An Examination of the Effectiveness of Precision Teaching

A thesis

submitted in fulfillment

of the requirements for the degree

of

Master of Social Sciences

at the

University of Waikato

By

DÉSIRÉE JULIA BETTINA McQUARTERS

University of Waikato

2009

Abstract

This research examined the effect of adding precision teaching to an already used method of times table practice, compared practice with and without precision teaching, and finally compared precision teaching to rate building. In the first experiment there was no significant difference in students' rates, endurance, stability, application or adduction of answering times table equations, depending on whether or not they had received precision teaching. Due to some confounding variables in the first experiment, a second experiment was performed where these variables where better controlled. The results from the second experiment also showed no significant difference in students' rates of answering time's table equations, or their retention of these rates, between students who had received precision teaching and those who had not. Again due to some confounding variables preventing a good comparison of practice with and without precision teaching, a further experiment was conducted. As the third experiment was conducted in the same setting as the second, precision teaching was compared to rate building instead of practice with no precision teaching. The results of this study suggest that rate building results in significantly larger increases in rates of answering times table equations than precision teaching. While there was a significant difference between the two groups' increases in rate, there were some confounding variables that may have affected the outcome of this study. Overall, students in all three experiments made increases in rate that are comparative to gains reported in the precision teaching literature. As such while this research does not add support for all the methods used in precision teaching, as described in the literature, it does suggest that the use of rate building results in the achievement of faster rates.

Acknowledgements

I would like to thank Dr Mary Foster and Eric Messick for their supervision, discussion and feedback, thought this process. For giving me the push in the right direction when I was stuck, as well as being able to maintain a sense of humor.

I would also like to thank Leanne Neshausen for providing a means with which to get started with mat lab.

I was incredibly lucky to have a very capable research assistant in Experiment 1. Melike Philipson was loved by all the students', and her efforts were much appreciated.

The schools that participated in this research were very accommodating and welcoming, and provided me with a huge learning experience for which I will always be grateful. I was also very lucky that all the students that participated were very eager to increase their rate, and were always interested and enthusiastic about the task at hand.

Finally I have to thank my husband, friends and family, who put up with me and provided moral support through.

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It is reasonable to suggest that the expected outcome of teaching and practice should be competent performance. Once a person is competent at the skill that was taught and practiced, there would be no further need of learning or practicing that particular skill. However, the difficulty is deciding when a performance can be considered competent. A commonly used method to determine competency is the accuracy of the performance. A performance that is 80 to 100 percent accurate is considered better than a performance that is 10 to 20 percent accurate. The question is, however, are all performances that have the same level of accuracy equally competent? With accuracy as the only measure it is not possible to answer this.

Perhaps another way to measure competency would be to measure the speed of performance. A person who can complete 100 maths problems in 1 min obviously finds the task easier than a person who can only complete 20 maths problems in 1 min. But again rate is an incomplete measure, as a speedy performance cannot be considered useful if the performance is not accurate.

A measure of performance combining accuracy and speed provides a better assessment of whether a performance is competent than accuracy or speed alone. As Kubina and Morrison (2000) assert, the number of items correct in a unit of time, or response rate, provides a better method of comparing performances than just accuracy, as time provides a standard unit of measurement. As such a performance over 10 s can be compared to a performance over 10 min or over 10 hr when converted to rate per min (or response rate).

The application of response rate to monitor peoples' learning in the classroom setting was first done in 1965 by Ogden Lindsley (Pots, Eshleman & Cooper, 1993).

Lindsley's refined use of response rate and cumulative recording to monitor students' learning was to become known as precision teaching (Lindsley, 1991). Since then precision teaching has been applied in a variety of settings, with different populations and behaviours (Johnson & Layng, 1992, Bucklin, Dickinson, Brethower, 2000, Downer, 2007, Pocock, 2006, Chiesa & Roberston, 2000, and Hartnedy, Mazzoni & Fahoum, 2005). While the monitoring of response rate is central to precision teaching, the frequency of measurement and how results are recorded and interpreted are also part of precision teaching.

Precision Teaching

Lindsley (1992) described precision teaching, as a method to monitor students learning which complements and improves any existing teaching strategy, as changes in teaching are directed not by external guidelines of what a child should be learning next, but by the learning picture created by the child's progress through a set curriculum. White (1986) and Kerr, Smyth and Mc Dowell (2003) agree that the methods that define precision teaching are pinpointing, counting and charting. Pinpointing refers to identifying the target behaviour and objectively defining it, how it is to change and the frequency required. During pinpointing, the learning channels to be used are identified. Learning channels identify the senses involved in receiving information by specifying the format of the problem/task to be completed, and the type of response required, these include combinations such as see/ say, hear/ write etc (Kerr et al., 2003). Counting consists of counting the number of times the pinpoint selected during pinpointing occurred in a set amount of time. The unit of measurement used is behaviours per minute, and the most commonly selected unit of time is 1 min, but the time selected for counting

can be shorter or longer as called for by the situation (Lindsley, 1992). During charting, the results obtained during counting are plotted on a semi-logarithmic graph. The y axis of this graph is the log component and displays the rate of behaviour while the x axis records calendar time (days, weeks, months or years). Lindsley created a Standard Celeration Chart (SCC) so that teachers could compare charted behaviour on a standard chart. The SCC is a semi-log graph with a landscape orientation and blue lines that is used by most precision teachers. The SCC was designed to display changes in frequencies as low as one in 24 hr to as high as 1000 in 1 min clearly, as changes in rate are proportional (White, 1986).

The term 'celeration' is derived from acceleration and deceleration, as those are the two ways that the frequency of behaviour can change (Cooper, Heron & Heward, 2007). When the rates of correct and incorrect responses are charted, the pattern produced by the changes in rate of correct and incorrect responses is referred to as the learning picture (Kerr et al., 2003). The learning picture is used during the charting phase by the person in charge of making changes to practice or to the curriculum, to evaluate whether the changes in the rate of correct or incorrect responses are accelerating, decelerating or staying the same. It is usually expected that the rate of correct responses will accelerate while the rate of incorrect responses decelerates. When rate stays the same, it indicates that the student is no longer learning and a change is needed (White, 2000). As changes in teaching strategy are based on the learning picture provided, changes made are specific to the students learning needs.

Lindsley (1992), Kerr et al. (2003), and Kubina, Morrison and Lee, (2002) all describe precision teaching as an overlay for existing teaching methods, which

complements and improves any existing teaching strategy, by providing a way to measure learning rate, and make curricular decisions based on these. Doughty, Chase and O Shields (2004), however, assert that some of the methods used in precision teaching, such as celeration aims, rate aims, rate building, 1 min timings, identifying components and composites, etc, are not just methods of measurement, as they are thought to affect the rate of learning. For example Johnson and Street (2004) found that rate-building was influenced by the celeration aims set, as students' actual acceleration tended to match their acceleration aims. While there is disagreement as to whether precision teaching is truly just a method of measurement, all are in agreement that the addition of precision teaching to an existing teaching method results in competent performance which can be described as fluent (Binder 1988, 1996, 2002).

Fluency

Binder et al. (2002) classifies behavior that is fast and accurate as fluent, they also add that behaviour that is fluent leads to the performance being automatic, thereby requiring less effort and concentration. Johnson and Layng (1996) suggested that the achievement of fluency in a newly learnt skill results in that skill: being retained for longer periods of time with no practice (retention), having endurance which is the ability to engage in that skill for periods of time that are longer than the usual practice (endurance), being unaffected by distractions (stability), being applicable, which is the ability to perform the skill in novel situations (application), and combining learnt components to solve unlearnt composite problems (adduction), which when combined form the acronym RESAA.

In the literature there is a split between those that argue RESAA results from fluency which by their definition is fast and accurate behaviour (Binder, Haughton and Bateman, 2002) , while others suggest that the definition of fluency is RESAA (Johnson & Street, 2004).

Haughton (1980) was the first to summarise the benefits of achieving fluency in the acronym R/APS, which stands for retention, application and performance standards. Performance standard refers to the setting of goals which specify the level of skill required before something is considered mastered (Binder, 1996). R/APS was later changed to REAPS, when increasing evidence suggested that fluency also results in students being able to sustain attention to a task for longer periods of time (Binder, 1977-1982). Johnson and Layng (1996) changed the REAPS acronym to RESAA. In RESAA, the definition of endurance was split into endurance and stability. Here the definition of endurance was narrowed to only refer to the ability to engage in the said behaviour for longer periods of time, and stability was added as a separate entity. The definition of application, was also further divided into application and adduction.

Discussion: What Causes Fluency?

It is suggested that there is a positive correlation between rates achieved, and the achievement of RESAA (Haughton, 1980, and White, 2000). Binder et al. (2002) even suggest that there are minimum rates to be achieved before RESAA will occur for skills such as reading, basic maths facts, hand writing and more. The rate aims that Binder et al. (2002) recommend are based on the average rates they believe competent performers of these skills can maintain. While this seems a logical way to set these, White (2000) indicates that this method of setting rate aims is not always guaranteed to result in

RESAA. In the example provided by White (2000) of a student with a pronunciation difficulty, the student was only able to apply and maintain the target skill once a rate aim that was double the rate of a fluent speaker, a rate aim which White (2000) described as super-fluency was set. While this makes it appear faster is better, there is some research that suggests progress is not always hindered by low rates, and that it is much more important that a students rate is accelerating rather than achieving pre set rate aims, and once acceleration stops to just move on White (2000).

A review of the precision teaching literature conducted by Doughty et al. (2004), indicated that there was not enough evidence supporting the idea that rate-building resulted in fluency as measured by RESAA. They concluded that once the effects of practice and reinforcement were controlled for, there was little evidence that the rate-building methods reviewed, were superior to accuracy-based methods in achieving fluency, they instead suggest that the achievement of fluency correlates better with the amount of practice and reinforcement available. Doughty et al. (2004) also comment on the fact that few studies which looked at retention and endurance controlled for the effects of practice and reinforcement. Furthermore no studies that looked at stability, application and adduction, controlled practice and reinforcement, and these studies were difficult to compare due to the varied definitions of stability, application and adduction.

More recent studies that compared rate-building and accuracy-based methods, and controlled the amount of practice and reinforcement, include a study done by Péladeau, Frogert and Gagné (2003), and unpublished maters theses completed by McGregor (2006) and Clarke (2007). These studies also found insufficient evidence supporting the superiority of rate-building methods in achieving fluency as measured by retention. What

these studies did find, was that the behaviours that were rate-built were performed at a faster rates at post-programme testing, than the behaviours where accuracy-based methods had been used. Thus, despite RESAA being attributed to the rate building that occurs in precision teaching, there is as yet not enough evidence to support this argument (Doughty et al., 2004).

Despite the shortage of evidence for the superiority of rate-building methods over accuracy-based methods to achieve fluency, Doughty et al. (2004) do conclude that teaching packages that include precision teaching, result in better outcomes. For example the Morningside Model of Generative Instruction which combines precision teaching with other methods such as Direct Instruction, Programmed Instruction, Personalized system of Instruction etc, have been so successful at increasing the speed with which students learn, that they can offer a money back guarantee if the student does not "gain two grade levels per year" (Johnson and Layng, 1994, p.174).

Furthermore it has been shown that the addition of precision teaching to a standard curriculum, results in students making larger gains, than they had with no precision teaching. This was the case in Great Falls precision teaching project that took place at the Sacajawea Elementary school in the 1970's. The addition of 20 to 30 min of precision teaching a day for three years, resulted in increases of 20 to 40 percentile points on standard achievement tests completed by the elementary school students (Kubina & Morrison, 2000). This was also the case in a UK primary school when Chiesa and Roberston (2000) applied principals of precision teaching to practicing maths facts. The students who had received precision teaching made much larger gains than students in the

control group, who in some cases preformed worse at post-programme testing than they did at pre-programme testing.

The general consensus in the literature is that when precision teaching is added to an already used curriculum, students perform better. Chiesa and Roberston (2000) defined better performance as the achievement of higher rates. Others such as Johnson and Street (2004) defined better performance in terms of whether or not RESAA was achieved. While there is much agreement that precision teaching improves any curriculum (Lindsley, 1992), since the Great Falls precision teaching project in the 1970's, only one study has been published that compares the addition of precision teaching to standard teaching, with standard teaching alone. This study is Chiesa and Roberston (2000), and is described below.

Precision Teaching in the Classroom

Chiesa and Roberston (2000) examined the use of precision teaching and its acceptability in the classroom. They designed a 12 Week precision teaching maths programme for 5, 9 to 10 year old students in the U K. The participants were selected by the classroom teacher and teacher aid due to them struggling to keep pace with the rest of the class. Before the programme started the teacher introduced the students to the concept that division was the same as find the missing factor of a times table equation. The composite to be tested was the division of two digit numbers, by the numbers one through to five. Before pre-programme tests were administered, the whole class was familiarised with time probes by completing a 1 min time probe using a worksheet containing addition and multiplication equations. The pre- and post-programme tests

consisted of one, 1 min probe of the composite skill (division) using the learning channels see equation/ write answer.

The first precision teaching session consisted of providing the students in the precision teaching group with folders containing a SCC, visual schedule and worksheets. During this session the students were instructed how to use the SCC and timers, visual schedule and worksheets. From then on the students in the precision teaching group worked on the work sheets, timed and marked each others work independently of the teacher, while the rest of the class was having their usual maths (this meant that amount of time spent working on maths was the same as the rest of the class). During the 12 weeks of the study, the researchers visited the class once a week for 30 min, to overview the precision teaching group's work, and make any changes needed based on the learning pictures provided by the SCC. During these times component and composite skills were analysed, and additional practice material was provided based on these analyses. In this study times tables up to and including the five times tables, and fill in the missing factor of times table equations were considered component skills as well as number writing. During the last two weeks of practice, the students worked on division equations. The rate aim was 40 to 50 equations a minute.

Chiesa and Roberston (2000) found that the students in the precision teaching group made much larger gains (increases of around 11-15 equations a minute) than did the students in the control group that had continued to receive their usual teaching, who in some cases preformed worse on the post-programme test, than they did on the pre-programme test (increases of around 0-14 equations a minute). Thus Chiesa and

Roberston (2000) managed to show that precision teaching can be successfully used to enhance an existing curriculum.

Experiment 1: A Comparison of Precision Teaching with Standard Teaching

In light of the previous discussion, the current study aimed to examine whether precision teaching can accelerate the learning of times tables when added to the method of teaching already in use in a classroom. This study also extended Chiesa and Roberston (2000) and examined whether precision teaching resulted in better endurance, stability, application and adduction than the ongoing teaching method. As in Chiesa and Roberston's (2000) study, the class teacher had already taught the class their times tables. Before this study began the teacher had the students practicing their times tables over the previous 3 school terms, with the aim of answering 100 multiplication equations in 7 min with at least 98 % accuracy. The method of practice selected for use in this study was as close as possible to the method the students had been using for this, with the addition of time probes and charting. Flash cards and a buddy system were used during practice. In order to test for rate, endurance, stability, application and adduction, four programme measures were created by the researcher that would be administered before the programme began and once the programme had finished.

Method

Participants

After ethical approval was gained from the Department of Psychology Research and Ethics Committee, at the University of Waikato, a school was approached, and a letter was given to the principal outlining what involvement in the study would include (Appendix A). After the board of trustees and the principal approved school participation in the study, teachers from the senior part of the school were given the option of

volunteering their class to be part of the study. One classroom teacher of year 5 and 6 students (ages 9-11), volunteered their class of 25 students to participate in this study.

Setting

Testing took place in the students' usual classroom, while practice took place in another small room (approximately 3x2m) between their classroom and a neighbouring class. The small room lead to both the girls and boys toilets, and had a drinking fountain. Because of this arrangement there was some traffic during practice sessions, due to other students using these facilities. Windows were situated in the walls that joined the small room to the other two classrooms. Also within the room was a table with eight chairs, a filing cabinet, and sports equipment.

Materials

The materials used in this study include measures to assess the students' rate of correctly answering times table equations before and after the programme, scripts and checks used during teaching, practice schedules, flash cards and checks.

Programme measures. The programme measures consisted of five different maths tests as shown in Table 1.1, all using the learning channels see equation/write answer.

The Rate, Stability, Endurance and Application/ Adduction Tests were created by the researcher and were used only for the purposes of this study. The 100-Equation Test was created by the school, and was used as a standard assessment measure throughout the school year. All equations printed on the Rate, Stability and Endurance Tests were times table equations ranging from 0 to 10 set out in a horizontal format (e.g. 2 x 3 = __). The

equations on the 100-Equation Test were set out in a vertical format (as shown in Appendix G) and also ranged from 0 to10. The Application/ Adduction Test included times tables as well as division equations and word problems. The problems were set out both horizontally and vertically. The Application/ Adduction Test was also the only test that had no time limit. All tests were printed in black ink, Times New Roman font, size 16 point, on white A4 paper.

Table 1.1

Properties of the five tests used to assess the participants' abilities

Assessments	No of problems	No of pages	Time to Complete (min)	Type of equations	Range of equations	Page layout	Appendix
Rate Test	125	1	1	Multiplication	0-10	Landscape	C
Stability Test	125	1	1	Multiplication	0-10	Landscape	D
Endurance Test	250	2	3	Multiplication	0-10	Landscape	E
Application/ Adduction test	62	1	As needed	Multiplication /Division/Words	0-55	Landscape	F
100-Equation Test	100	1	7	Multiplication	0-10	Portrait	G

Flash cards. Each student in the precision teaching group (PT group) was provided with 125 laminated flash cards, which were then divided into different decks based on a card allocation method discussed later. Each card measured 3.5 × 6 cm, and had an equation printed horizontally (e.g. 2 x 3 = __) on one side and the answer on the other. The equations covered the 0 to 10 times tables, with equations that contained a combination of the numbers: 4,6,7 and 8, being repeated, to provide extra practice opportunities, as these equations were identified by the class teacher as being commonly found difficult by students. All the numbers were printed in black ink, size 36 point Arial,

and each student's set of cards was a different colour from the cards of the other students in the group.

Precision teaching folders. A folder was provided for each of the 8 students in the PT group, each containing: A semi-log graph which also had space for recording the rate and timing floor on the right hand side of the page (Appendix H), a Daily Practice Record Sheet which had space for the participants to record the number of flash cards they answered correctly as well as the flash cards that were answered incorrectly or skipped during each practice, as well as the timing floor used (Appendix I), a Visual Schedule which in writing outlined the procedure to be followed by the participants during practice, providing tick boxes to tick after each step had been competed (Appendix J) and a folder sleeve that held the students flash cards.

Teaching to chart materials. The teaching to chart material included; Charting Worksheets for the students to fill out that introduced different components of charting separately (Appendix K), and a Charting Script outlining the instructions for the researcher to read to the participants while working on the Charting Worksheets (Appendix L). The work sheets and script were adapted from Vargas (1998).

Timers. Four digital timers that could be set to count down in seconds, minutes or hours, and then emit an audible beep were used.

Integrity Checking Forms. Three integrity check forms were used: an Assessment Integrity Check, which listed the equipment to be used, the procedure to be followed and the instructions to be read while testing next to blank tick boxes (Appendix M); a Teaching-to-Chart Integrity Check, which had the same content as the Charting Script with blank tick boxes next to listed criteria which had to be fulfilled (Appendix N); and a

Student Integrity Check, which listed actions to be completed and whether tasks such as providing feedback and counting cards were done accurately next to blank tick boxes (Appendix O).

Precision teaching script. A precision teaching script (Appendix P) which consisted of two A4 sheets instructing the students on how to use the flash cards, timers, and follow the Visual Schedule was used.

Procedure

Participant recruitment, as discussed in the participants section, was followed by allocating students to their groups.

Group allocation. The classroom teacher was given the option of splitting the class into two groups (one to receive precision teaching and one to continue to receive the standard teaching), based either on a random method of selection or on the students' inability to keep up with the rest of the class in math. The teacher chose to nominate students who in the last three terms had not managed to answer at least 98 equations correctly on the 100-Equation Test, within the 7-min time limit. As such, 8 students (7 year 5 students, 3 boys and 4 girls, and 1 year 6 boy), were nominated for the PT group. The rest of the students that were not nominated (17 students, 6 year 5 and 11 year 6 students), would continue receive their usual teaching and consequently formed the standard teaching group (ST group). Information sheets and consent forms were sent home to the guardians of all the students in the class (Appendix B).

All of the students' guardians consented for the scores the students obtained on some math tests to be used in this study. All guardians of the students nominated to be in

the PT group consented to their student receiving precision teaching and to receive any rewards for good work.

Pre-Programme testing. Once students had been allocated to their groups pre-programme testing was carried out. Four of the five programme tests (Rate, Stability, Endurance and Application/ Adduction Test) were administered by the research assistant. in the morning, right after roll call, on the first day of the study which was in the first week of Term 4 (the last term of the school year). The 100-Equation Test was administered in Week 2 and again in Week 8 of Term 4 by the classroom teacher. As the students were already used to doing timed tests, there was no practice round. The research assistant told the students that they were racing the clock, and to write down as many answers as they could before the timer went. It was emphasised that if they did not know the answer to an equation, then they should just skip it and move onto the next one. The research assistant also told the students that once the timer went, all students would have to stop writing. The research assistant then, with the help of the classroom teacher, handed the tests out face down. Students were instructed to turn over their paper just before the timer was started and to start the test. Once the timer went, they were instructed to stop writing answers and to write their name on their test, after which the tests were collected, and the next test handed out. The order of the tests was: the Rate Test, the Stability Test, the Endurance Test and then the Application/ Adduction Test. The timing was operated by the research assistant, whilst the teacher filled in the Assessment Integrity Check.

