact the Chair of the University of Canterbury Educational Research Human Ethics Committee if I have any complaints.

Name (first and last): ____

Signature: ____ Date: __________________

Please provide your e-mail address if you would like a copy of the research findings.

e-mail: ____

Please return this form to the school office for collection by Mike Sleeman prior to 5/5/17.

Mike Sleeman

Students' Consent Form

College of Education, Health and Human Development

Email: mike.sleeman@pg.canterbury.ac.nz

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

The Effects of a Self-Regulated Learner Framework on the Fluency of Single-Digit with Year 5 & 6 Students.

Consent Form for Children

Please tick all the check boxes below to indicate you understand and agree with the following statements.

- ☐ This project has been explained to me and I have been given the chance to ask questions.
- ☐ I understand what I need to do if I agree to take part in this research.
- ☐ I understand that my taking part is voluntary and that I may withdraw at any stage without penalty.
- ☐ I understand that information I provide will be kept confidential to Mike Sleeman and his supervisors and it will not identify my family, or me.
- ☐ I understand that all data collected for the study will be kept in locked and secured facilities and/or in password protected electronic form and will be destroyed after five years.
- ☐ I understand that I will be able to receive a report on the results of the study.
- ☐ I understand that I can contact the researcher or supervisor for more information.
- ☐ I understand that I can contact the Chair of the University of Canterbury Educational Research Human Ethics Committee if I have any complaints.

Name (first and last): ____

Signature: ______________________________ Date: ______________

Please provide your e-mail address if you would like a copy of the research findings.

e-mail: ____

Please return this form to the school office for collection by Mike Sleeman prior to 5/5/17.

Mike Sleeman

Appendix C

Example 1-Minute Multiplication Probe

Name					**1-minute basic facts probe**
					Post-programme test (a)
2 X 6 =	....	5 X 7 =	....	6 X 10 =	....
3 X 1 =	....	3 X 8 =	....	8 X 9 =	....
6 X 8 =	....	2 X 1 =	....	2 X 4 =	....
2 X 8 =	....	7 X 7 =	....	3 X 4 =	....
5 X 7 =	....	4 X 1 =	....	4 X 6 =	....
6 X 10 =	....	3 X 9 =	....	2 X 10 =	....
8 X 1 =	....	9 X 9 =	....	4 X 10 =	....
9 X 1 =	....	4 X 10 =	....	2 X 1 =	....
7 X 8 =	....	5 X 1 =	....	4 X 9 =	....
2 X 9 =	....	2 X 3 =	....	8 X 10 =	....
6 X 9 =	....	4 X 1 =	....	6 X 8 =	....
3 X 7 =	....	2 X 9 =	....	7 X 7 =	....
2 X 4 =	....	6 X 1 =	....	3 X 8 =	....
3 X 4 =	....	2 X 5 =	....	9 X 9 =	....
4 X 4 =	....	2 X 10 =	....	5 X 9 =	....
5 X 8 =	....	2 X 8 =	....	7 X 8 =	....
2 X 7 =	....	7 X 10 =	....	2 X 6 =	....
7 X 9 =	....	4 X 5 =	....	6 X 7 =	....
9 X 10 =	....	4 X 9 =	....	2 X 3 =	....
4 X 8 =	....	8 X 8 =	....	9 X 10 =	....
3 X 3 =	....	3 X 10 =	....	7 X 9 =	....
3 X 9 =	....	5 X 6 =	....	4 X 7 =	....
3 X 5 =	....	7 X 1 =	....	6 X 6 =	....
8 X 10 =	....	3 X 6 =	....	2 X 7 =	....
2 X 5 =	....	2 X 2 =	....	4 X 4 =	....
4 X 7 =	....	5 X 10 =	....	3 X 5 =	....
4 X 6 =	....	5 X 8 =	....	8 X 1 =	....
5 X 9 =	....	5 X 5 =	....	3 X 3 =	....
6 X 6 =	....	6 X 7 =	....	3 X 7 =	....
2 X 2 =	....	8 X 9 =	....	3 X 1 =	....

Appendix D

Self-efficacy Measure

Name:

How confident are you that you could answer the following questions, instantly, if given them in a test?

Circle the number below that best represents your confidence. Use the descriptions above the numbers to help you with your choices.