Teaching to chart. The same day as the pre-programme testing took place, the students in the precision teaching (PT) group were taught how to chart results on the

semi-log chart. This was done using the Charting Worksheets and Charting Script (see Appendix K & L). During this time the research assistant filled out the Teaching-to-Chart Integrity Check as the researcher read, and did the scripted actions. This took approximately one and a half hours, and was done after lunch.

Pinpointing. After being asked to identify a target to be taught using precision teaching, the classroom teacher selected the times tables 0 through to 10 to be the material for precision teaching. The learning channels to be used during practice were the same as the learning channels that had been used during times table practice for the previous three terms, which was see equation/ say answer. The rate aim set was 60 equations a minute. This rate aim was picked instead of the 70 equations a minute rate aim recommended by Binder et al. (2002) as the rate in this case was limited by the need for an observer to be able to recognise the number on the back of the flash card. This rate aim was slightly higher than participants in Hartnedy et al.'s (2005) study had achieved. The acceleration aim used was 2x based on Johnson and Street (2004).

Card allocation. While the PT students were finishing their charting, they were called up individually to be tested by either the researcher or the assistant researcher to see which of the times-tables printed on the 125 flash cards they could answer accurately within approximately 2 s (as counted: one thousand and one, one thousand and two) and which ones they could not. The deck of cards used was held by the researchers and shuffled, to ensure that the flash cards would be presented in a random order. The students were told to answer the shown equation as fast as they could, and that they could 'pass' on equations that they did not know, and that if they were too slow in responding the researcher would move on to the next card. From this two groups of cards were

formed, those the students could answer within approximately 2 s of presentation, which from then on were considered known, and those they could not, which from then on were considered unknown. Table 1.2 shows the equations each student did not know. From all the cards (both the known and unknown) two decks of cards were created for each student: an Easy Deck, which contained only known equations, and a Hard Deck, which contained some unknown and some known equations.

Table 1.2

The equations that were not answered within 2 s of presentation for each student.

Student	Equations Used													
Olivia	3×7	3×8	3×9	4×8	4×9	5×6	6×5	6×7	6×9	7×3	7×7	7×9	8×4	9×9
Kevin	3×6	3×8	4×4	4×6	6×9	7×4	8×9	9×6						
Daniel	4×9	6×7	7×3	7×7	8×4	8×7	8×8	9×8						
Tracy	3×8	4×8	4×9	6×7	6×8	7×4	7×6	7×8	8×6	8×7	8×8	9×4	9×6	9×7
Felicity	4×6	4×9	6×8	6×9	7×6	7×9	8×6	8×7	8×8	9×6	9×7	9×8		
Luke	3×7	3×8	3×9	4×7	4×8	4×9	5×9	7×3	7×5	7×8	7×9	8×4	8×7	8×9
Luke ctnd.	9×4	9×5	9×7	9×8										

As the rate aim was 60 flash cards a minute it was decided that the size of the Easy Deck should be 70 flash cards. In this way the students would be able to achieve, and slightly exceed the rate aim while still being able to manage their deck easily. As the number of known equations ranged from 106 to 117 flash cards, cards with equations containing 0, 1 and 10 were excluded from the Easy Deck (these cards were regarded as easier than cards that did not contain these numbers) to achieve the deck size of 70 flash cards.

The number of unknown equations ranged from 8 to 18 equations across the students. This was too small a number of cards for the student to answer each flash card only once and achieve the rate aim with a timing of 60, 30 or even 15 s. As such, the Hard Deck was set at 20 cards, this meant the students could achieve the rate aim with a 15-s timing with one go through the deck. A deck size of 20 was chosen as it was decided that there would be a higher probability of the unknown equations being presented during a time probe than if the deck size had been set to 70. To achieve the deck size of 20, known equations that were not included in the Easy Deck and so had not been previously practiced (equations with 0, 1 and 10), were selected at random added to the Hard Deck.

All students in the PT group practiced using their Easy Deck until the rate aim of 60 equations a minute had been achieved. Once the rate aim was achieved the students practiced using the Hard Deck. Once the rate aim was achieved using the Hard Deck, a Mastery Deck was formed by randomly adding 50 cards from the Easy Deck to the Hard Deck, so that the deck size would be appropriate for a larger timing floor of 30 or 60 s.

Precision teaching sessions. The precision teaching sessions took place for about half an hour every morning during the school week and began the day after pre-programme testing and after students had been taught how to chart. During the first precision teaching session, the PT students were assigned buddies from the other students in the PT group, and given their precision teaching folders containing flash cards, Visual Schedule, Daily Practice Record Sheet and semi-log graph. The researcher explained what was in the folders and why, then guided the students through their first practice, and taught students how to use the timers, by reading the precision teaching script (see

Appendix P). During this time the researcher and assistant researcher observed the students' practice and provided corrective feedback where necessary.

Precision teaching sessions consisted of students completing three rounds of practice with a buddy, by following and ticking of the Visual Schedule provided in their folders, independently of the classroom teacher. Each round consisted of a 1-min practice session, where the both buddies had 1 min to practice a skill of their choosing, ranging from answering specific equations/ handling their flash cards, or just practicing answering as many equations as they could. This was then followed by a speed trial. The speed trial consisted of one buddy answering as many equations as they could in the set time, placing cards with equations they answered correctly in a separate pile from those they skipped, while the other buddy observed to ensure that the number said by the student doing the speed trial matched the number on the back of the flash card. When the number said by the student doing the speed trial matched the number on the back of the flash card, the buddy watching did not do anything, when the number said did not match up with the number on the back of the flash card, the watching buddy would remove that flash card from the correct pile and place it onto the skipped pile. The student doing the speed trail was encouraged to skip a card rather than spend time thinking of the answer.

After a student had completed a speed trial, that student counted the number of cards they had answered correctly, and the number of cards they had skipped or answered incorrectly, and then recorded this on the Daily Practice Record Sheet. After this the students swapped roles. To avoid conflict between the students about who would do their speed trial first, the Visual Schedule's were headed as either A or B, and coordinated so that the students were instructed to monitor their buddy's speed trial while their buddy

was instructed to do the speed trial. At the end of each practice session, the students record their best rate from the Practice Record Sheet, on the semi-log chart. Once the students charted their best rate, the researchers drew a 2 x acceleration line for each calendar week from the data plotted that day for the next two days and explained that the students' goal was to stay above the line. As soon as the rate aim had been achieved, the students were moved onto the next deck of cards.

Either the researcher or the research assistant or both were present at every precision teaching session for the first 3 weeks of the study, after this the students did their practice on Tuesdays and Thursdays independently of the class teacher and researchers. When a researcher was present, the researcher would help students with their practice, be a buddy for participants whose usual buddy was away, observe a pair of students practice while filling out the Student Integrity Check, and make curricular decisions based on the data provided by the students' graphs. As long as acceleration aims were met, the acceleration aim was extended for anther two days and practice continued as usual till the rate aim of 60 cards a minute was met. When the acceleration aims were not met for two consecutive days in a row, attempts were made by the researchers to determine why, and then timings, cards or practice were altered.

Standard teaching sessions. During the precision teaching sessions, the rest of the class (the ST group) practiced their times tables using the learning channels see equation/ say answer using flash cards and a buddy system for approximately 10 to 15 min. The observing buddy would let their buddy know when they made a mistake answering their times tables. These practices were un-timed and the results were not recorded. Once times tables practice had finished, the students worked on other parts of the number

strand. The classroom teacher conducted timed tests (the 100-Equation Test), where the students had clear speed and accuracy aims, in the first and last two weeks of each term, including the term the study was done in. In addition she had students tracking their progress by graphing their results on bar graphs after each test was taken. When the students achieved the rate aim they received a certificate during assembly and a chocolate fish, and a new speed aim of 3 min would be set.

Post-programme testing. Post-programme testing occurred on the last day of the study, which was after eight weeks of times tables practice. The procedure followed was the same as the procedure outlined for the pre-programme testing, except that the researcher administered the tests instead of the research assistant.

Calculating interobserver reliability. The percentage of interobserver reliability for marking programme measures was calculated by dividing the number of marking agreements, by the number of marking disagreements added to the number of marking agreements, multiplied by 100. The percentage of rounds observed by either the researcher or the assistant researcher was calculated by dividing the number of rounds observed by the number of rounds completed by the students. The percentage of times that the students were observed to give accurate feedback, and count their cards and record their scores correctly was worked out by dividing the number of times that these events were observed to happen correctly by the number of observations.

Statistical analysis. Two-way repeated-measures ANOVAs were used to compare the results achieved on the Rate, Stability, Application/Adduction, Endurance and the 100-Equation Test completed by the students in the PT group and the ST group.

Results

Integrity Check for Programme Measures

The classroom teacher ticked all of the tick boxes on the Assessment Integrity Check at both pre- and post-programme testing.

Integrity Check for Teaching how to Chart

The integrity check for teaching how to chart showed that the researcher read the script and followed scripted actions accurately, as 100 % of the tick boxes were filled out by the assistant researcher.

Student Integrity Check

There were 33 days of precision teaching over 8 weeks. During every session of precision teaching, there were 3 rounds of practice. As students were away due to holiday, sickness or other extra curricular activities, the number of rounds of practice completed by each student was different, and these are recorded in Table 1.3. Of the 99 rounds of practice (3 rounds x 33 days) that occurred over the 8 weeks, 42 rounds were observed and recorded on the Student Integrity Check by either the researcher or the assistant researcher.

The number of rounds each student in the PT group was observed for and the corresponding percentage, as well as the percentage of times students provided accurate feedback and counted their cards accurately is also recorded on Table 1.3.

Based on the Student Integrity Check, all the students did the allocated practice, monitored their buddies speed trial, completed their own speed trial using the correct

speed trial length, and recorded their results 100 % of the times they were observed, as Table 1.3

The number of rounds each students completed, the percentage of these round that were observed, the percentage of times that each student was seen providing accurate feed back for their buddy, and the percentage of times that the students counted their cards accurately

Participant	Number of rounds completed	Number of rounds observed	Percentage of rounds observed	Percentage of accurate feed back given	Percentage of times cards were counted accurately
Olivia	90	15	16.67	80	60
Kevin	93	3	3.13	100	100
Luke	96	4	4.17	75	100
Felicity	90	6	6.67	83	100
Tracy	83	2	2.41	100	100
Dante	94	2	2.13	100	100
Daniel	79	8	10.13	100	87.5
Dorothy	60	2	3.33	100	100

worked out by dividing the frequency these tasks were performed by the number of rounds observed. The percentage of times students gave accurate feedback ranged from 75 to 100 % of the time when observed. Only Olivia, Luke and Felicity were observed to provide inaccurate feedback. In this case inaccurate feedback was accepting an answer as correct when in fact is was incorrect, or moving a card to the incorrect pile when in fact it was answered correctly. The percentage of times the students counted their cards accurately when observed ranged from 60 to 100 % of the time. Olivia and Daniel were the only students observed to miscount their cards, in that they recorded more

corrects than there actually were. The percentages were worked out by dividing the frequency of correct responses observed by the number of rounds observed.

Interobserver Reliability

The interobserver reliability for marking the programme measures was high, above 99.64 % for both pre- and post-programme testing. The interobserver reliability for marking the pre- and post-programme tests are shown in Table 1.4.

Table 1.4

The interobserver reliability for marking four of the programme measures from pre- and post-programme testing

Test	Pre	Post
Rate test	99.64	99.87
Stability test	99.85	100
Application/ Adduction test	99.78	99.77
Endurance test	100	100

Precision Teaching Results

Figure 1.1 shows the rate of correct and incorrect answers achieved each day by each student, over the study, as well as the speed trial length (timing floor) each day. The different decks used by each student are indicated by the numbers next to the solid vertical lines, and which deck each number relates to is shown in Table 1.5. The rule of when to change a students' practice, as described in the method (i.e., two sessions falling below the acceleration aim, or the achievement of the rate aim at least once), was followed in most cases. In cases where the rate aim was achieved, but recorded rates had a large range, i.e., from 32 to 88 (Day 9, Daniel), the student was required to achieve the

rate aim at least once more before the speed trial length was increased or they were moved onto the next deck.

Seven out of the 8 students in the PT group achieved the rate aim using the Easy Deck. For 6 of these 7 students decreasing the speed trial length to 15 s after their rate had plateaued with a 60-s speed trial length was the only intervention required for them to reach the performance aim at 15, 30 and 60 s. As can be seen on Figure 1.1, Kevin's rate plateaued with a 15-s speed trial length, as such his rate of flipping cards, his rate of see number/ say number while flipping cards (Kevin had to read the number on the

Table 1.5

Details of the phase changes shown in Figure 1.1, together with their associated decks.

Phase	Deck
1	Easy Deck
2	Hard Deck
3	Mastery Deck
4	Hard Deck- 8 times tables
5	8 times tables only
6	All 125 cards combined
7	11 and 12 times tables
8	Mastery Deck+ 11 and 12 times tables
9	13 and 14 times tables
10	Mastery Deck + 11,12,13 and 14 times tables
11	15 and 16 times tables
12	Mastery Deck + 11,12,13,14,15 and 16 times tables

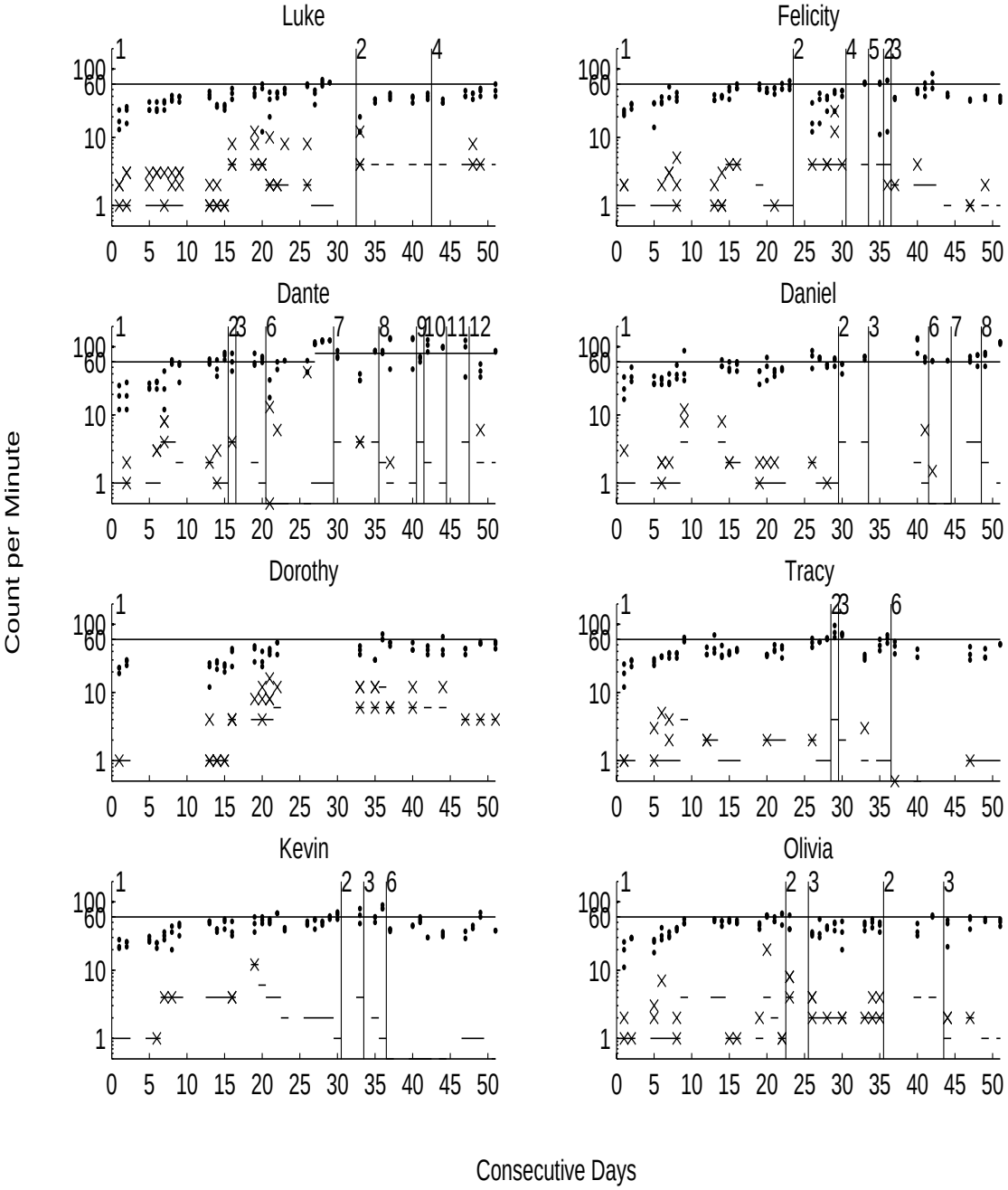


Figure 1.1 The correct rate as indicated by the dot, the incorrect/skipped rate as indicated by the x, obtained by each student in the Precision Teaching group during the three rounds of times table practice, graphed individually along with the timing floor as indicated by the broken horizontal lines, the rate aim as indicated by the solid horizontal line and the phase changes as indicated by the numbers next to the solid vertical line.

back of the cards while flipping them) and his accuracy with the times tables was checked (the researcher flipped the cards). Based on these results (flipping rate: 96 cards per min, rate of see number/ say number: 72 per min, and accuracy: 100 %) as well as one of the researcher's observation that Kevin tended to be slow to start the speed trial, it was decided to reduce the speed trial length to 5 s. From then on Kevin's rate continued to accelerate and his rate reached the performance aim with 5-, 10-, 15-, 30- and 60-s speed trial lengths.

Dorothy was the only student who did not manage to reach the performance aim using the Easy Deck. As can be seen on her graph in Figure 1.1, her rate did not accelerate when the speed trial length was reduced to 15 s. As she only skipped between 2 and 3 flash cards each speed trail, it was assumed that endurance was the problem and so the speed trial length was reduced to 10 s, which was then again reduced to 5 s after her rate decreased on Day 35. At 5 s Dorothy immediately achieved the rate aim, and so the speed trial length was increased to 10 s and then to 15 s.

Six of the students in the PT group achieved the performance aim with the Hard Deck, with no intervention from the researchers. Felicity achieved the performance aim with her Hard Deck only after her Hard Deck was split into two decks (Hard Deck- 8 times tables(4), 8 times tables only (5)) and practiced individually. Luke did not achieve the performance aim with the Hard Deck, as can be seen on his graph in Figure 1.1, his rate plateaued till flash cards containing the 8 times tables were removed from the Hard Deck.

As can be seen on their graphs in Figure 1.1, Dante, Daniel, Tracy and Kevin all reached the performance aim with the Mastery Deck before the end of the study. To make practice harder, all 125 cards were combined into one deck, as indicated by the

Phase Change 6, and their speed trial lengths were increased to 2 min (120 s). Before the end of the study Tracy's and Kevin's speed trial lengths were reduced to 60 s, as can be seen on the graphs. The reason for reducing the speed trial length for Tracy was that she had been away for a week, and before she left her rate had dropped, so it was reasoned that some time spent with a 60-s speed trial length would help her achieve the performance aim. Kevin's speed trial length was reduced to 60 s, in an attempt to increase his rate after his rate decreased. Upon further investigation, it was found that the drop in rate was due to Kevin having learnt that when held at the right angle, the flash cards became see-through. So instead of answering the equation, Kevin was trying to read the number on the back of the flash card. The researcher explained with the help of the graph, that by trying to read the number on the back of the card, Kevin was actually slowing him self down.

Dante and Daniel managed to achieve the performance aim using all 125 cards with a 2-min speed trail length. Thus the times tables 11 and 12, 13 and 14, and finally 15 and 16 were introduced a pair at a time, and then mixed with the rest of the deck as shown by the phase change lines 7 to 12.

Programme Measures

To compare the use of precision teaching with standard teaching when practicing times tables, all the students in both the PT group and the ST group completed the programme measures at pre- and post-programme testing. Four of the five tests were

administered on the first and last day of the study (Week 1 and Week 8 of Term 4), and the 100-Equation Test was administered in Weeks 2 and 8 of Terms 2, 3 and 4, and was administered by the classroom teacher.

100-Equation Test. The mean rates achieved by 5 of the 8 students in the PT group and 12 of the 17 students in the ST group are shown in Figure 1.2. If a student was away for one test, all their data was excluded from the calculations.

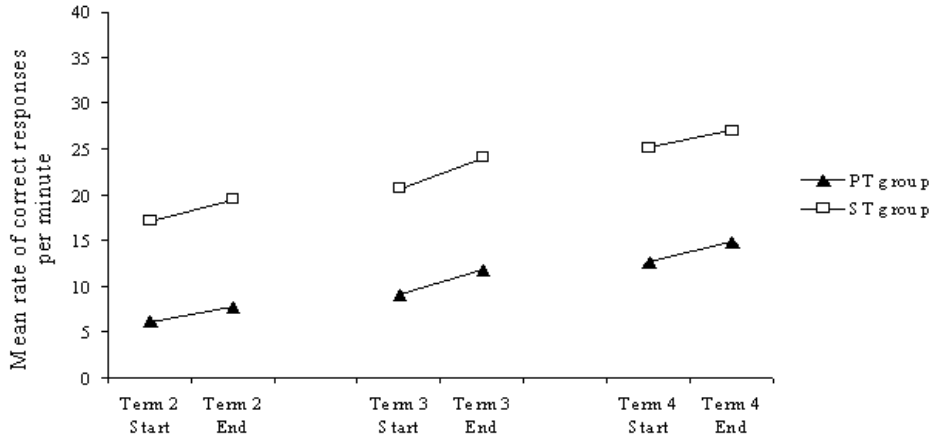


Figure 1.2. The mean correct rate on the 100-Equation Test for the PT group and the ST group at the start and end of Terms 2, 3 and 4.

As can be seen, there is a difference in mean rates of the PT group and that of the ST group, however, both groups made similar increases in their rates from the start of the year to the end of the year. A two-way repeated-measures ANOVA showed that the difference between the two groups ($F(1, 15) = 8.43$, $\eta^2 = 0.36$, $p < 0.05$) and the increases in rate across the terms ($F(5, 75) = 12.75$, $\eta^2 = 0.46$, $p < 0.05$) were both significant. While the interaction between these was not significant ($F(5, 75) = 0.09$, $\eta^2 = 0.01$, $p > 0.05$). Examining the change in rates for the students in the PT and ST groups separately, gave effect sizes (Cohen's d (Cohen (1977)) as follows; Term 2, 0.59 for the PT group and 0.51 for the ST

group, Term 3, 3.64 for the PT group and 0.61 for the ST group, Term 4, 1.28 for the PT group and 0.47 for the ST group.

Rate Test. The mean rate of answering multiplication equations at pre- and post-programme testing for all the students in the PT group and ST group are shown in Figure 1.3. The rate increased for both groups by about the same amount.

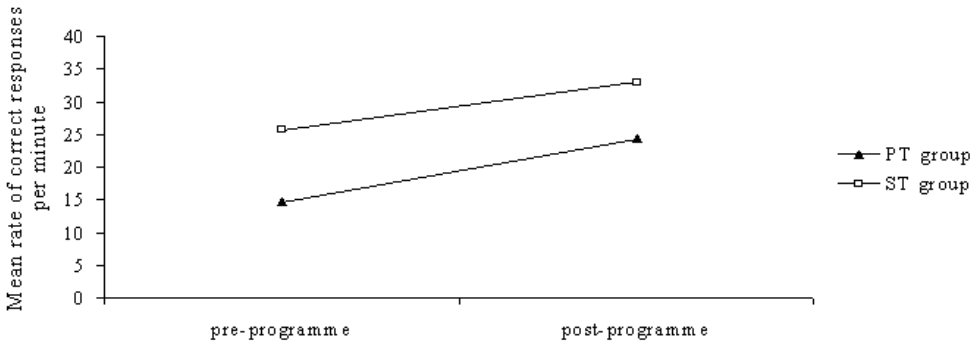


Figure 1.3. The mean rate of answering multiplication equations correctly at pre- and post-programme testing for the PT group and the ST group on the Rate Test.

A two-way repeated-measures ANOVA showed that the change in rate from pre-programme to post-programme testing was significant ($F(1, 23) = 59.51$, $\eta^2 = 0.72$, $p < 0.05$) for both the PT group and the ST group, but that the groups were significantly different ($F(1, 23) = 11.78$, $\eta^2 = 0.34$, $p < 0.05$). The interaction between these, however, was not significant ($F(1, 23) = 1.30$, $\eta^2 = 0.05$, $p > 0.05$). Examining the change in the rates for each group separately gave effect sizes (Cohen's d) of 5.48 for the PT group and 1.99 for the ST group, both would be classified large effects by Cohen (1977).

Stability Test. The Stability Test had the same format and equations (arranged in a different order) as the Rate Test, differing in that a distracter was added in the form of a radio playing during the 1-min duration of the test. The mean rates for the PT group and the ST group from pre- to post-programme testing are shown on Figure 1.4. The mean

rate of answering multiplication equations increased by about the same amount for both the PT group and the ST group.

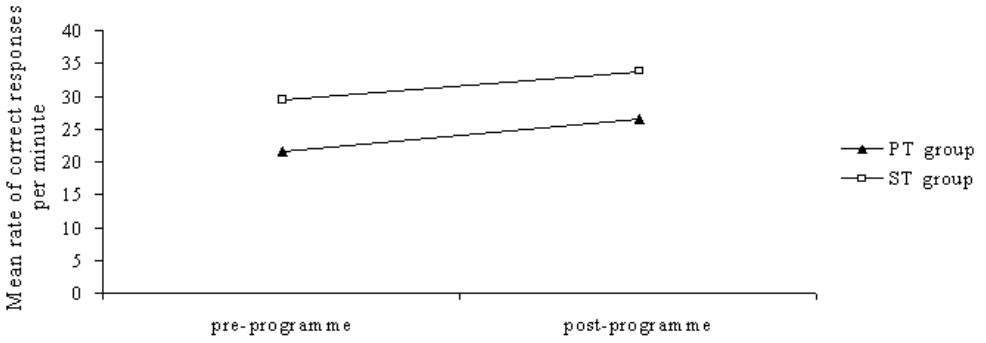


Figure 1.4. The mean rate of answering multiplication equations correctly at pre- and post-programme testing for the PT group and the ST group on the Stability Test.

A two-way repeated-measures ANOVA showed that the increase in rate ($F(1, 23) = 14.09$, $\eta^2 = 0.38$, $p<0.05$), and the difference between the two groups ($F(1, 23) = 6.54$, $\eta^2 = 0.22$, $p<0.05$) was significant. However, the interaction between these was not ($F(1, 23) = 0.06$, $\eta^2 = 0.00$, $p>0.05$). Separate comparisons of the rates students in the PT and ST group achieved at pre- and post-programme testing gave effect sizes (Cohen's d) of 2.73 for the PT group and 1.09 for the ST group (Cohen, 1977), both would be classified as large by Cohen (1977).

Application/Adduction Test. This test differed from the other tests in format as well as content, and was split into seven different sub sections ranging from a to g. Sections a, b and d all consist of 12 equations. Section a. consisted of filling in the missing fact (i.e., 4 × _ = 12), section b. was comprised of division equations ranging from the 0 to 10 (20 ÷ 10 = _), and section d. consisted of multiplication equations ranging from 0 to 10 but presented in a vertical format instead of horizontal. Section c. of the test consisted of ten multiplication equations that used numbers larger than 9 (i.e. 20 ×

40 = _). Section e. and g. of the test had 6 problems. Section e. consisted of multiplication equations presented in a vertical format with a two digit number at the top and a single digit at the bottom. Section g. consisted of word problems. Section f. had 4 multiplication equations presented in vertical format, with two digit numbers at the top and the bottom.

The mean score for the PT group and the ST group from pre- to post-programme can be seen on Figure 1.5. Examinations showed that there was no consistent difference between the groups or any large change from pre- to post-programme testing.

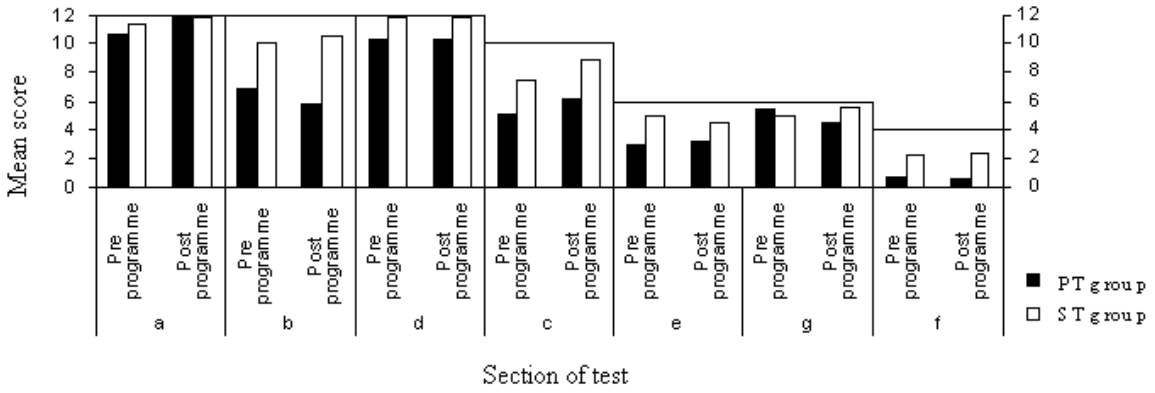


Figure 1.5. The mean score on each section, as described in text, of the Application/Adduction test from pre-to post-programme testing for both the PT group and the ST group, as well as the corresponding max score as indicated by the solid horizontal line.

Endurance Test. Mean rates for the PT group and the ST group from pre- to post-programme testing are shown on Figure 1.6. The PT group's rate increased slightly more than the ST group's rate as can be seen by the line for the PT group having a somewhat steeper slope than that of the ST group. However, a two-way repeated-measures ANOVA showed that while the mean increases in rate from pre- to post-programme

testing ($F(1, 23)= 15.91$, $\eta^2 = 0.41$, $p<0.05$) and the difference between the two groups ($F(1, 23) = 4.33$, $\eta^2 = 0.16$, $p<0.05$) was significant, the interaction between these was not significant ($F(1, 23) = 0.61$, $\eta^2 = 0.03$, $p>0.05$). Comparing the rates students in the PT and St group achieved at pre- and post-programme testing for each group separately gave effect sizes (Cohen's d) of 1.94 for the PT group and 0.84 for the ST group, these would be classified as large effects by Cohen (1977).

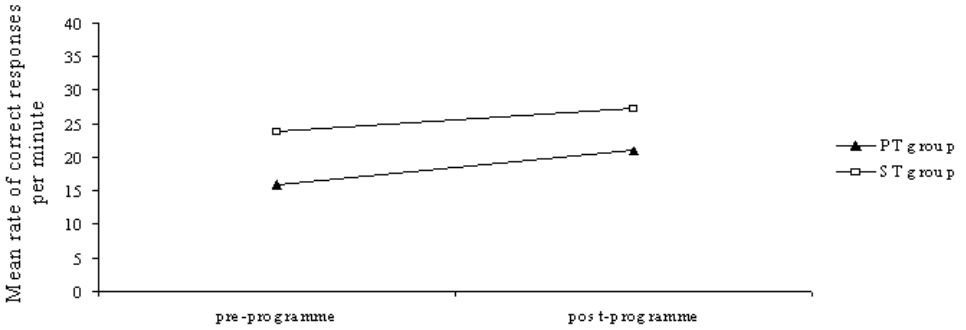


Figure 1.6 The rate of answering multiplication equations correctly at pre- and post-programme testing for the PT group and the ST group on the Endurance Test.

Across-test performance. Figure 1.7 shows that when the students' rates are compared across the 100-Equation, Rate, Stability and Endurance Test at the beginning of the study, 3 of the 8 students in the PT group and 7 of the 17 students in the ST group had their slowest rates on the 100-Equation Test.

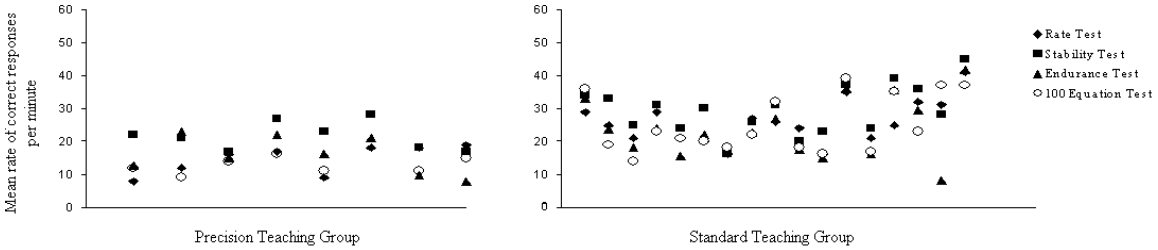


Figure 1.7. The rate each student in the PT group on the left and the ST group on the right, achieved on Rate, Stability and Endurance Test, at pre-programme testing, with the rate the students achieved on the 100-Equation Test as the start of Term 4.

By the end of the study 7 students in the PT group and 8 students in the ST group had their slowest rate on the 100-Equation Test, as can be seen on Figure 1.8.

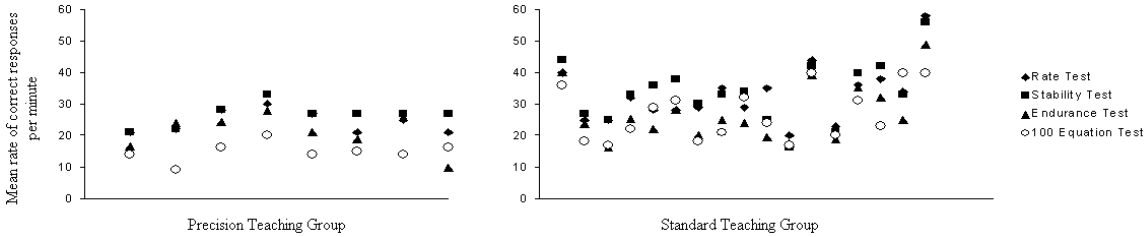


Figure 1.8. The rate each student in the PT group on the left and the ST group on the right, achieved on Rate, Stability and Endurance Test, at pre-programme testing, with the rate the students achieved on the 100-Equation Test as the end of Term 4.

Correlation of Practice and Changes in Rate for the PT group

Table 1.6 lists the number of equations each student answered correctly and the number of equations each student answered incorrectly or skipped over the 8 weeks of the study. The changes in rate for each student from pre- to post- testing on the Rate Test are also given in Table 1.6. Correlation between the total number of equations each student was exposed to (correct plus skipped or incorrect) and the change in rate on the Rate Test resulted in a correlation of -0.17 which was not significant ($n = 8$, $p>.05$).

Table 1.6

The combined number of flash cards/equations students answered correctly or incorrectly/skipped with the improvement each student made on the Rate Test from pre- to post-programme testing.

Name	Number of equations exposed to	Improvement from pre to post testing on Rate Test
Luke	2150	13
Felicity	2555	13
Dante	4763	2
Daniel	3589	10
Dorothy	801	3
Tracy	3071	7
Kevin	3096	12
Olivia	2462	18

Discussion

This study aimed to replicate and expand Chiesa and Roberston (2000). Chiesa and Roberston (2000) showed that the addition of precision teaching to an existing maths curriculum, in a UK primary school, resulted in better outcomes (faster rates on the post-programme measures) than standard teaching alone. In this present study there was a significant improvement from pre- to post-programme testing for both groups, but no significant difference in improvement between the two groups on four out of the five programme measures used (Rate, Stability, Endurance, and the 100-Equation Test). However, the addition of precision teaching produced larger effect sizes in the change in rate from pre- to post-programme testing for the PT group, a finding showing that with a larger number of participants the differences may have been significant.

The finding of no significant difference in the degree of improvement for the two groups differs from that of Chiesa and Roberston (2000) who, however, used a similar numbers of participants. Possible reasons for this difference in outcomes are discussed below.

The learning channels used (see equation/ write answer) in the study completed by Chiesa and Roberston (2000) were the same in practice and testing. However, in the current study the learning channels used for testing (see equation/ write answer) were different from those used during practice (see equation/ say answer). As the skill practiced did not involve any writing, any lack of fluency in the tool skills required to write the answers to the written equations on the programme measures would not have been detected during practice and so it unlikely that writing would have improved in fluency. As the pre- and post-programme tests involved writing only, they were probably not a good assessments of any changes in the students' rate of saying the answer. The students' charts show that they obtained larger increases in their rate of see equations/say answer during practice than their rates on the programme measures, which used the learning channels see equation/write answer, suggest. A better way to measure changes in the students' rates from pre- to post-programme would have been to test the students see equation/ say answer rate using either flash cards or a work sheet. However, this was not the way the teacher normally measured performance and using this would have probably disadvantaged the rest of the class. Another alternative would have been to get the students to practice using the learning channels see equation/ write answer. This, however, would have altered the method of practice that the teacher was currently using more than just adding precision teaching did.

A small difference between the studies comes from the procedures used to select participants. The method used by Chiesa and Roberston (2000) was that the classroom teacher selected the students to receive precision teaching based on the students being "unable to keep pace with the rest of the class" (pp 302). In this study, however, the classroom teacher identified the selected students as those unable to keep pace with the rest of their class based on the students not having managed to answer 100 equations with 98 % accuracy within 7 min. This difference is not large and probably does not contribute to the different outcomes.

It is also possible that the students who were selected to be in the PT group here already had difficulty with applying what they had learnt to novel situations such as a test. If the students in the PT group were really biased against being able to apply what they had learnt to novel situations, differences between the practice and the test environment would all reduce application. These differences included; the learning channels used, the seating arrangement, the font size and type, the number of equations presented in one go, the colour of the paper used, the format of the equations (horizontal or vertical), and the level of noise. Possible outcomes from using different learning channels during practice and testing have already been discussed above while the difference in the level of noise from practice to test environment, and the format of equations are discussed below.

One difference between practice and testing was the noise level. During practice there was a high level of noise in the precision teaching environment with students saying numbers out loud, timers going off, as well as noise from the neighbouring class rooms. In contrast, in the test environment there was little to no noise, apart from during the Stability Test. Interestingly, all the students did much better on the Stability Test than

they did on the Rate Test both before and after the programme. Whether this was because of the level of noise or because the test was some how easier cannot be known without further testing, but it is possible the students in the PT group would have done better on the programme measures had the level of noise been kept consistent during practice and testing.

Another difference between practice and testing was the equation format. It stands to reason that if the students had difficulty with application, their rates achieved on tests where the format of the equations was the same as the format used during practice should be higher than their rate on tests where the format is different. The format of equations printed on the flash cards which were used during practice was horizontal. When the students rates on the Rate, Stability and Endurance Test (equations horizontal) were compared with the students' rate on the 100-Equation Test (equations vertical) at pre-programme testing it was found that 3 out of 7 students in the PT group and 7 out of 17 students in the ST group achieved the lowest rate on the 100-Equation Test. For both groups there was no real difference in rates across the four tests. But by post-programme testing it was found that 7 out of 8 students in the PT group and 7 out of 17 students in the ST group had the slowest rate on the 100-Equation Test. Clearly the students in the PT group had the most difficulty with the 100-Equation Test, indicating that the format of the tests may have affected the students' performance. However, another explanation for the students' lower rate on the 100-Equation Test could be a lack of endurance. During the 100-Equation Test, students had 7 minutes to answer 100 equations, it is possible that the students were not able to maintain the rate that they were able to for a 1-min test. Support

for this is that it can be seen on the celeration charts that rate dropped as timing floors increased.

Chiesa and Roberston (2000) do not report whether there was any correlation between the amount of practice and increases in rate from pre- to post-programme testing. In this study, however, there was a weak negative correlation (-0.17) between the amount of practice as measured by the number of flash cards students answered correctly, incorrectly or skipped, during practice and the improvement students made on the Rate Test from pre- to post-programme testing. Given the old cliché 'practice makes perfect', a stronger positive correlation between practice and improvement might have been expected (Ericsson, Krampe & Tesch-Romer, 1993, Doughty et al., 2004). It may be that the lack of a positive correlation between practice and change in rate from pre- to post-programme testing resulted from the use of different learning channels during practice which has been discussed above.

A further difference from Chiesa and Roberston (2000) is that they used a practice test to familiarise students with timed tests but this was not done here. It was reasoned that as the students had experience doing a timed test several times already during the year (the 100-Equation Test) a 1-min test would not be so different. However, when the results were examined, the effect of the students being unused to a test that was only a minute long may have resulted in the students rate on the Rate Test being lower than their usual rate, which would have explained the sudden increase in rate on the Stability Test. By post-programme testing all the students still did better on the Stability Test, but the difference between rates on the Rate Test and the Stability Test was not as large. Thus it is possible that the increases in rate from pre- to post-programme testing on the Rate Test

maybe somewhat inflated by the students becoming more familiar with the 1-min test by post-programme testing.

Chiesa and Roberston's (2000) students plotted their scores on a SCC. In this study the students plotted their scores on a different semi-log graph. This means that the learning picture created by the plotted correct and incorrect rates was different from the learning picture that would have been created had a SCC been used. For the purposes of replicating the Chiesa and Roberston (2000) study the use of a different type of semi-log graph should not have affected the outcome. The researcher was still able to make curricular decisions based on whether rates were accelerating, staying the same or decelerating. The use of a chart other than a SCC does pose a problem for creating the acceleration line for students to beat. On a SCC a 2x acceleration line is one that runs parallel to a line that runs from the bottom left corner to the top right corner (White, 1986). Thus the 2x acceleration line drawn on the students' charts in this study could only have been a best guess of a 2x acceleration line. Possibly, in future studies a SCC should be used, or curriculum decisions should be based only on whether rates are accelerating or not.

In this study either the researcher, or the research assistant was present at every session of precision teaching for the first three weeks of the study, after which the researcher was present every Monday, Wednesday and Friday for the rest of the study. In Chiesa and Roberston (2000), the researchers visited the classroom only once a week. That the researchers were present more in this study should not have detrimentally affected the results of this study.

In this study curriculum decisions were made sooner than in Chiesa and Roberston (2000). Here practice was changed after two days of rates failing to reach the acceleration aim whereas Chiesa and Roberston (2000) made curriculum decisions at the end of each week. White (2000) recommends making curriculum decisions after 3 days of rates failing to achieve the acceleration aim. Thus it may be that the quick curriculum changes were not sensible.