	I would not be able to answer this.		I would need to use my fingers.		I could work it out from another basic fact I know.		I know this answer but it might take me a few seconds to remember it.		I am extremely confident I could answer this question instantly.	
2 × 7 =	1	2	3	4	5	6	7	8	9	10
5 × 8 =	1	2	3	4	5	6	7	8	9	10
10 × 3 =	1	2	3	4	5	6	7	8	9	10
2 × 4 =	1	2	3	4	5	6	7	8	9	10
5 × 3 =	1	2	3	4	5	6	7	8	9	10
4 × 7 =	1	2	3	4	5	6	7	8	9	10
9 × 3 =	1	2	3	4	5	6	7	8	9	10
7 × 8 =	1	2	3	4	5	6	7	8	9	10
6 × 7 =	1	2	3	4	5	6	7	8	9	10
8 × 9 =	1	2	3	4	5	6	7	8	9	10

Appendix E

Basic Facts Questionnaire

Basic fact questionnaire

Please complete this questionnaire as honestly as possible. Only the researcher will see the answers you put on this questionnaire.

Name (first and last): ……………………………………………………………………………………………………

1) On how many days did you practise your basic facts at home over the last week?

Please circle the most appropriate answer below.

0 days	1 day	2 days	3 days	4 days	5 days	6 days	7 days

2) On average how long did you practise them for?

Please circle the most appropriate answer below.

0 minutes	5 minutes	10 minutes	15 minutes	20 minutes	More than 20 minutes. Please write the number of minutes here: ……………………

3) What was the **most common** strategy you used for learning your basic facts?

Please circle the most appropriate answer below.

Maths games	Tested by another person	Using flash cards	Completing activity sheets	Other (please state below)

If you selected other, please describe how you practised your basic facts: ……………………………………….

………

4) How enjoyable did you find this basic fact programme?

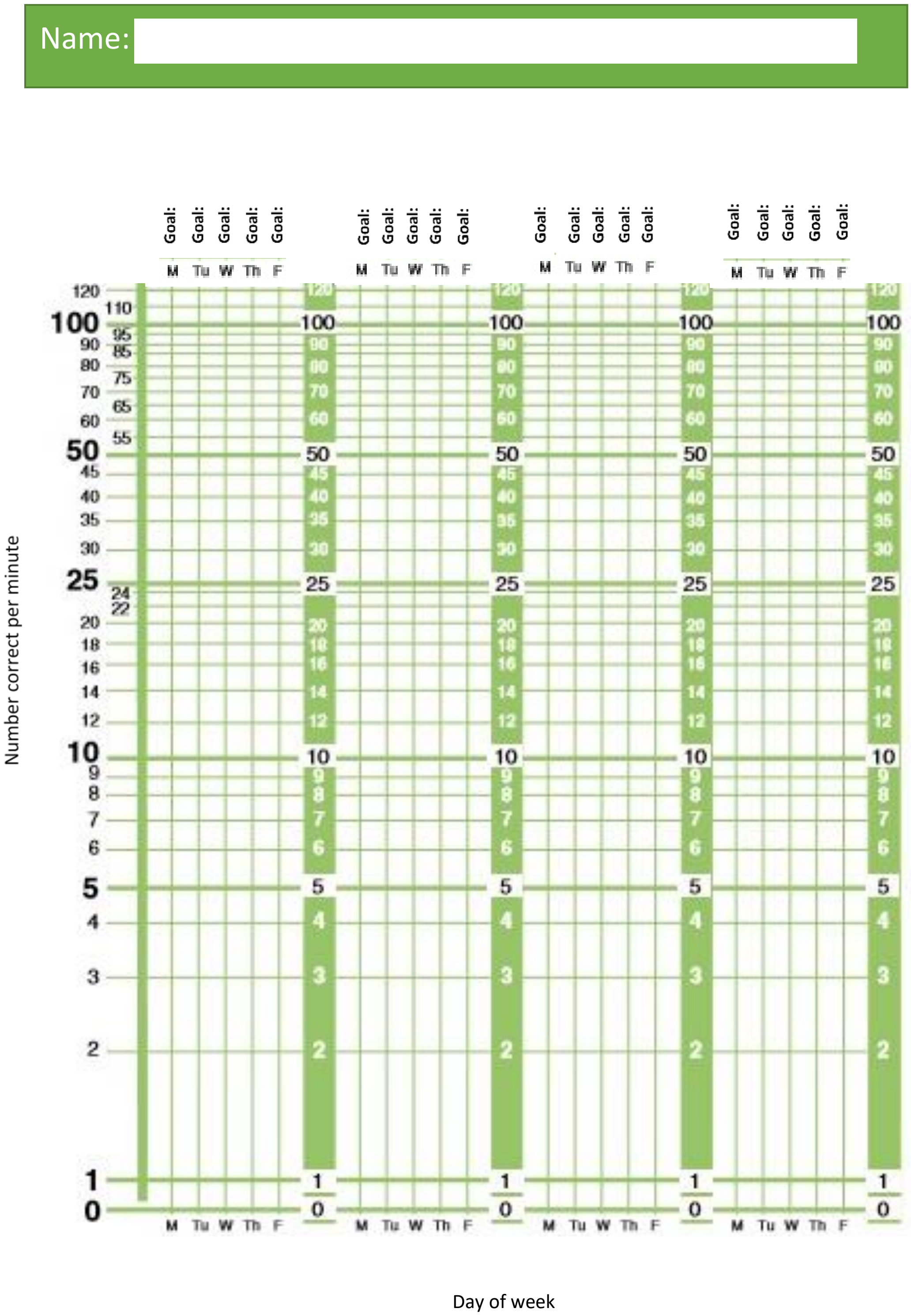
Not enjoyable	A little bit enjoyable	Fairly enjoyable	Very enjoyable	Extremely enjoyable