Because of the low number of integrity checks performed for each student (42 practice rounds were observed, which when distributed across the 8 students meant that each student was observed between 2 to 15 times), the integrity of the charted results cannot be guaranteed. It is possible that some reported rates were inaccurate, especially rates above 100 equations a minute as it was believed that the student observing the speed trail would have struggled to recognise the numbers on the back of the cards. If charted rates were inaccurate it would have been expected that there was a large variability in students' rates. This was not the case as can be seen on Figure 1.1. Furthermore students did compensate for the difficulty of recognising the number on the back of the flash card by lowering their eye level to that of the flash cards, or by checking the card only once it has been placed on the table, and some of the unexpectedly high rates reported by the students were observed by the researchers during the integrity checks.

An important variable here is the quality of the existing teaching. Although referred to as "standard" teaching the teaching in this classroom appears to difer somewhat from that in the Chiesa and Roberston's (2000) study. The students in the ST group in this present study made larger gains on average from pre- to post-programme testing on the Rate Test (about seven equations a minute) than did the students in the

control group of the Chiesa and Roberston (2000) study (average increase in rate of about one equation a minute). The larger gains made by the students in the ST group could be explained by the classroom teacher already using some of the methods used in precision teaching. For example, the students were tested at the start and end of each term using the 100-Equation Test, where the students had a speed aim (complete 100 equations within 7 min) as well as an accuracy aim. Furthermore the students recorded the accuracy and speed results on a bar graph. While testing and graphing did not occur as frequently as it does in precision teaching, the clearly set out speed and accuracy aims and the incentive to achieve these (certificate and chocolate fish) are likely to produce better learning outcomes than if these methods were not in place.

The rates of both the PT group and ST group improved significantly over the programme. In actual fact the change in the rate from pre- to post-programme testing for the PT group gave a larger effect size than for the ST group – but the difference was not big enough for the difference between the groups to be statistically significant. The size of the variances, the unequal group size and the small numbers of participants in the PT group all contribute to this result. While these may be part of the reason why the PT group's improvements were not significantly larger than the ST groups, given the other discussed variables they are unlikely to be the major factor in the difference between this study's and Chiesa and Ronbertson's (2000) results. Furthermore the groups in Chiesa and Roberston (2000) study were even more unbalance with only 5 students in the PT group and 20 students continuing to receive the standard teaching, and a significant result was still achieved.

In conclusion the use of different learning channels for testing and practice, and that the students in the PT group may have been those with specific difficulties in application, are both likely explanations as to why the students in the PT group did not achieve significantly faster rates or better endurance, stability, application or adduction than the ST group. Furthermore, the "standard" teaching contained elements of precision teaching and it is possible that it was of better quality than the standard teaching used in the Chiesa and Roberston (2000) study. Thus a further study, where more variables (such as the learning channels, participants bias, and teaching methods used) are controlled, is needed to allow a better comparison between compare practice with and without precision teaching.

Experiment 2: A Comparison of Practice With and Without Precision Teaching

As has been mentioned previously, it is often reported that the addition of precision teaching to an already used curriculum results in better outcomes such as faster rates, higher accuracy and faster progress along a curriculum (Doughty et al., 2004). Furthermore it is often reported that students enjoy precision teaching, that practice becomes fun (Lindsley, 1992). However, as yet there is a lack of published studies showing this (Doughty et al., 2004). The results of the previous experiment here were inconclusive.

The purpose of this next study was to determine whether the addition of precision teaching to times tables practice would result in faster and more accurate rates of answering the 1 to 10 times table equations, and whether these would be better retained after a period of no practice. This next study also looked at whether students preferred practice with precision teaching or practice without precision teaching.

The study involved 6 students receiving precision teaching, while another 6 students practiced their times tables with no precision teaching. In this study it was ensured that the same learning channels were used for practice and testing. The use of the same learning channels during practice and testing was hypothesised to result in rates on the programme measure being similar to practice rates. The programme measures used in this study were a Practice Test containing addition equations and a Speed Test containing multiplication equations ranging from 1 to 10, and a Personalised Test created for some of the students' containing only equations that the students had experienced during practice. Programme measures were taken both before times table practice began and after practice had finished. To measure the students' retention of their times tables, a

measure was also taken after two weeks of no practice. As in the last study the students were already familiar with the times tables to be used during practice which were the 1 to 10 times tables.

Method

Participants

After ethical approval was gained from the Department of Psychology Research and Ethics Committee, at the University of Waikato, the principal of a school was approached, and provided with an information sheet (Appendix Q) outlining what involvement in the study would include. The principal then referred the researcher to the head teacher for year 6 students. The procedure was outlined to the head teacher, who then decided which maths class would be involved. As such the classroom teacher randomly selected 12 students ages 10-11 to take part in the study.

Setting

The research took place in the "hub" which is a room (approximately 6 x 4 meters) between four classrooms, four days a week from 9.10 am, (or when the class teachers sent out the students) to 9.30 am. The hub contained two sinks, a drinking fountain, access to a resource and learning recovery room as well as the boys and girls toilets. As such there was some traffic, due to other students and teachers using these facilities. Available for use in the hub were four desks, and two tables, which when combined created the shape of a hexagon, and could seat six students, as well as space on benches attached to the wall.

Materials

Programme measures. The programme measures consisted of two tests, a Practice Test which consisted of addition equations (Appendix R), and a Speed Test which consisted of multiplication equations (Appendix S). For 5 students an additional personalised measure was created that contained only the equations that the student had practiced. The tests contained 120 equations which were arranged in a horizontal format, distributed across 6 columns and 25 rows. The column on the far right and the row on the bottom were left blank for marking purposes. The equations were arranged in a random order on the tests and were printed in black ink, using the Times New Roman font size 14 point, on white A4 paper, the page orientation was portrait. The learning channels tested were see equation/write answer. The time limit for each test was 1 min.

Worksheets. Three different types of worksheets were used, the standard worksheet, the R (rate building) worksheet and the E (error correction) worksheet. The number of rows and columns in each grid, as well as the number of equations per grid and time to complete each grid, for each worksheet are shown in Table 2.1 below. The format of the standard worksheet was like the format of the Speed Test, 120 times table equations ranging 1 to 10, were arranged in a random order over 6 columns and 25 rows, with the column on the far right and the row on the bottom being left blank. Depending on the timing floor used the R worksheets contained one (60 s), two (30 s) or four (15 s) grids, and always had 60 s worth of practice. The way that the R worksheets differed from the standard worksheets was that only equations considered known (procedure for equation selection described later on) were included in the R worksheets. As can be seen on Table 2.1, the E worksheets either contained one large or two smaller grids depending

on the timing floor, each work sheet provided 60 s worth of practice. The grids on the E worksheets contained three to four fact family equations (1x2 and 2x1 were counted as the same fact family), that were considered unknown, repeated in a random order. Like the programme measures the worksheets were printed in times new roman font, size 14, on white A4 paper, and can be seen in Appendix T, U, V, W, X, Y.

Table 2.1

The number of grids on each worksheet, and the number of equations in each grid, as well as the grid lay out and the amount of time allowed to complete each grid.

Worksheet name	Number of Equations per grid	Rows/ Columns	Number of grids per page	Time to complete each grid	Appendix
Standard	120	25/ 6	1	10min	T
R 60s	120	25/ 6	1	60s	U
R 30s	50	11/6	2	30s	V
R 15s	25	6/6	4	15s	W
E 60s	80	20/4	1	60s	X
E 30s	40	10/4	2	30s	Y

Folders. Twelve folders were used in this study, six of these folders contained, a semi-log graph (Appendix H), Daily Practice Record Sheet (Appendix AA), times table chart used for marking (Appendix Z), and a folder sleeve which held new worksheets. The other six folders contained a Practice Record Sheet, and a times table chart (Appendix AB).

Charting materials. These included Charting Worksheets, that introduced the different components of charting separately, and a Teaching to Chart Script outlining the instructions for the researcher to read to the participants while they worked on the

Charting Worksheets (Appendix AC & AD). Work sheets and script were altered from Experiment 1.

Timers. The same timers as were used in Experiment 1 were also used in this study.

Integrity checking forms. Two integrity checking forms were used; the Assessment Integrity Check, used to check that the same procedure and equipment was used at each testing, and a Teaching-to-Chart Integrity Check which was used to ensure the researcher read the Teaching to Chart Scrip accurately and did scripted actions. These checks each had instructions/ criteria to be fulfilled next to blank tick box, and can be seen in Appendix AF & AE.

Procedure

The procedure consisted of participant selection, the administration of the programme measures at pre-programme testing, teaching the students in the PT group how to chart, times table practice and the administration of the programme measures at post-programme and retention testing as well as the administration of the Personalised Tests. Finally programme measures were assessed using a two-way repeated-measures ANOVA

Group allocation. The 12 year six students that were selected by the classroom teacher to participate in this study were randomly assigned to one of two groups by the researcher. As such 6 students (2 girls and 4 boys) were assigned to a group that would receive precision teaching while they were practicing their times tables (PT group), and 6 students (3 girls and 3 boys) were assigned to a group that would not receive precision teaching while practicing their times tables (NPT group).

The teacher was then provided with 12 consent forms with the students' names already written on them to send home to the guardians of the students. Consent was received for all 12 participants. Before precision teaching began the classroom teacher recommended that one of the students assigned to the PT group should change to the NPT group due to him attending a music classes on the day the students in the PT group were taught how to chart. The classroom teacher's advice was followed, and to keep the groups even another student who had been assigned to the NPT group was reassigned to the PT group.

Pre-programme testing. Pre-programme testing took place before times table practice began, which was the Monday of Week 4 of Term 1. Testing took place in the Hub, and all the students were seated at either a table or a desk with a gap between them and the next student. The researcher explained to the students that they were racing the clock, that they had 1 min to complete each test, and to write down as many answers as they could before the timer went, but to stop writing as soon as they heard the timer. It was emphasised that if the students did not know the answer to an equation, they should skip it and move onto the next equation.

The tests were handed out separately, and face down. Students were instructed to turn over their paper just before the timer was started. Once the timer sounded the end of the minute, the students were instructed to write their name on their test, after which the tests were collected. The Practice Test was completed first, in order to get the students used to doing a timed 1-min test, with out giving the students a chance to practice their times tables, as done by Chiesa and Roberston (2000). After the Practice Tests were named, dated and collected, the Speed Test was handed out and completed.

After the students had completed the Speed Test, they were asked to indicate their like or dislike for times tables practice by drawing a face to indicate either like ☺, ok ☺ or dislike ☹, as modelled by the researcher on a blank white A4 piece of paper. During this time a volunteer completed the Assessment Integrity Check.

Teaching to chart. Before times table practice began, the students in the PT group were taught how to chart results on the celeration chart. This was done using Charting Work Sheets and the Teaching to Chart Script. During this time a volunteer filled out the Teaching-to-Chart Integrity Check as the researcher read, and did the scripted actions. This took approximately half an hour.

Times table practice. After pre-programme measures were taken and the students in the PT group had been taught how to graph results, both groups did times table practice. Times table practice took place for 20 min (from 9:10 to 9:30), four days a week in the hub over five weeks, starting the day after pre-programme testing. The learning channels to be used during practice were the same as the learning channels used during testing (see equation/ write answer). The PT group did timed practice and recorded their results, while the NPT group had 10 min to complete one worksheet. At the end of every day that times table practice had taken place the researcher would remark all the students' worksheets, and calculate the agreement between the students and researchers marking. Agreement was calculated by dividing the number of problems that were marked the same by the student and the researcher (agreements) by the number of problems that were not marked the same by the student and the researcher added to the number of agreements.

For the students in the PT group, times table practice consisted of students completing three worksheets (one R worksheet and two E worksheets, or vice versa)

using various timing floors, marking their own work, recording their scores, and charting their best score. While practicing their times tables each student in the PT group either had their own timer, or shared a timer with one other student. The students set their own timers, or took turns when the timer was shared.

The criterion to change a student's practice was based on their rate having plateaued over three consecutive days, or once the rate aim had been achieved. In the case of a plateau, the researcher would aim to determine what was slowing the student's rate by cheeking the student's writing speed, or accuracy and then adjust practice in a way to overcome this. When a student's rate reached or exceeded 70 equations a minute the timing floor was increased till student achieved the rate aim using a 1-min timing floor.

To determine which equations the students could answer accurately under time pressure the students spent the first two practice sessions, completing six standard worksheets (three worksheets each session), with a 60-s timing floor. Based on these results as well as the students performance on the Speed Test equations were divided into those the students could always answer accurately under time pressure (known equations) and those that they answered incorrectly or skipped at least once (unknown equations).

All known equations were included in the R worksheets that were created for each student. The aim of the R worksheets was to rate build the known equations until the students could answer at least 70 equations correctly in 1 min. As the results from Experiment 1 suggested the most effective way to increase a students rate of correctly answering already known equations was to start with a low timing floor, the R worksheets started with a 15-s timing floor, and once the rate aim had been achieved, moved onto a 30-s timing, and then finally a 60-s timing.

All the unknown equations were introduced three to four equations at a time in the E worksheets. The purpose of the E worksheets was to first introduce new equations and then rate build. Thus the first timing used when new equations were introduced on the E worksheets was 60 s, and only after a plateau a 30-s timing was used to help the student reach the performance aim. The rate aim on the E worksheets was 60 equations a minute. When the rate aim was achieved on an E worksheet (60 equations a minute), the equations were transferred to the R worksheets, and a new set of equations were introduced.

For the students in the NPT group, practice consisted of answering as many equations as they could in 10 min using the Standard worksheet. If the students finished before 10 min had passed, as measured by an electronic timer, they recorded the time left on the timer, and then started marking their own work. Once they had marked their work, the students recorded the worksheet number, and the number of equations they got correct and the number of equations they got wrong on their Practice Record Sheet. The students were not encouraged to answer the equations quickly by the researcher, but did start to race each other by seeing who could finish first. One timer was shared between the 6 students, so they had to wait for all students to be present before they could start the timer.

Post-programme testing. Post-programme testing consisted of; a post-programme test which took place in Week 10 of Term 1, a retention test which was completed in the first week of Term 2, after two weeks of holiday, and a Personalised Test for five of the six students in the PT group which was administered once the students had achieved rates similar to what they had achieved before the two week holiday. For most students this

was after two practice sessions. The procedures followed during post-programme and retention testing were the same as the procedure followed at pre-programme testing.

Results

Integrity Checks

On the Assessment Integrity Checks filled out at pre-programme, post-programme and retention testing, 100 % of the tick boxes were filled out, indicating that the same equipment and procedure had been used.

All of the tick boxes were filled out on the Teaching-to-Chart Integrity Check.

Interobserver Reliability

The agreement, calculated as in Experiment 1, between the students marking of worksheets and the researchers marking of worksheets were all above 97.13 %. The most common marking mistake the participants of this study made was that they marked an incorrect answer as correct. As such students that made zero mistakes while answering equations also made zero mistakes while marking. The marking agreement between the students in the PT group and the researcher was higher than the marking agreement between researcher and the students in the NPT group, as can be seen on Table 2.2. The interobserver reliability for marking the programme measures were all 100 % apart from an agreement of 99.63 % on the Practice Test completed at pre-programme testing.

Table 2.2

Marking agreement between the researcher and the students who completed the worksheets

Pt group		NPT group	
Cameron	99.98	Erin	99.06
Edward	99.97	Tracy	99.23
Brenda	100.00	Jessica	99.23
Dorothy	100.00	Kim	98.98
Cody	100.00	Isabel	97.13
Kelvin	100.00	Clarke	99.16

Times Table Practice

Figure 2.1 shows the rate each student in the PT group answered equations correctly or incorrectly/ skipped on the R and E worksheets, shown on separate graphs, during each day of practice, along with the timing floors used each day. The equations present on each worksheet used are indicated by the numbers next to the solid vertical lines, and which group of equations relate to the numbers are listed on Table 2.3. Practice was altered as described in the method (when rate had plateaued for three consecutive days, or when the student had achieved the rate aim). One exception was when Edward achieved the rate aim on the R worksheet with a 15-s timing floor. As can be seen on his graph in Figure 2.1, instead of increasing the timing floor to 30 s, equations from his E worksheet were added to the R worksheet instead.

Interventions used when rates plateaued in this study include the removal of equations from the R worksheet and checking the students writing speed. Students that required these interventions were Cody and Dorothy. For these students equations were

removed after their rate had plateaued after observations revealed that these students were skipping equations that had been classified as known (refer to method), as such the researcher removed these equations from their R worksheets, with the effect that their rate increased, as can be seen on their graphs in Figure 2.1. Cody's writing speed was assessed before times table practice began on the 28th and 34th day of practice by measuring how many numbers he was able to transcribe (see number/ write number) in

Table 2.3

The phase changes, as represented by the numbers next to the solid vertical line on Figure 2.1, together with the equations they represent.

Phase	Equations in each phase
1	1,2,10 times tables
2	1,2,3,10 times tables
3	3x3,4,5,6, added
4	3x3,4,5,8 added
5	3x8, 4x8,9,5x5 added
6	3x8,9,4x9 added
7	3x4,6,4x7 added
8	3x6,7,9 added
9	4x4,5,6,7 added
10	4x8,9,5x5 added
11	5x6,7,8,9 added
12	1,2,3,4,5,6,7,8,9,10 times tables
13	11 times table
14	12x1,2,3,10 added
15	12x,4,5,6 added

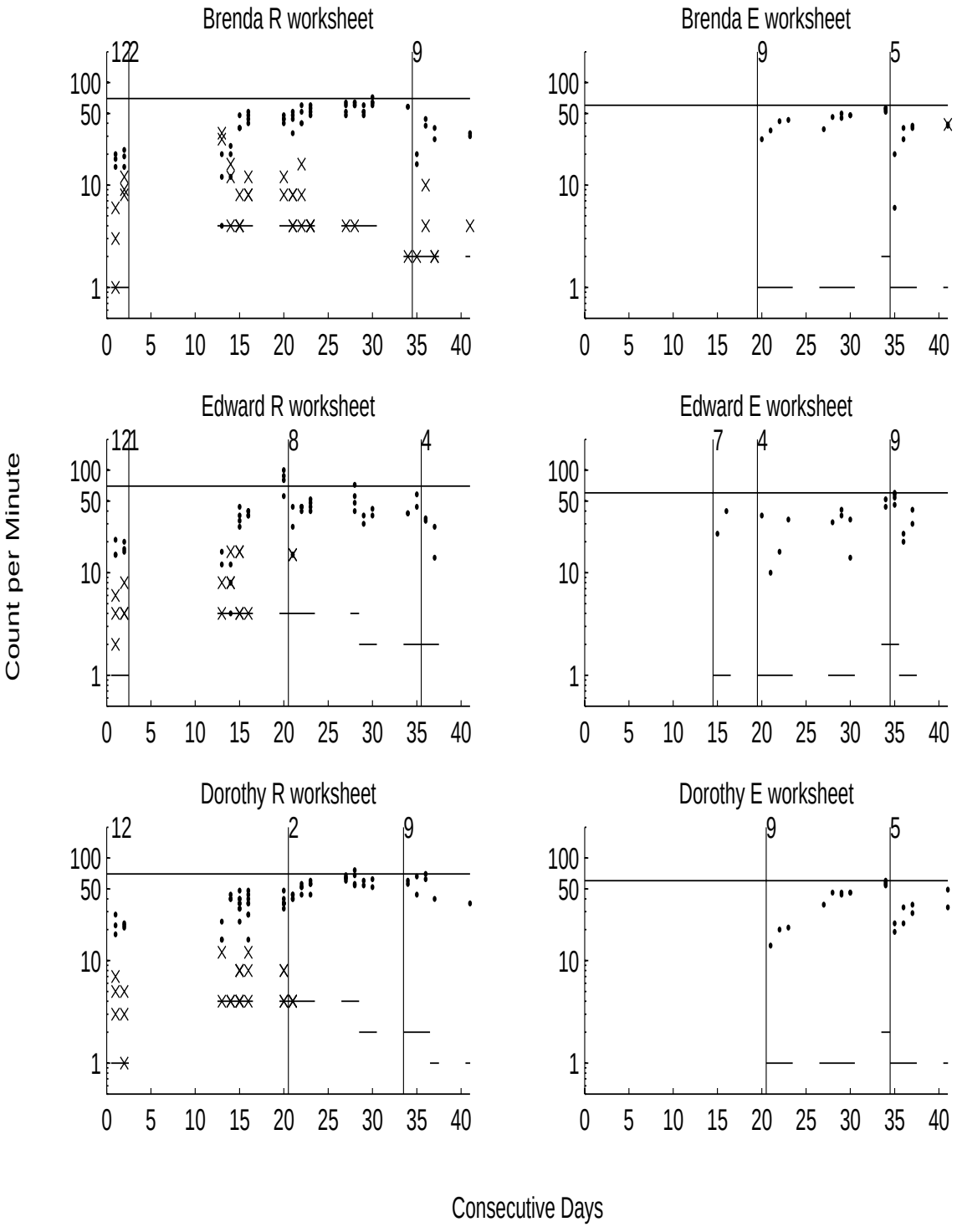


Figure continued on next page.

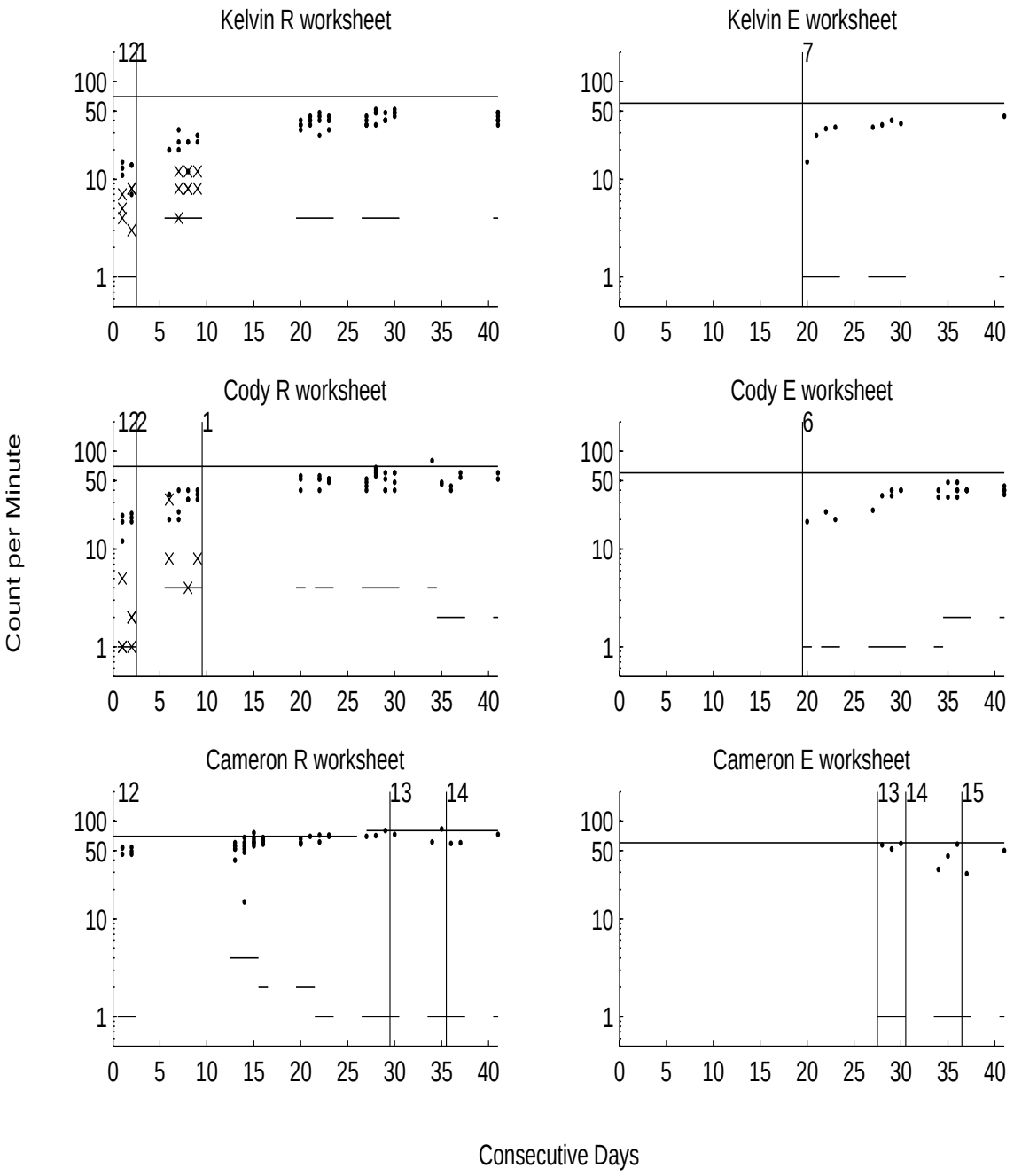


Figure 2.1. The graphs containing the correct rate as indicated by the dot, incorrect/skipped rate as indicated by the x, achieved by the student's in the PT group during times table practice, as well as the timing floor as indicated by the broken horizontal line, the rate aim as indicated by the solid horizontal lines and the phase changes as indicated by the solid vertical line for each of the students.

15-s, after his rate had plateaued, see Figure2.1. As can be seen on his graph, his rate on the R worksheet during practice increased when his writing speed was tested on Day 28, to rule out writing practice as the cause, two more practice sessions were completed without writing speed being measured. During these two sessions, the rate achieved during practice decreased again, and as such his writing speed was again accessed on Day 34 of the study. As can be seen on his graph in 2.1 Cody's rate had exceeded the performance aim with the 15-s timing floor, and as such the timing floor was increased to 30-s the next day. As Cody had achieved the performance aim, it was assumed his writing speed was fast enough for him to achieve the performance aims on the R and E worksheets.

As can be seen on Figure *, Cameron was the only student who achieve the performance aim using the R worksheet with a 60-s timing floor. After achieving the rate aim on the R worksheet as his rate aim was increased to 80 equations a minute. After this rate aim was achieved, the 11 times table, then 12x1, x2, x3 and x10 were first introduced in the E worksheets and then added to the R worksheet after the rate aim had been achieved on the E worksheets (Figure 2.1).

The rates the students in the NPT group achieved during practice are shown on Figure 2.2. Apart from 10 min, a timing floor was not used during practice, but the time it took the students to compete their worksheet was used to determine the students' correct, incorrect and skipped rate during practice, and displayed in the way a timing floor would be on each student's graph.

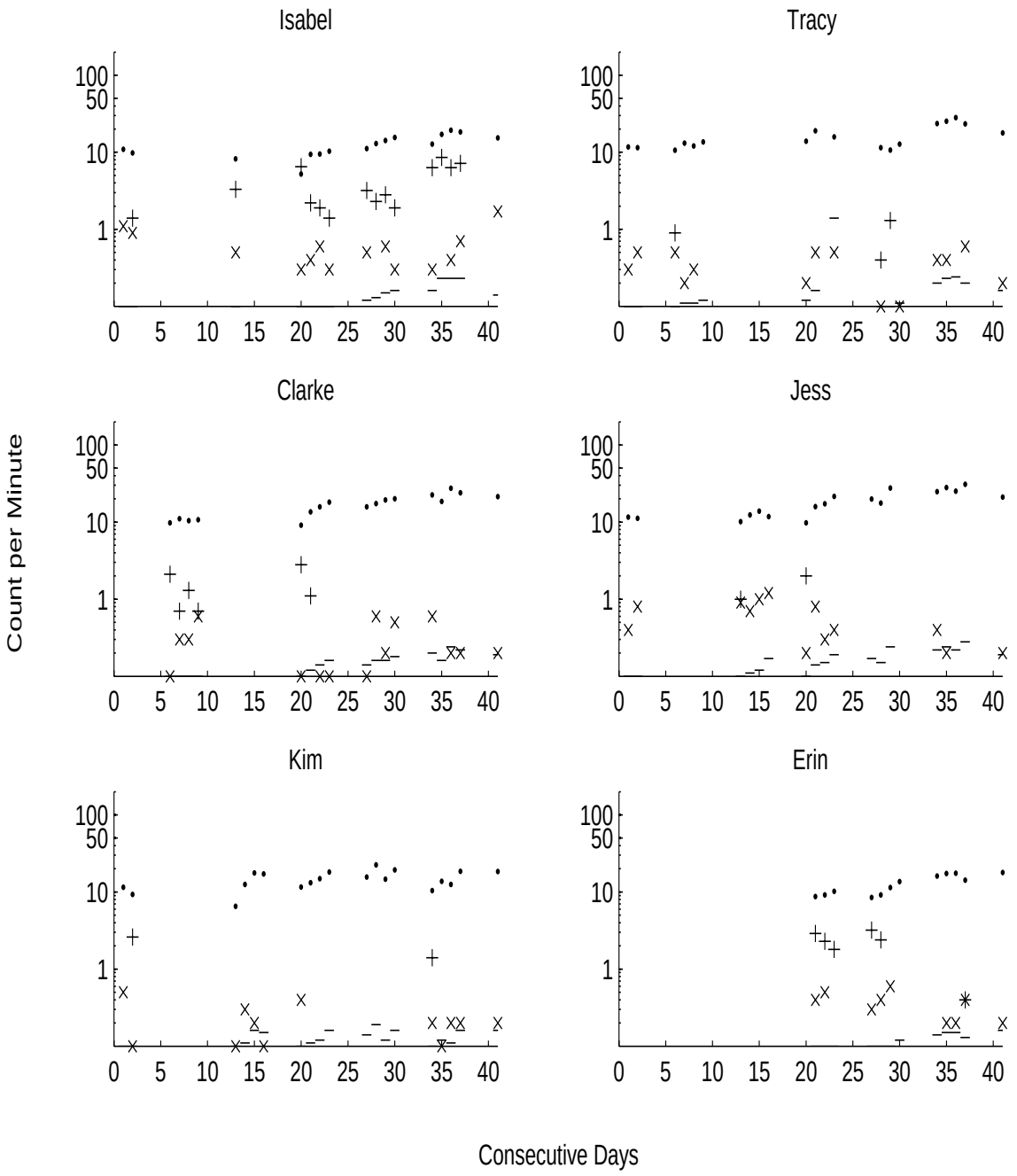


Figure 2.2. The graphs containing the correct rate, as indicated by the dot, incorrect rate as indicated by the x, and skipped rate as indicated by the +, achieved by the students' in the NPT group during times table practice, as well as the time it took the students' to complete each worksheet converted to look like a timing floor as indicated by the broken horizontal line for each of the students.

As can be seen in Figure 2.2 the students in the NPT group increased their rate over the five weeks of practice from rates between 8 to12 per min at the start of practice to rates between 15 and 30 per min at the end of practice. As a group, incorrect and blank rates stayed very low, around 0.2 per min. Holli is the exception in that her incorrect and blank rate also increased with her correct rate, indicating that even though she was getting faster, she was not necessarily getting more accurate.

Programme Measures

To compare the effect of using precision teaching versus no precision teaching while practicing times tables, the results on the Speed Test completed before practice started, once practice had finished and after two weeks with no practice were compared. To get a measure of whether the students had learnt their times tables better, or whether they had just increased their writing speed, their performance on addition equations was also measured by the Practice Test. Furthermore to assess whether tested rates would be closer to practice rates, a Personalised Test was created for 5 of the 6 students in the PT group who had not practiced all the equations (1 to 10) during practice.

Practice Test. The mean correct and skipped rate on the Practice Test (no students answered any equation incorrectly) for 5 of the 6 students in the PT group, and 5 of the 6 students in the NPT group, across the pre-programme, post-programme and retention testing, are shown in Figure 2.3 below. As Edward and Kim were away for one test, all of their data were excluded from the calculations. The correct rate decreased from pre- to post-programme testing as well as from post-programme to retention testing for both groups as can be seen in Figure 2.3. A two-way repeated-measures ANOVA showed that the decrees was not significant ($F(2, 16)= 0.51$ $\eta 2 = 0.01$, $p>0.05$). The

difference between the two groups was the smallest at post-programme testing, and was similar between pre-programme and retention testing, and was also not significant ($F(2, 18)=2.63$ $\eta^2 = 0.25$, $p>0.05$). The interaction between these was also not significant ($F(2, 16) = 0.54$, $\eta^2 = 0.63$, $p>0.05$). The changes in the PT groups' mean correct rate from pre- to post-programme testing, and from post-programme to retention testing gave effect sizes (Cohen's d (Cohen, 1977)) of -0.52 and 0.16. The changes in the NPT groups' mean correct rate from pre- to post-programme testing, and from post-programme to retention testing gave effect sizes (Cohen's d) of 0.52 and -0.54.

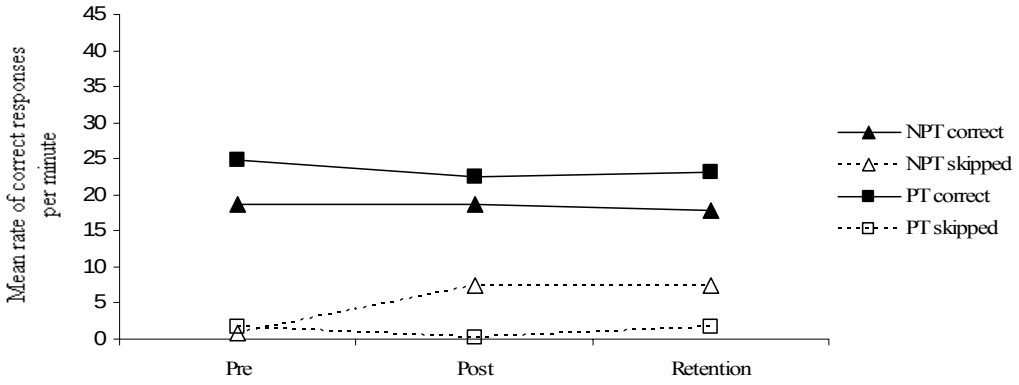


Figure 2.3. The mean rate of answering addition equations correctly, and the mean rate of skipping equations at pre-, post-post programme and retention testing for the PT group and the NPT group on the Practice Test, there were never any incorrect answers, so these are not shown on the Figure.

The skipped rate increased from pre- to post-programme testing and again at retention testing for the NPT group but not for the PT group. The difference across the tests was not significant ($F(2, 16) = 45$, $\eta^2 = 0.05$, $p>0.05$), and neither was the difference between the groups ($F(2, 8) = 2.63$, $\eta^2 = 0.25$, $p>0.05$), nor was the interaction between these significant ($F(2, 16) = 0.54$, $\eta^2 = 0.089$, $p>0.05$). The changes in skipped rates

from pre- to post-programme testing, and from post-programme to retention testing for the PT group gave effect sizes of -1.79 and1.60. The changes in skipped rates from pre- to post-programme testing, and from post-programme to retention testing for the NPT group gave effect sizes of 1.48 and 0.26 ,

Speed Test. The mean correct and skipped rate (no students answered any equation incorrectly) on the Speed Test for 5 of the 6 students in the PT group, and 6 of the 6 students in the NPT group, across pre-, post-programme and retention testing, are shown in Figure 2.4. If a student was away for one test, all their data were excluded from the calculations, as such Edward's data were excluded from the calculations.

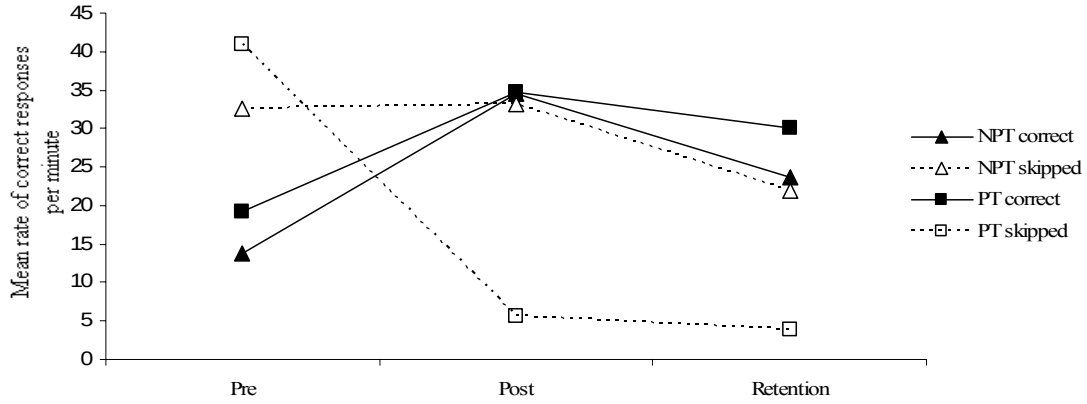


Figure 2.4. The mean rate of answering multiplication equations correctly, and the mean rate of skipping equations at pre-, post-programme and retention testing for the PT group and the NPT group on the Speed Test, there were never any incorrect answers, so these are not shown on the Figure.

The PT group had a higher mean correct rate than the NPT group at pre-programme testing. At post-programme testing the NPT group had a higher mean correct rate than the PT group, but this then reversed at retention testing, where the PT group again had a higher mean rate. However, a two-way repeated-measures ANOVA showed

that while the changes in correct rate across the test times was significant ($F(2, 18) = 45.30$, $\eta^2 = 0.83$, $p<0.05$), the difference between the two groups was not ($F(2, 18) = 0.27$, $\eta^2 = 0.03$, $p>0.05$). There was also no significant interaction between these ($F(2, 18) = 0.2.57$, $\eta^2 = 0.22$, $p>0.05$). The changes in the PT groups' mean correct rate from pre- to post-programme testing, and from post-programme to retention testing, gave effect sizes of 1.90 and -0.40. The changes in the NPT groups' mean correct rate from pre- to post-programme testing, and from post-programme to retention testing, gave effect sizes of 11.97 and -5.29,

The decrease in skipped rate across the test times was not significant ($F(2, 18) =1.43$, $\eta^2 = 0.14$, $p>0.05$), the difference between the two groups' skipped rates was also not significant ($F(1, 9) =1.21$, $\eta^2 = 0.12$, $p>0.05$). The sizes of the changes in skipped rate were different between the two groups. The PT group's skipped rate decreased from 41 to 6 from pre- to post-programme testing and then to 4 on the retention test, and the NPT group's skipped rate stayed at 33 from pre- to post-programme testing and then decreased to 22 at retention testing. However, a two-way repeated- measures ANOVA showed that the interaction between changes in mean skipped rate across testing and group membership was not significant ($F(2, 18)= 0.88$ $\eta^2 = 0.09$, $p>0.05$). This lack of significance can probably be attributed to the variability in the data. At pre-testing the standard deviation for the PT groups was 48.65 and it was 44.77 for the NPT group. By post-programme testing the standard deviation had decreased to 4.62 and 34.26 for the PT and NPT groups, respectively. It decreased to 3.03 and 32.94 for the PT and NPT group respectively, by the time of the retentions testing. Much of the change in the standard deviation from pre- to post-programme testing can be attributed to Brenda's and Cody's

skipping rates decreasing. Brenda's skipped rate at pre-testing was 79 and was 8 at post-programme testing, while Cod's skipped rate at pre- testing was 107 and was 5 at post testing. The range of decreases in skipped rate was 3 to 7 per min for the other students in the PT group. The effect sizes for changes in correct rate (Cohen's d) for the PT group were -2.97 for pre- to post-programme testing, and 0.16 for post-programme to retention testing, and for the NPT group these were 0.11 and -0.84.

Personalised Test. The Personalised Test measured the students' rates with equations that they had practiced. The mean of the rates during the last practice, the mean of the rates on the Personalised Test and the mean of the rates on the Speed Test for 4 of the 6 students in the PT group are shown in Figure 2.5.

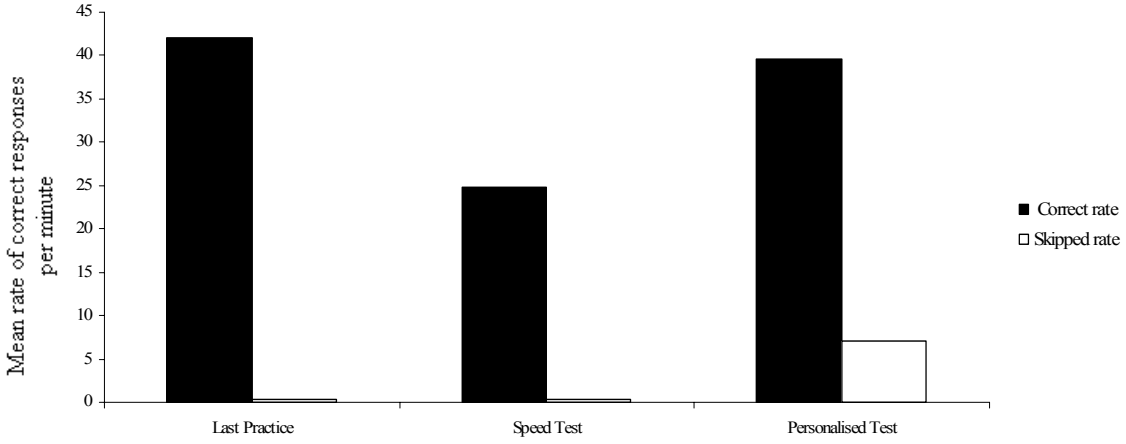


Figure 2.5. The rates the students in the PT group (Cameron and Edward excluded) achieved during the last precision teaching session, and the rate achieved on the Speed Test and the Personalised Test at post-programme testing.

Edward's data were excluded as he had not completed a Speed Test at post-programme testing, and Cameron's data were excluded as he had experienced all the equations contained in the Speed Test during practice. As can be seen, the students

achieved the highest mean correct rate, 42 per min, during the last practice and the combined incorrect and skipped rate was 0.40 per min. The lowest mean correct rate was on the post-programme Speed Test at 24.81 per min. The mean rate for the Personalised Test at 39.53 per min was closer to the mean rate achieved during practice (42 per min) than the mean rate obtained on the Speed Test at post-programme testing.

The mean correct and skipped rate all of the students in the NPT group achieved during the last practice session and on the Speed Test at post-programme testing, are shown in Figure 2.6. The mean correct rate during the last practice session at 18.74 per min was well below the mean correct rate of 34.51 per min achieved on the Speed Test during post-programme testing. The mean skipped rate also increased from a mean rate of 0 during practice to a mean rate of 33.20 per min during testing.