5) How much do you think this programme helped improve your basic fact recall.

Not helpful	A little bit helpful	Fairly helpful	Very helpful	Extremely helpful

Appendix F

Celeration Chart



Appendix G

Fidelity Check Form

Fidelity check **SRL condition**

Date observed: **Teacher:**

Pre-action					
Teacher leads discussion focussed on the setting selection, setting modification and attention deployment. [2]	**1**	**2**	**3**	**4**	**5**
Students are engaged in the pre-action phase. [1]	**1**	**2**	**3**	**4**	**5**
Action					
Students have access to their own set of flash cards. [1]	**1**	**2**	**3**	**4**	**5**
Students are following the 'detect' procedure.[1]	**1**	**2**	**3**	**4**	**5**
Students are following the practice procedure. [1]	**1**	**2**	**3**	**4**	**5**
Students are following the repair procedure. [1]	**1**	**2**	**3**	**4**	**5**
Students are engaged in the five-minute practice phase. [1]	**1**	**2**	**3**	**4**	**5**
Students are following the correct sprint procedure. [1]	**1**	**2**	**3**	**4**	**5**
Post-action					
Teacher leads the post-action reflection. [2]	**1**	**2**	**3**	**4**	**5**
Students are engaged in the post-action phase. [1]	**1**	**2**	**3**	**4**	**5**
Total score: / 50					

[1]Additional information for engagement scores:

The following guidelines are used for engagement scores (class size = 24), based on the average engagement over the course of the observation: 5 = up to two students not engaged; 4 = up to four students not engaged; 3 = up to six students not engaged; 2 = up to 8 students not engaged; 1 = ten or more students not engaged.

[2]Additional information for content scores

The following guidelines will be used for content scores: 5 = feature is clearly presented to students in an engaging manner; 4 = feature is communicated quite clearly to students and in a relatively engaging manner; 3 = feature is communicated relatively clearly to students and in a somewhat engaging manner; 2 = feature is presented but presentation is incomplete or very confusing and unengaging; 1 = feature is not presented.

Appendix H

SRL Diary Page

Please circle or highlight the day of the week below.

Week 1	Mon	Tue	Wed	Thu	Fri	Sat	Sun

Number of practice sessions today: ……………………………………

Remember to write the facts that you learned on the back of this page.

a) How confident are you that you could instantly answer the facts you learned if someone asked you them now?

Not confident at all	A little bit confident	Fairly confident	Very confident	Extremely confident

b) Did you use setting selection?

No	Yes, but it was not helpful	Yes, it was somewhat helpful	Yes, it was very helpful

c) Did you use setting modification?

No	Yes, but it was not helpful	Yes, it was somewhat helpful.	Yes, it was very helpful

d) Did you use attention deployment?

No	Yes, but it was not helpful	Yes, it was somewhat helpful	Yes, it was very helpful

Appendix I

Trad Diary Page

Please circle or highlight the day of the week below.

Week 1	Mon	Tue	Wed	Thu	Fri	Sat	Sun

a) How long did you practice your basic facts for:

…………………………………….

Remember to write the facts that you learned on the back of this page.

b) How did you practice your basic facts?
Place a tick next to the most appropriate category.

Maths games	
Tested by another person	
Using flash cards	
Activity sheets	
Other (please state below)	

If you selected the option 'other' please describe your practice below.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………