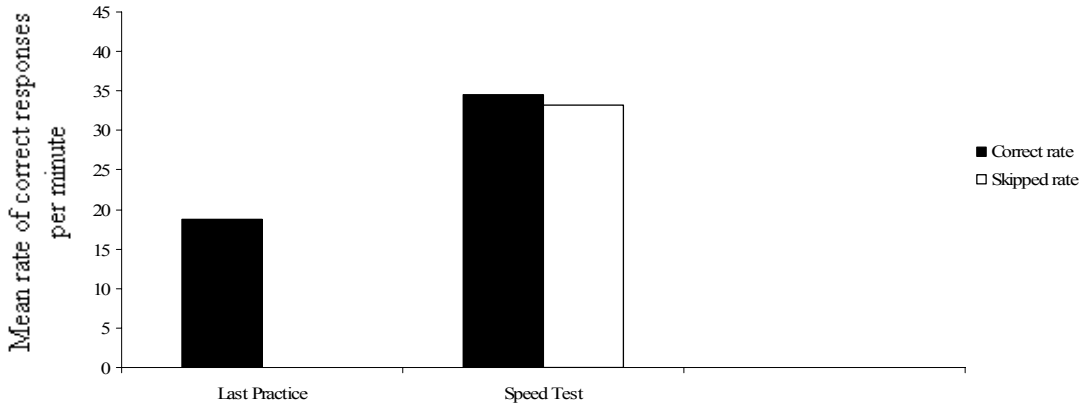


Figure 2.6. The rates students in the NPT group achieved during the last precision teaching session, and the rates achieved on the Speed Test at post-programme testing.

Like/dislike of times table practice. When the students were asked to indicate their like/ dislike of times table practice at the pre-programme testing, all of the students in the NPT group indicated they felt ok about times table practice. In the PT group 1

student indicated that they were happy with times table practice, 4 students indicated they were ok with times table practice and 1 student indicated he disliked times table practice. By the post-programme testing all of the students in the NPT group indicated that they liked times table practice, while 3 of the 5 students in the PT group that were present at post-programme testing indicated they liked times table practice, which was an improvement of 2, while 2 of the 5 students indicated they felt ok about it, which meant that for two students in the PT group there was no change in like/ dislike of times table practice (Edward's data were not reported due to his absence from the post-programme testing, but at pre-programme testing he had indicated that he disliked times table practice.

Correlation of Practice and Changes in Correct and Skipped Rate

The students in the PT group on average completed 17.80 practice sessions and 1541.17 equations by the end of the study. Table 2.4 lists the number of equations each student in the PT group answered correctly, incorrectly or skipped (practice opportunities),

Table 2.4

The number of practice opportunities students in the PT group along with the change in correct and skipped rate from pr- to post-programme testing.

Name	Number of equations practiced	Improvement from pre to post testing	Change in skipped rate from pre to post testing
Cameron	2132	25	0
Brenda	1701	11	-71
Dorothy	1688	19	-7
Kelvin	919	5	3
Cody	1450	10	-102
Edward	1357		

from pre- to post-programme testing. along with the changes in the students correct and skipped rate on the Speed Test from The correlation of between practice opportunities and the change in correct rate was 0.91 which was significant ($n = 5$, $p<0.05$), while the correlation between change in correct rate and change in skipped rate at 0.37 was not significant ($n = 5$, $p>0.05$).

The students in the NPT group on average completed 16.71 practice sessions and 1947.33 equations by the end of the study. Table 2.5 lists the number of equations each student in the PT group answered correctly, incorrectly or skipped (practice opportunities), along with the changes in the students correct and skipped rate on the Speed Test from pre- to post-programme testing. When the practice opportunities were correlated with the change in correct rate a correlation of 0.51 resulted, which was significant ($n = 6$, $p<0.05$). The correlation between the change in correct and skipped rate was also significant at 0.86 ($n = 6$, $p<0.05$).

Table 2.5

The number of practice opportunities students in the NPT group along with the change in correct and skipped rate from pre- to post-programme testing.

Name	Number of equations practiced	Improvement from pre to post testing	Change in skipped rate from pre to post testing
Tracy	2040	18	13
Isabel	1809	27	34
Kim	2207	28	78
Jess	2148	24	-2
Clarke	2040	14	-78
Erin	1440	13	-33

The correlation between practice opportunities and change in correct rate for all participants was 0.80 and was significant ($n = 11$, $p<0.05$), the correlation between change in correct and skipped rate for all participants was 0.68 and was significant ($n = 11$, $p<0.05$).

Discussion

The purpose of this study was to determine whether the addition of precision teaching to times tables practice would result in faster and more accurate rates of answering the 1 to 10 times table equations. This study also looked at whether students preferred practice with precision teaching or practice without precision teaching. As it was hypothesised in Experiment 1 that the use of different learning channels during practice and testing reduced students rates on post-programme measures, it was ensured that in this study the same learning channels were used for practice and testing. The use of the same learning channels during practice and testing was hypothesised to result in rates on the programme measure being similar to practice rates.

The results of this study showed no significant difference between the PT group and the NPT group in their rate of correctly answering equations, or their rate of answering equations incorrectly (as no student answered any equation incorrectly). The mean rate of skipping equations on the Practice and Speed Test decreased for the PT group across the tests more than the mean skipped rate for the NPT group did. The results also showed that preference for times table practice increased similarly for both groups. Finally the students' graphed rates during practice were not predictive of the rate that they achieved on the Speed Test at post-programme testing. The students' charted rates, however, were predictive of the rate the students achieved on the Personalised Tests.

The finding that precision teaching did not result in significantly higher correct rates than times table practice without precision teaching is contrary to the findings of most studies. Results from other studies show that times table practice with precision teaching, results in faster rates on the post-programme testing than times table practice without precision teaching (Chiesa & Roberston 2000, Clarke 2007, McGregor 2006). That the students in the PT group did not achieve a higher mean correct rate than the students in the NPT group could be due to the fact that the students in the NPT group were skipping equations during testing. Another factor could be that, towards the end of the study, the students in the NPT group started focusing on finishing their worksheet quickly and thus were actually rate building, and that the students in the NPT group on average attempted more equations during practice than the students in the PT group.

The trend in mean skipped rate (the PT group had a lower rate of skipped equations than the NPT group) for each group was unexpected. Given that the students in the PT group had not experienced all the equations presented on the Speed Test during practice it would have been reasonable to expect these students to have a higher mean skipped rate than was obtained on the Speed Test completed at post-programme testing. Furthermore the high mean skipped rate at post-programme testing for the NPT group was not in keeping with their mean skipped rate during practice, as all the students in the NPT group, apart from Isabel, had a near zero skipped rate which can be seen on Figure *. As 5 of the 6 students in the PT group did not practice at least half of all the equations that were presented in the Speed Test, it can be suggested that the mean correct rate of the PT group would have been slowed by the fact that the students were spending time

answering equations that they had not practiced. That the students achieved faster rates on the Personalised Test would support this argument.

It could be suggested that the mean correct rate for the NPT group increased more than the mean correct rate for the PT group due to the students in the NPT group skipping more equations at post-programme and retention testing than the students in the NPT group. Support for this argument is that there was a strong positive correlation (0.86) between the change in correct and skipped rate from pre- to post-programme testing for the NPT group but not for the PT group who had a weak correlation of 0.37 between change in correct and skipped rate. Also the correlation between the amounts of practice with changes in correct rate from pre- to post-programme testing was less at 0.51 for the NPT group than the PT group where there was a strong positive correlation of 0.91. A possible reason why the student in the NPT group started to skip equations at post-programme testing and the students in the PT group did not is that the students in the PT group were made more aware of their skipped and error rate by graphing their rates than the students in the NPT group. Thus it is possible that the NPT group made large increases in rate (on average 20 per min) because they were rate-building (which is often identified as a vital component of precision teaching) and because on average they had more opportunities to practice.

To be able to compare times table practice with precision teaching and practice without, the NPT group was supposed to have no time limit when answering equations. As it was requested by the classroom teacher that all students were to be back in class 15 to 20 min after they had been sent out to do their times table practice, a 10-min time limit was set for the students in the NPT group to answer as many equations as they could on

their worksheet. After the timer sounded the end of 10 min the students had to stop answering equations and start marking their work. While having a time limit provided information on the students' rates during practice, it may have encouraged rate building, especially as towards the end of the study as the students in the NPT group started to race each other to see who could finish first. This means that the NPT group was not just practicing their times tables, but also rate building. That the students rate was increasing can be clearly seen on the graphs showing their change in rate (Figure), even though the only feedback students were getting from practice was how many equations they had answered correctly and how many had been answered wrong or skipped out of 120 equations. While the students did not have speed and accuracy goals set for them by the researcher, the students were trying to finish before the other students. Other studies have shown that having clear aims during practice does lead to higher rates (e.g., McGregor, 2006; Pocock, 2006).

Graphing practice results is an important part of precision teaching. As Pocock, (2006) points out, reasons for it being seen as important include the feedback provided to the teacher as to whether a student is progressing, the feedback provided to the learner and the opportunity for social reinforcement. Given that students in the NPT group made large gains without getting feedback from a graph it can be questioned whether the use of a graph really does promote better learning. Research done by Pocock (2006) indicated that, for a non-academic skill at least, the use of a graph did not result in significantly different results from not using a graph, indicating that charting alone does not accelerate learning. Pocock (2006) does caution that her results may not apply to academic skills.

In most studies it is reported that students prefer practice with precision teaching that is fun, hence the acronym PRACTICED MUSIC REAPS FUN (Lindsley 1992). In this study there was no real difference in preference between the PT group and the NPT group and both groups indicated that their preference for times table practice increased. A possible explanation for this is that the NPT group also started to enjoy times table practice due to the element of speed and competition added by the students trying to be the first to finish all 120 equations.

In conclusion, this study could have failed in its aim to compare times table practice with and without precision teaching, as it was believed that the NPT group ended up rate building. The improvements from pre- to post-programme testing for the PT group are in keeping with what other studies on precision teaching have achieved.

Experiment 3: A Comparison of Rate-Building and Precision Teaching

It was concluded in Experiment 2 that a comparison of practice with and without precision teaching could not be made in the current setting as the NPT group started to rate build. Given that rate-building was attributed to the time limit place on times table practice by the classroom teacher, it was decided that a continuation of Experiment 2 or a further study comparing practice with and without precision teaching would not be warranted. Instead it was decided that a comparison of rate-building and precision teaching would be better.

The purpose of this study was to compares times table practice with precision teaching and times table practice with just rate building. This study took place in the same setting, and used the same participants as used in Experiment 2. Changes from the method used in Experiment 2 include; the use of a linear graphs instead of a semi-log graph, the NPT group doing short time probes and recording their rates on a graph, the adjustment of the timing floor the NPT group doing short time probes and recording their rates on a graph, the adjustment of the timing floor used by the NPT group students based on the rates recorded on their graphs. The graphs used by the students in this study were changed to linear. This change was made, as research done by Marston (1988) indicated that students made larger increases in rate when a linear graph was used to record practice results, than when a semi-log graph was used. For this Experiment 10 min four days a week was allocated to times tables practice.

Method

Participants

The participants from Experiment 2 also participated in this study.

Setting

This experiment took place in the same setting as Experiment 2.

Materials

Programme measures. This experiment used the same programme measures as Experiment 2.

Worksheets. The worksheets used in Experiment 2 were also used in this study. A further Standard worksheet was added that had two grids to accommodate a timing of 30-s (Appendix AG).

Folders. Twelve folders were used in this study, six of these folders contained, two linear graphs that indicated the rate aim with a red line (one to graph R worksheet rates, and one to graph E worksheet rates) (Appendix AH), times table chart for marking (Appendix Z), and a folder sleeve which held new worksheets. The other six folders contained only one linear chart (Appendix AH), that indicated the rate aim with a red line, and a times table chart for marking (Appendix Z).

Timers. The same timers as used in Experiment 1 and Experiment 2 were used in this study.

Integrity Checking Forms. Only the Testing Integrity Check form was used in this study, which remained unchanged from Experiment 2.

Procedure

The procedure consisted of the pre-programme testing, time's table practice and post-programme testing.

Group allocation. Students stayed in the same groups that they were assigned to in study two.

Pre-programme testing. The rates students achieved on the Practice, Speed and Personalised Test at retention testing in Experiment 2 were used as the pre-programme measures in this experiment.

Times table practice. Times table practice occurred for four days every week for 5 Weeks, starting the day after pre-programme testing. As only 10 min was allocated for practice, students completed two worksheets during each practice session. This meant that 2 min was spent on times table practice every session. While the classroom teacher had requested the shorter time period for practice, students still took between 10 and 15 min, organising themselves for practice (finding their folder, finding a place to sit etc), completing the timings and marking their own work, despite only 2 min of this time being actually spent on answering equations.

The students in the PT group continued to practice their times table the same way they had practiced them in Experiment 2, with the exception being that in this study the students each completed only two worksheets, an R worksheet and an E worksheet. The criteria to make changes and the type of changes made also continued to be the same as had been used in Experiment 2, with the exception that students were charting their rates on a linear graph where a red line indicated the rate aim the students were trying to achieve.

For the students in the NPT group practice consisted of timed practice using two Standard worksheets, marking their own work and graphing the achieved rate on a linear graph, where a red line indicated the rate aim the students were trying to achieve. The rate aim set for the not PT group was 70 per min. In order to help the students rate build, the timing floor was reduced after the their rate had plateaued over three days, and only increased once the rate aim had been achieved with the current timing floor.

While practicing their times tables the students in the NPT group shared a timer with other students who had the same timing floor as them, taking turns to set the timer.

Post-programme testing. All the students completed a Practice Test and a Speed Test in Week 5 of Term 2. The same 5 students, who completed a Personalised Test at retention testing in Experiment 2, also completed a Personalised Test at this testing. The procedure followed to administer the post-programme tests was the same as the procedure followed as followed in Experiment 2 to administer the tests.

Results

Integrity Checks

At both pre- and post-programme testing 100 % of the tick boxes were filled out on the corresponding Assessment Integrity Check.

Interobserver Reliability

The agreement between the students marking of worksheets and the researchers marking of worksheets were all above 96.9 %. As in Experiment 2 the most common marking mistake students made was marking an incorrect answer as correct, or miscounting the number of equations they got correct, incorrect or skipped. In this study

the students in the PT group had a higher marking agreement with the researcher than the students in the NPT group as shown on Table 3.1. The interobserver reliability for marking the Practice Test, Speed Test and Personalised Test was 100 % apart for the Speed Test completed at post-programme testing which was 99.86 %.

Table 3.1

Marking agreement between the students who completed the worksheets and the researcher

PT group		NPT group	
Cameron	99.9	Erin	99.3
Edward	100	Tracy	99.3
Brenda	100	Jess	99.4
Dorothy	99.9	Kim	98.9
Cody	99.9	Isabel	97.2
Kelvin	100	Clarke	96.9

Times Table Practice

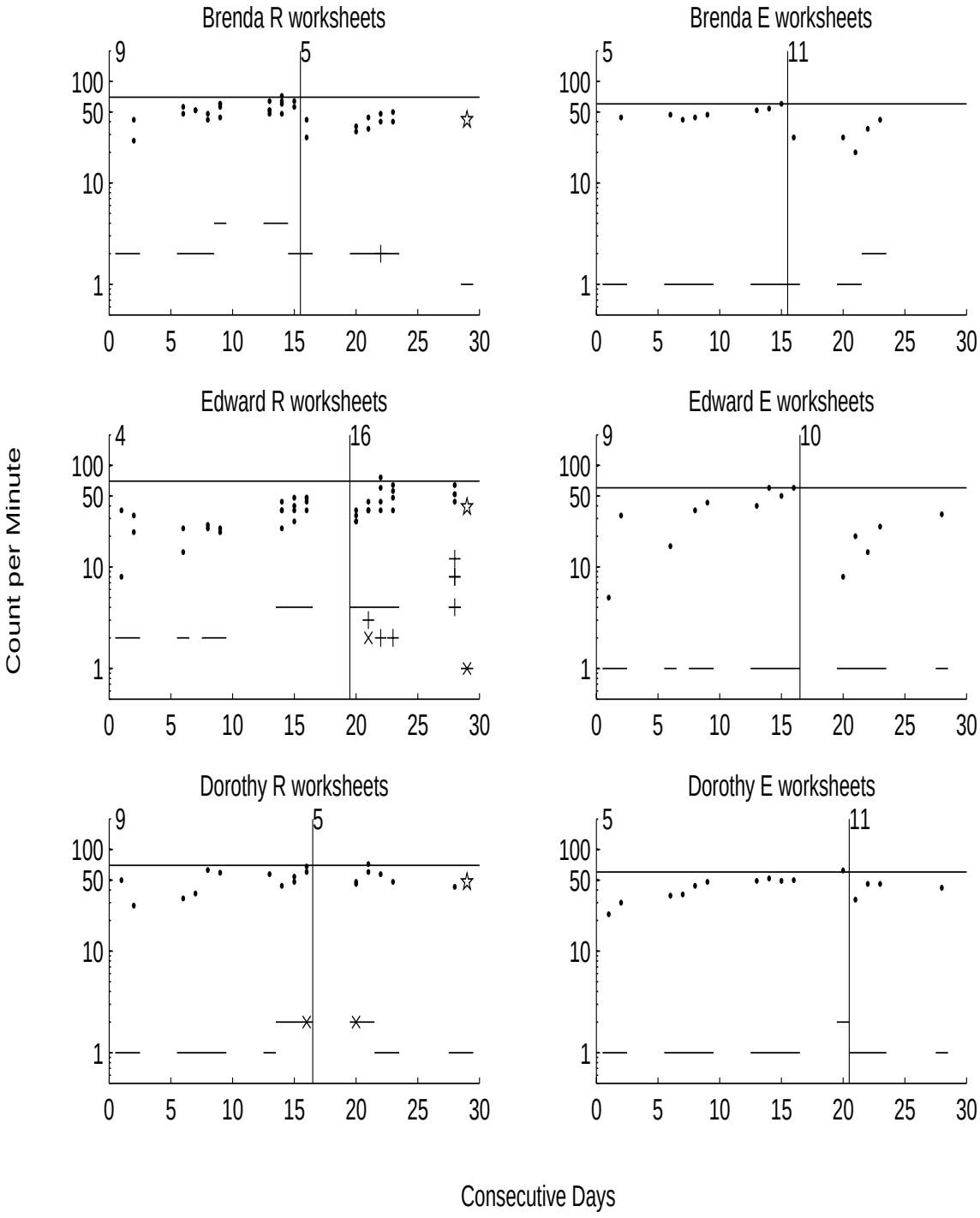
Figure 3.1 shows the rate of correct, incorrect and skipped equations achieved each day by each student in the PT group, over the study, as well as the timing floor used each day. The rates students achieved each day on the R and the E worksheets are shown on separate graphs. On five of the R worksheet graphs, students rate on the Personalised Test are shown as a star. The equations presented on each worksheet are indicated by the numbers next to the solid vertical lines, and which group of equations each number relates is shown in Table 3.2. Students practice was altered after the rate aim had been achieved, or after three consecutive days of the rate not accelerating, as described in the method. As can be seen on Figure 3.1, the students in the PT group made almost no

errors, nor did they tend to skip more than three equations during each timing. When rates did not accelerate for three days the timing floor used was altered, or to test a students writing speed, by checking how many numbers a student could transcribe using the learning channels see number/ write number.

Table 3.2

The phase changes, as represented by the numbers next to the solid vertical line on Figure 2.1, together with the equations they represent.

Phase	Equations in each phase
1	1,2,10 times tables
2	1,2,3,10 times tables
3	3x3,4,5,6, added
4	3x3,4,5,8 added
5	3x8, 4x8,9,5x5 added
6	3x8,9,4x9 added
7	3x4,6,4x7 added
8	3x6,7,9 added
9	4x4,5,6,7 added
10	4x8,9,5x5 added
11	5x6,7,8,9 added
12	1,2,3,4,5,6,7,8,9,10 times tables
13	11 times table
14	12x1,2,3,10 added
15	12x,4,5,6 added
16	Flash cards used in stead of worksheets


Brenda R worksheets
9
5
Brenda E worksheets
5
11
Edward R worksheets
4
16
Edward E worksheets
9
10
Dorothy R worksheets
9
5
Dorothy E worksheets
5
11
100
50
10
1
0
5
10
15
20
25
30
Count per Minute
Consecutive Days

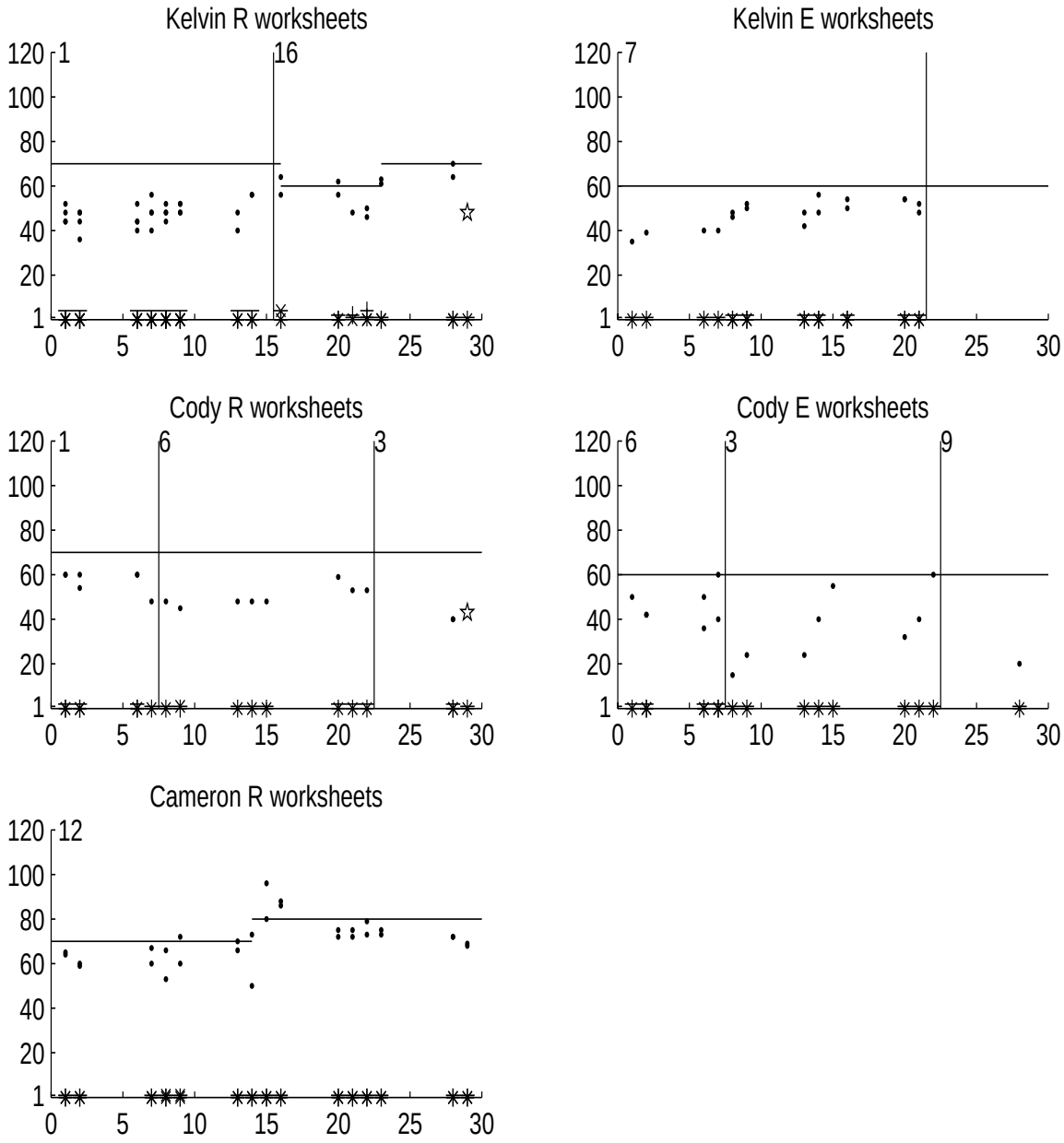


Figure 3.1. The graphs containing the correct rate as indicated by the dot, incorrect rate as indicated by the x, and skipped rate as indicated by the +, achieved by the student's in the PT group during times table practice, as well as the timing floor as indicated by the broken horizontal line, the rate aim as indicated by the solid horizontal line and the phase changes as indicated by the vertical line for each of the students. The star represents students' correct rate on the Personalised Test.

When a student's writing speed was below the target rate of answering multiplication equations, flash cards were used during practice instead. This was the case for Kelvin and Edward. Kelvin's writing speed was tested over Days 9, was shown to be between 44 and 64 numbers per min, Edwards writing speed was similarly low between 44 and 60 numbers per min. When it was shown that writing speed was not the problem, as was the case for Cody, who achieved a writing speed of 80 numbers per min when tested on Days 14 and 15, the timing floor was decreased instead of using flash cards. As can be seen in Figure 3.1, Kelvin's and Cody's rate aims were adjusted. In Kelvin's case the rate aim was decreased when he started practicing the times tables using flash cards. The decision to decrease the rate aim was based on the fact that the first study which used flash cards had a rate aim of 60 per min. Once Kelvin had reached the rate aim of 60 per min with a timing floor of 60 s, his rate aim was again increased to 70 per min. In Cameron's case the rate aim was increased to 80 per min as he had achieved the rate aim of 70 per min with all the equations (1 to 10x) at a 60 s timing.

Edward was seen pausing the timer while he thought of the answer on Day 13 of the study. It is not know how long Edward had been doing this, or how many other students may have done this, but the rates Edward recorded for Day 13 were excluded from his graph. From Day 13 onwards it was ensured that Edward shared a timer with another student to prevent him from pausing the timer during a time probe.

In order to compare the rate the students achieved on the Personalised Test with their practice rates, the rates on the Personalised Test are recorded as the last day on Brenda's, Edward's, Dorothy's, Kelvin's and Cody's graphs in Figure 3.1. As can be seen, Brenda's, Dorothy's and Cody's rates on the Personalised Test were within or

above the range of rates achieved during their last practice. Kelvin's and Edward's rates on the Personalised Tests were below the rates they achieved on their last practice.

The rates of correct, incorrect, and skipped answers achieved each day by each student in the NPT group over the study, as well as the timing floor used each day are shown on Figure 3.2. Changes in timing floor were the only change to practice made for the students in the NPT group. The decision of when to change the timing floor was always made after three days of no acceleration.

Only Erin's timing floor was not adjusted. Otherwise all students' rates benefited from decreasing the time limit to 30-s. Jess was the only student who did not reach the rate aim of 70 equations per min with a 30-s time limit. As she asked to move onto a 60-s time limit, and her rate had effectively plateaued, her timing floor was increased to 60-s.

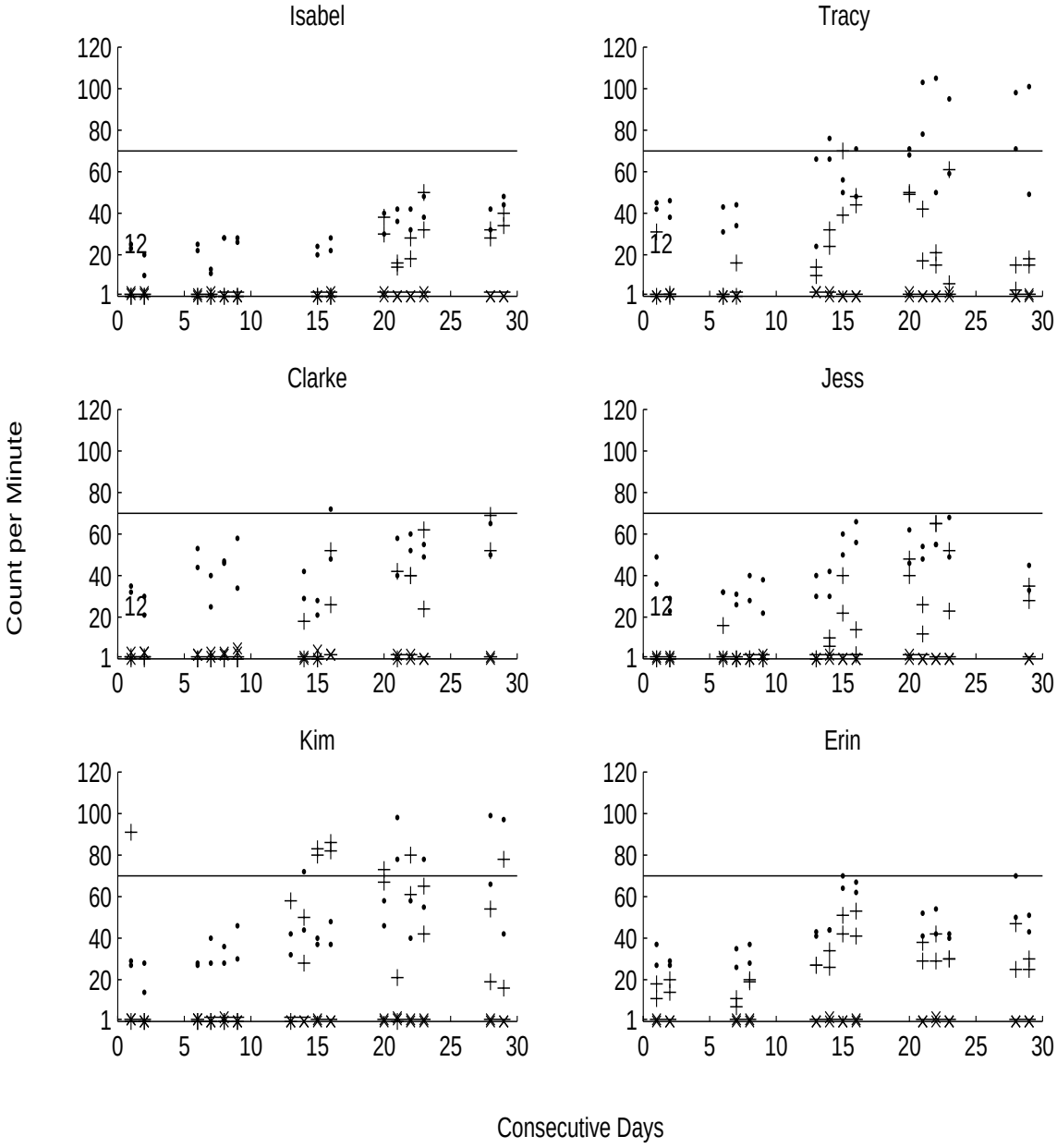


Figure 3.2. The graphs containing the correct rate as indicated by the dot, incorrect rate as indicated by the x, and skipped rate as indicated by the +, achieved by the student's in the NPT group during times table practice, as well as the timing floor as indicated by the broken horizontal line and the rate aim as indicated by the solid horizontal line for each of the students.

Programme Measures

To compare the effect of rate-building versus precision teaching students completed a Practice Test, a Speed Test and a Personalised Test administered Week 1 (retention testing) and Week 5 (post-programme testing) of Term 2.

Practice Test. The mean rates for 11 of the 12 students that participated in this study can be seen in Figure 3.3. Kim's score on the final test was excluded before the mean was calculated as he had not sat the Practice Test at retention testing; as such the graph compares the NPT group of 5 students with the PT group of 6 students.

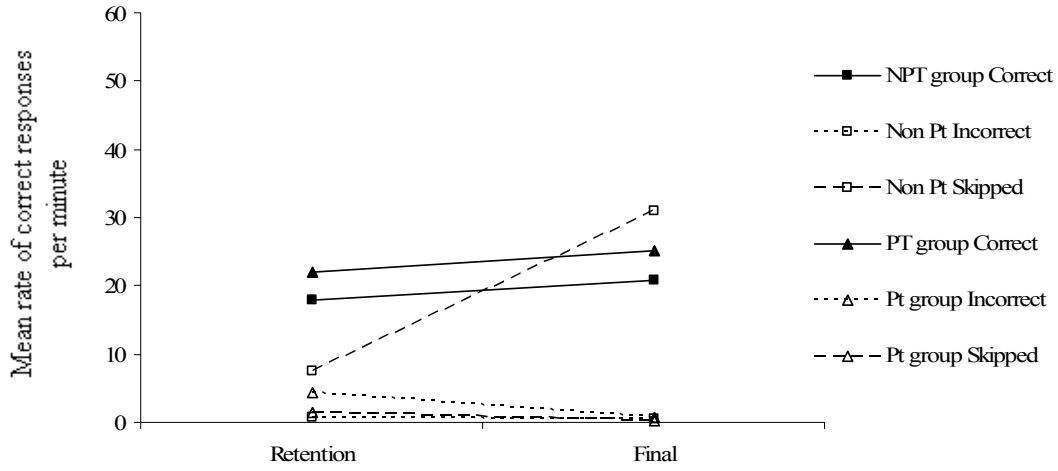


Figure 3.3. The mean rate of answering addition equations correctly, incorrectly, or skipping equations at pre-, and post-post programme testing for the PT group and the NPT group on the Practice Test.

As can be seen on Figure3.3, the mean rate of correctly answering multiplication equations increases similarly for both the non PT and the PT group from retention to post-programme testing, a two-way repeated-measures ANOVA showed that this change was not significant ($F(1, 9)= 0.1.42$, $\eta^2 = 0.136$, $p>0.05$). The difference between the two groups means was not significant ($F(1, 9) = 0.64$, $\eta^2 = 0.00$, $p>0.05$). There was also no

significant interaction between these ($F(1, 9) = 0.00$, $\eta^2 = 0.00$, $p>0.05$). The effect sizes (Cohen's d (Cohen, 1977)) based on changes in the mean correct rate for the PT and NPT groups from retention to post-programme testing were 0.57 and 2.07, respectively.

The PT group had a higher, but not significantly higher, rate of incorrectly answering addition equations than the NPT group ($F(1, 9)= 0.85$, $\eta^2 = 0.09$, $p>0.05$). The rate of incorrect answers did not change significantly from pre- to post-programme testing ($F(1, 9) = 0.86$, $\eta^2 = 0.09$, $p>0.05$). The interaction these was also not significant ($F(1, 9) = 0.56$, $\eta^2 = 0.58$, $p>0.05$). The effect sizes (Cohen's d (Cohen, 1977)) based on changes in the mean incorrect rate for the PT and NPT groups from retention to post-programme testing were -1.52, and -0.81, respectively.

Changes in skipped rate from pre- to post-programme testing were not significant ($F(1, 9) =1.79$, $\eta^2 = 0.17$, $p>0.05$) but the difference between the mean skipped rate for the PT and NPT group was significant ($F(1, 9) =28.05$, $\eta^2 = 0.76$, $p>0.05$). However, there was no significant interaction between these ($F(1, 9) =2.6$, $\eta^2 = 0.22$, $p>0.05$). The effect sizes (Cohen's d (Cohen, 1977)) based on changes in the mean skipped rate for the PT and NPT groups from retention to post-programme testing were -1.16, and 2.40, respectively.

Speed Test. The mean scores obtained by the NPT group and the PT group on the Speed Test at pre- and post-programme testing can be seen below in Figure 3.4. The mean correct rates for both the non PT and the PT group increased from pre- to post-programme testing, a two-way repeated-measures ANOVA showed that this was significant ($F(1, 10)=101.53$, $\eta^2 = 0.91$, $p<0.05$). At pre-programme testing the NPT group had a lower mean rate than the PT group, but by post-programme testing this trend

had reversed with the NPT group having a higher mean rate than the PT group. The difference between the two groups was not significant ($F(1, 10) = 0.09$, $\eta^2 = 0.01$, $p>0.05$). However, the interaction between these was significant ($F(1, 10) = 22.59$, $\eta^2 = 0.69$, $p<0.05$).). The effect sizes (Cohen's d (Cohen, 1977)) based on changes in the mean correct rate for the PT and NPT groups from retention to post-programme testing were 0.95 and 8.28, respectively.

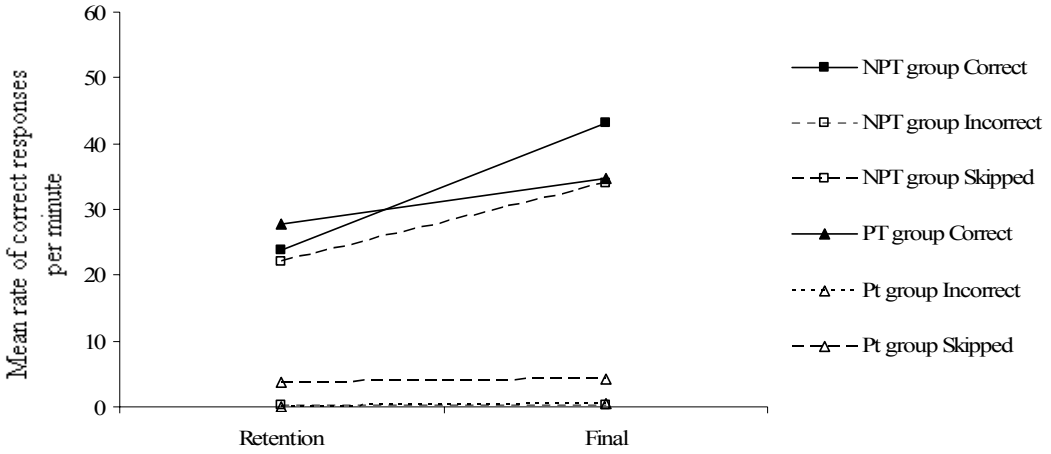


Figure 3.4. The mean rate of answering multiplication equations correctly, incorrectly, or skipping equations at pre-, and post-programme testing for the PT group and the NPT group on the Speed Test.

shows that there was no differences between the students' incorrect rates from pre- to post-programme testing and a two-way repeated-measures ANOVA showed was also not significant ($F(1, 10) = 0.77$, $\eta^2 = 0.07$, $p>0.05$) nor was there any difference between the groups and an ANOVA confirmed this ($F(1, 10) = 0.00$, $\eta^2 = 0.00$, $p>0.05$). There also was no significant interaction between these ($F(1, 10) =3.08$, $\eta^2 = 0.24$, $p>0.05$). The effect sizes (Cohen's d (Cohen, 1977)) based on changes in the mean incorrect rate for the

PT and NPT groups from retention to post-programme testing were 4.08 and 0.81, respectively.

The rate of skipping equations did not change significantly from pre- to post-programme testing ($F(1, 10) = 0.33$, $\eta^2 = 0.07$, $p>0.05$). The mean difference in skipped rate between the PT and NPT group was, however, significantly different ($F(1, 10) =9.91$, $\eta^2 = 0.50$, $p<0.05$) while the interaction between group membership and time was not significant ($F(1, 10) = 0.0.27$, $\eta^2 = 0.03$, $p>0.05$). The effect sizes (Cohen's d (Cohen, 1977)) based on changes in the mean skipped rate for the PT and NPT groups from retention to post-programme testing were.26 and 3.39, respectively.

Across practice and test performance. The mean rates for five of the six students in the PT group were compared from the last practice session, the Speed Test at post-programme testing as well as on the Personalised Test. Cameron's rate was excluded from the PT group, as he had experienced all the equations during practice, and so his results on the Speed Test were considered representative of his practice, thus no Personalised Test was created for him. The mean rates achieved during the last practice session were compared with the results achieved on the Speed Test at post-programme testing for the NPT group.

As can be seen on Figure 3.5, the PT group's mean rate was similar to the NPT groups mean rate for the last practice session. The PT group's mean rate on the Speed Test decreased more than the mean rates obtained by the NPT group on the Speed Test. The mean correct rate on the personalised was also similar to the mean rate the NPT group achieved on the Speed Test.

As can be seen on Figure 3.5, change in rate from pre- to post-programme testing on the Personalised Test for 5 of the students in the PT group was almost the same as the mean change in rate achieved on the Speed Test by the PT group. The change in correct rate from pre- to post-programme testing was not significant (repeated measures $t(5) = -1.649$, $p>0.05$).

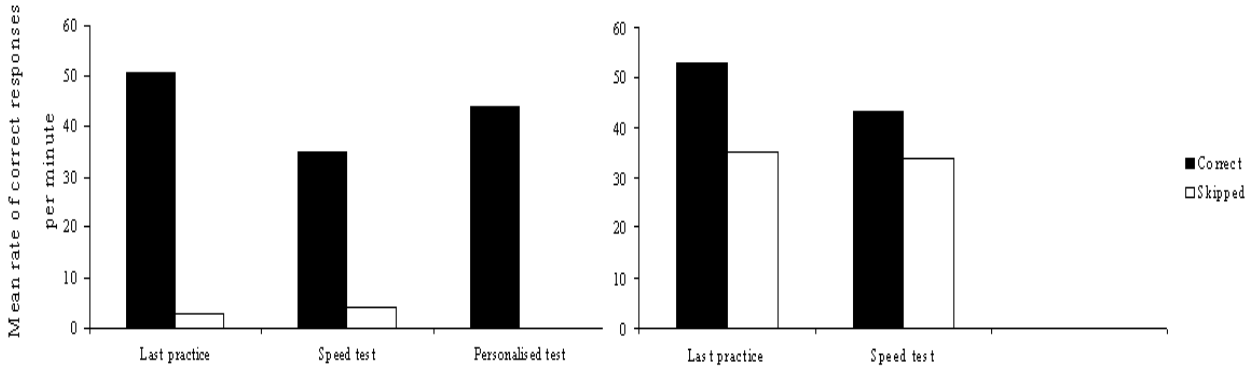


Figure 3.5. The graph on the left compares the PT groups mean correct and skipped rates on the last practice session, the Speed Test and on the personalised test. The graph on the right compares the NPT groups mean correct and skipped rates on the last practice session with the NPT groups mean correct and skipped rates on the Speed Test.

Correlation of Practice and Changes in Correct and Skipped Rate

The students in the PT group completed 14.2 practice sessions and 1307.00 equations on average by the end of the study. Table 3.3 lists the number of equations students in the PT group answered correctly, incorrectly or skipped (practice opportunities) next to the change in correct and skipped rate on the Speed Test from pre- to post-programme testing. When practice opportunities were correlated with the change in correct rate a correlation of 0.60 (which was not significant) resulted ($n = 6$, $p>0.05$).

The correlation between change in correct and change in skipped rate was even smaller at 0.04 and was also not significant ($n = 6$, $p>0.05$).

The NPT group completed 14.2 practice sessions and completed on average 1299.3 equations on average. Table 3.4 lists the number of equations each student answered correctly, incorrectly or skipped (practice opportunities) with the change in correct and skipped rate for each student. The correlation between practice opportunities was and change in correct rate was -0.44 which was not significant ($n = 6$, $p>0.05$). The correlation between change in correct and change in skipped rate at 0.47 was also not significant ($n = 6$, $p>0.05$).

Table 3.3

The number of practice opportunities students in the PT group along with the change in correct and skipped rate from pre- to post-programme testing.

Name	Number of equations	Change in correct rate	Change in skipped rate
Tracy	1739	15	-81
Isabel	807	21	-9
Kim	1562	23	53
Jess	1450	15	22
Clarke	1064	19	69
Erin	1174	24	18

Table 3.4

The number of practice opportunities students in the NPT group along with the change in correct and skipped rate from pre- to post-programme testing.

Name	Number of equations	Change in correct rate	Change in skipped rate
Cameron	2112	14	0
Brenda	1141	10	-7
Dorothy	1193	4	0
Kelvin	1329	7	10
Cody	1139	-1	-3
Edward	928	8	3

When practice opportunities were correlated with change in correct rate for all students, a correlation of 0.10 results which is not significant ($n = 12$, $p>0.05$). The correlation between change in correct and change in skipped rate was also not significant ($n = 12$, $p>0.05$).

Discussion

The purpose of this study was to compares times table practice with precision teaching and times table practice with rate-building. The results were recorded on a linear graph in both cases. Rate-building resulted in a significantly larger increase in rate than did precision teaching. These results suggest that the changes in timing floor used during rate building accelerated rate better than the combination of altering the curriculum and changing the timing floor used during precision teaching. There are some possible reasons why the NPT group out performed the PT group in this study and these are discussed below.

In the precision teaching and fluency training literature there is no consensus as to whether students need to be accurate before rate-building begins. Some, such as Binder et al. (2002), suggest that if students are not accurate, they will not benefit from rate-building. While others such as, White (2000), suggest that errors are learning opportunities. A more middle ground is taken by Johnson and Street (2004) who suggest that it varies from student to student. In this study it appeared that skipping equations during practice did accelerate learning more than not skipping, as the NPT group, who skipped equations during practice and testing, made larger increases in rate than the PT group, who skipped very few equations during practice and testing. That the PT group did not skip equations on the Speed Test is an unusual result, as this means that the NPT group spent time answering equations that they had not practiced. Given that the PT group did not make errors while answering these unpractised equations it is possible that the students were able to answer unpractised equations due to adduction, or that they were already able to be accurate with these equations before practice began. If the students were already accurate on all the equations before practice began, skipped equations may have just indicated which equations the students were less fluent with. Thus, in this study it appears that rate-building only the equations that students were not skipping slowed the learning rate of the PT group, as they had fewer 'learning opportunities'.

The NPT group had learnt the strategy of skipping the times tables equations they found hard to get to the easy ones. This resulted in much higher rates on the times tables equations, but not on the addition equations. That the NPT group's mean rate of answering addition equations was similar to the PT groups mean rate of answering addition equations, despite their higher rate of skipping times tables equations, makes it

less likely that the NPT group achieved a higher rate on the Speed Test than the PT group by skipping equations alone. Adding support to this argument is that while the correlation between changes in skipped and correct rate from retention to post-programme testing for the NPT group is 0.47 and larger than the correlation for the PT group at 0.04, the correlation is neither strong nor significant.

A possible confounding variable was that the students in the NPT group were better at learning than the PT group. The use of random assignment should have negated this effect, but it cannot be ruled out. Possible support for this argument is that in the PT group Kelvin's and Edward's rates were slowed by their writing speed (which was between 44 to 64 numbers per min). The only student in the NPT group whose performance may have been slowed by their writing speed was Isabel. Isabel is identified here as she was the only one who did not manage to achieve the rate aim, but without further testing it cannot be known if this was due to her writing speed or not.

Another issue is that some of the curricular decisions made when Cody's rate had plateaued did not help accelerate his rate. Because Cody's rate never really accelerated during practice, it was not so surprising that his rate had decreased by one equation a minute on the final Speed Test, decreasing the mean rate achieved by the students in the PT group at post-programme testing. Apart from Cody, all the other students did make improvements. Given that there are no standardised procedures to be followed in precision teaching about how and what to change, apart from the rule of thumb that if there is no acceleration make a change, it appears the selection of what to change is based largely on the experience of the teacher. Thus changes that were not successful at accelerating rates even with hindsight but without other information, seem sensible.

Finally given that the participants in this experiment were also participants in Experiment 2, it is possible that the combination of the practice done in the two studies may have influenced this result. The combination of practice with a focus on task completion and accuracy (Experiment 2 condition) before rate-building for the NPT group may be responsible for the larger gains made by the NPT group. For example, McGregor's (2006) participants received accuracy training before they started rate building, and the increases in rate reported in that study are very large (approx 48-55 equations per min).

In conclusion, the results from this experiment suggest that rate building, and changes in timing floor (based on graphed rates) accelerated students' rate faster than the combination of rate building, changes in timing floor (based on graphed rates), and other curriculum changes. Some confounding variables such as students in the NPT group skipping more equations during practice and testing than the PT group, that the writing speed of some students in the PT deflated their actual rate, and a possible carryover effect from Experiment 2, however, suggest caution when interpreting these results.

Results Summary for Experiments 1, 2 and 3

Experiment 1

Experiment 1 aimed to examine whether precision teaching can increase rates of answering times tables, as well as increase the stability, endurance, application and adduction of answering times tables more than the currently used method of teaching. The participants in the PT group were selected by the teacher as being those who had not succeeded as well as the rest of the class with her present teaching methods.

There was no significant difference between the PT and the ST groups' rates or endurance, stability, application, and adduction at post-programme testing. In hindsight, apart from the change in learning channels used from practice to testing, the Rate and Endurance Tests were appropriate to measure the rate and endurance of writing answers to times table equations, as the students rate of answering equations was easily measured, and the effect of a 1- or 3-min timing clearly seen. The Stability and Application/ Adduction Test on the other hand were not as affective at measuring the stability, application and adduction of times tables. The Stability Test used a played radio as a distracter, but the effectiveness, or even consistency of the radio as a distracter from pre- to post-programme testing could not be ensured. The Application/ Adduction Test consisted of sections that were aimed at measuring different aspects of application and adduction. However, as the definitions of application and adduction are varied and inconsistent in the literature, it was hard for the researcher to provide an operational definition of application and adduction, and therefore the attempt to measure these was unlikely to have been successful.

The effect sizes for the measures that were rate based, showed that the students in the PT group made larger gains than the students in the ST group but the group sizes and the variability were such that these differences were not statistically significant. It was suggested that the effect on rate of correct responses was smaller than found by Chiesa and Robertson (2000) could be attributed to several confounding variables. These included the use of different learning channels for testing and practice, that the students in the PT group may have been those with specific difficulties in application, and that the standard teaching was of better quality than the standard teaching used in the Chiesa and Roberston (2000) study and that it included elements of precision teaching such as a focus on rate based measurement, as well as the setting of goals and the graphing of results. It was suggested that had the students in the two groups of participants been more similar, and had the same learning channels been used during practice and testing, then the rates achieved on the post-programme measures might have been closer to rates recorded during practice.

Experiment 2

As a result of Experiment 1, Experiment 2 was designed to compare the difference in students' rates and retention of answering times tables correctly, depending on whether they had received precision teaching or not. This study used two groups of participants who were randomly assigned to the two treatments.

This experiment did not show any significant differences between the PT and NPT groups in terms of the change in correct rate from pre- to post-programme, and to retention testing. While there was no significant difference between the two groups, that is both changed in correct rate similarly, the correct rate changed significantly across pre-

post-programme and retention testing. The improvements seen for both groups were comparable to the changes in correct rate students who had received precision teaching in other studies had made. It was argued that it was possible that the NPT group had started rate building towards the end of the study which might have affected their results. Additionally it was shown that the NPT group had practiced more equations by the end of the study, and that the students in this group were skipping more equations at post-programme and retention testing than those in the PT group.

Experiment 3

Given the results of Experiment 1 and Experiment 2, Experiment 3 aimed to compare the effect of rate building or precision teaching on students' rates of answering times table equations. This study used the same participants as were used in Experiment 2.

The results from this study were that the students in the NPT group on average made larger increases in rate than students in the PT group. Some confounding variables such as the different rates of skipping between the two groups, some students in the PT group having low writing speeds, and possible carryover from Experiment 2, meant that these results need to be interpreted in the context of these discussed variables.

Conclusions

Overall, while the increases in rate of correct equation completion made by all students in the various PT groups were similar to increases in rate reported by other studies (e.g., Chiesa & Robertson, 2000; Clarke, 2007, students in these groups did not achieve significantly faster rates on average than students in the comparison groups (i.e., the ST and NPT groups). Furthermore the results from this research did not show that the

addition of precision teaching to practice results in RESAA, as measured by the programme measures used. The lack of significant results can be attributed to various confounding variables. However, had the outcomes been as expected, confounding variables would not have been as closely scrutinised as was done.

The results from this research do, however, suggest that rate building is just as effective as precision teaching, if not more so, at increasing a student's rate (or fluency – in terms of rate). Whether higher rates result in better outcomes as described by RESAA is as yet unclear based on this research and other literature, but Doughty et al. (2004), does suggest that it results in faster movement along a curriculum which is seen as desirable.

The precision teaching literature is not clear as to whether rate building is part of precision teaching or not. Authors such as White (1986) and Kerr et al. (2003) do not describe rate building as part of precision teaching. Instead they focus on pinpointing, counting and charting as the main elements of precision teaching. In contrast authors such as Miller and Heward (1992), clearly spell out the role of rate building. Miller and Heward (1992) identify two stages of learning, an acquisition phase, and a rate building phase where precision teaching takes place. The results from this research suggest that rate building produced better outcomes at testing than precision teaching, and can be reasoned to be why the students in the PT group made increases in rate. As such further research on the role of rate building in precision teaching would clarify the importance of rate building, as well as the best way to do this.

Whether the achievement of high rates, or just an emphasis on accelerating rates, results in better outcomes is unclear in the literature. Doughty et al. (2004) have

suggested that the amount of practice and reinforcement may be better indicators of progress along a curriculum, than the achievement of high rates alone. The results from Experiment 2 suggested that there is a positive correlation between practice higher rates at testing. It is possible that an emphasis on the achievement of high rates provides more practice opportunities during a training session

The findings in Experiment 2 which showed that the NPT group started to rate build and accelerate their rates without plotting results on a graph, brought into question the importance of charting. In the precision teaching literature the importance of graphing, and even the type of graph used (a semi-log graph, preferably in the form of a SCC) are much emphasised by authors such as Lindsley (1992), White (1986), White (2000), and Kerr et al. (2003). The use of these graphs is proposed to provide a method to allow timely curriculum decisions, based on the learning picture provided by the graphed rates. However, research done by Marston (1988) would suggest that the use of a linear graph results in better outcomes than the use of a semi-log graph. Furthermore Pocock (2006) found that graphing results did not produce better outcomes than no graphing. So further research looking at how and in which conditions (ie teacher making curricular decisions or the student making decisions) graphing affects the acceleration of students rates. Also research into the type of graph used would be useful, as the use of a semi-log graphs, particularly the SCC is highly recommended, but this recommendation is not backed up with a lot of data.

In conclusion the precision teaching literature needs to focus more on which elements of precision teaching are important and which are just parts of the cult of precision teaching. As discussed above the scrutiny of the methods used, and results

produced in this research lead to the researcher concluding that the role of rate-building, how it is done, as well as how result are recorded or even whether results need to be recorded, and what sort of curricular decisions should be made, are sections of precision teaching that are not discussed clearly in the literature. The lack of clear discussion on these parts means that any application of precision teaching is likely to go through a period of trail and error before a successful method is established.

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Appendix A

A copy of the letter to the principal of the primary school that participated in Experiment 1. The letter provides information on what participation in the Experiment involved.

Department of Psychology **The University of Waikato** **Private Bag 3105** **Hamilton,** **New Zealand**	**Phone +64 7 838 4466** **Ext 8400** **www.psychology.waikato.ac.nz**	 THE UNIVERSITY OF WAIKATO *Te Whare Wānanga o Waikato*

Dear

As part of my Masters Thesis at the University of Waikato, I am undertaking a Experiment that looks at whether the application of a teaching method called precision teaching, to teaching maths will be successful in a New Zealand primary school. Research in the USA and UK has shown that this method of teaching has increased the speed with which students learn new material in some cases between two and four times the national average. Supporters of this teaching method have also made claims that skills taught using this method will be retained without practice for longer periods of time, and that the performance of these skills can be done for longer periods of time and are immune to distraction, as well as being applicable to novel environments and untaught problems.

In this Experiment I will expand on a Experiment done in the UK by Chiesa & Roberston, 2000, that used precision teaching to teach maths to a group of nine to ten year olds. Alongside testing whether this method of teaching works in a New Zealand setting, I will test whether this method of teaching results in the taught material being retained better over periods of no practice, and if it will aid in subsequent learning of new maths skills.

To do this Experiment I need to work with a teacher, who is interested in the research, is willing to administer three sets of timed maths tests to the whole class (this should take about five minutes per set of tests), and who is willing to have a group of six children of her choice receive precision teaching during the usual maths class. The teaching aims for the children will follow the teaching aims set out for the rest of the class by the teacher.

If you are prepared to participate, then we will send an information sheet about the Experiment and a consent form to the parents of all the children in the class. Once consent is received, the children that receive precision teaching will be selected in one of two ways, depending on the teacher's preference. The teacher may choose to select the six children to be part of the precision teaching group, based either on them having difficulty with maths as compared to the rest of the class as was done by Chiesa & Roberston, 2000, or they may be randomly selected from those who have consented to

participate. The teacher will continue to teach those who do not receive precision teaching as usual.

The children in the group receiving precision teaching will be involved in completing maths work sheets, timed tests (using timers that count down, and sound an alarm), marking each others work and charting their results independently of the teachers help during their usual maths class. During the first sessions the children will be taught how to use the timers, work sheets and graph their results. During this time the researcher will be present so that no extra burden will be placed on the teacher to help these children. After this the children should be able to do this independently, and the researcher will visit the class at the end of each week during the usual maths time, to monitor the children's progress, provide rewards for good work and achievements (praise, stickers, or anything else the teacher usually uses), address any issues that may have arisen and to identify what new working material is needed for the children, which will be dropped off at the start of the next week.

The first set of maths test will be administered at the start of the Experiment (as close as possible to the start of the term). Precision teaching will continue till the end of the term at which point another set of maths tests will be given. From these two tests it will be possible to compare the learning of the children who received precision teaching and those who did not. To determine whether precision teaching promotes greater retention another set of maths tests will again be administered at the start of the following term. To determine whether the learning of new maths skills will be easier for the children who received precision teaching I will seek consent for access to the results of their maths tests administered in the next term.

At the end of the Experiment you will be provided with a copy of the results, and are welcome to discuss developments during the course of the Experiment with me or my supervisor at any time. My supervisor for this Experiment is Professor Mary Foster, from the department of psychology at the University of Waikato. She can be contacted at m.foster@waikato.ac.nz.

If this Experiment shows that precision teaching does result in more learning, better retention and in easier learning of new material, I would be happy to share these methods with any interested teachers. In accordance with ethical guidelines real names will not be used in my thesis so that neither the school, nor the teacher nor the children involved in the Experiment can be identified. During the Experiment you have the right to withdraw participation at any time.

So if want to know more please contact me by phone on 021 045 8638 or by email at djbh1@waikato.ac.nz.

Yours sincerely

Desiree Horlacher and Prof Mary Foster, DipPsychClin, PhD.

Appendix B

Copy of the letter and consent forms provided to the parents of the participants in Experiment 1. The letter provides information on what participation in the Experiment involved.

Department of Psychology **The University of Waikato** **Private Bag 3105** **Hamilton, 3240,** **New Zealand**	**Desiree Horlacher** **Djbh1@waikato.ac.nz** **and** **Prof Mary Foster** **Phone +64 7 838 4466** **Ext 8400** **M.Foster@waikato.ac.nz**	 THE UNIVERSITY OF WAIKATO *Te Whare Wānanga o Waikato*

Examination of the Effectiveness of Precision Teaching for maths skills
Information

As part of my Masters Thesis at the University of Waikato, I am undertaking a Experiment that looks at whether the application of a teaching method called precision teaching, to teaching maths will be successful in a New Zealand primary school. Research in the USA and UK has shown that this method of teaching has increased the speed with which students learn new material in some cases between two and four times the national average. Supporters of this teaching method have also made claims that skills taught using this method will be retained without practice for longer periods of time, and that the performance of these skills can be done for longer periods of time and are immune to distraction, as well as being applicable to novel environments and untaught problems.

To do this Experiment, I need to be able to compare the results that children receiving their usual teaching and children receiving precision teaching obtain on some maths tests throughout the year. Both the children receiving their usual method of teaching and precision teaching will be following the same maths curriculum, so there will be no disadvantage for either group. The class teacher will select candidates for precision teaching either randomly, or based on them struggling to keep pace in maths with the rest of the class. Participation in the PT group will involve your child completing maths work sheets, timed practice, marking another child's work and charting their own results during their usual maths class.

As such I would like to ask you for your consent to use the scores your child obtains on some maths tests thought the year, and whether you provide consent your child to receive precision teaching. If your child is selected to receive precision teaching, then I will need your permission to use the types of rewards for any good work or achievement that the teacher would usually use.

All results will be presented anonymously (with no names used) so that neither the school, nor teacher nor your child can be identified.

At the end of Experiment you will be provided with a summary of the results, and are welcome to discuss developments during the course of the Experiment with me or my

supervisor at any time. My supervisor for this Experiment is Professor Mary Foster, from the department of psychology at the University of Waikato. During the Experiment you have the right to withdraw at any time and for any reason.

If you have any questions, or would like to know more please contact me at djbh1@waikato.ac.nz.

Yours sincerely

Desire Horlacher and Prof Mary Foster, DipPsychClin, PhD.

Department of Psychology **The University of Waikato** **Private Bag 3105** **Hamilton, 3240,** **New Zealand**	**Desiree Horlacher** **Djbh1@waikato.ac.nz** **and** **Prof Mary Foster** **Phone +64 7 838 4466** **Ext 8400** **M.Foster@waikato.ac.nz**	 THE UNIVERSITY OF WAIKATO *Te Whare Wānanga o Waikato*

University of Waikato
Psychology Department

CONSENT FORM

PARTICIPANT'S COPY

Research Project: Examination of the Effectiveness of Precision Teaching for maths skills

Name of Researcher: Desiree Horlacher

Name of Supervisor (if applicable): Prof Mary Foster, DipPsychClin, PhD.

I have received an information sheet about this research project. I have had the chance to ask any questions and discuss my participation with other people. Any questions have been answered to my satisfaction.

I agree/ do not agree for my child's results on some maths tests thought the rest of the year to be used in this research project.

Participant's
Name:_____Signature:_____Date:_____

I agree/ do not agree to my child receiving precision teaching, and for them to receive any rewards that the teacher would usually provide for any good work or achievements. I understand that I may withdraw at any time, and that if I have any concerns about this project, I may contact the convenor of the Research and Ethics Committee (Dr Robert Isler, phone: 838 4466 ext. 8401, e-mail r.isler@waikato.ac.nz)

Participant's
Name:_____Signature:_____Date:_____

Department of Psychology **The University of Waikato** **Private Bag 3105** **Hamilton, 3240,** **New Zealand**	**Desiree Horlacher** **Djbh1@waikato.ac.nz** **and** **Prof Mary Foster** **Phone +64 7 838 4466** **Ext 8400** **M.Foster@waikato.ac.nz**	THE UNIVERSITY OF WAIKATO *Te Whare Wānanga o Waikato*

University of Waikato
Psychology Department

CONSENT FORM

RESEARCHER'S COPY: TO BE RETURNED TO SCHOOL

Research Project: Examination of the Effectiveness of Precision Teaching for maths skills

Name of Researcher: Desiree Horlacher

Name of Supervisor (if applicable): Prof Mary Foster, DipPsychClin, PhD.

I have received an information sheet about this research project. I have had the chance to ask any questions and discuss my participation with other people. Any questions have been answered to my satisfaction.

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Participant's
Name:_____Signature:_____Date:_____

Appendix C

Shows the format of and equations used in the Rate test.

Name: _____ Test 1

9 × 6 =	2 × 2 =	8 × 5 =	4 × 3 =	8 × 1 =
4 × 4 =	6 × 8 =	1 × 0 =	8 × 3 =	5 × 4 =
10×1 =	7 × 2 =	5 × 5 =	3 × 0 =	6 × 6 =
1 × 5 =	4 × 6 =	8 × 7 =	10×9 =	3 × 2 =
2 × 8 =	0 × 0 =	9 × 4 =	7 × 7 =	4 × 8 =
4 × 1 =	6 × 5 =	3 × 3 =	0 × 2 =	5 × 9 =
6 × 3 =	3 × 5 =	8× 8 =	7 × 9 =	7 × 0 =
2 × 6 =	9 × 8 =	6 × 1 =	2 × 4 =	3 × 9 =
9 × 9 =	5 × 2 =	0 × 8 =	10×3 =	0 × 6 =
9 × 0 =	4×10 =	7 × 4 =	1 × 9 =	6×10 =
2×10 =	2 × 1 =	10×7 =	9×10 =	9 × 2 =
7 × 6 =	8×10 =	5 × 0 =	5 × 7 =	10×10=
10×5 =	3 × 7 =	8 × 9 =	0×10 =	0 × 4 =
1 × 3 =	7 × 8 =	6 × 9 =	2 × 7 =	3 × 8 =
1 × 8 =	4 × 7 =	5×10 =	3 × 6 =	6 × 7 =
5 × 8 =	6 × 9 =	2 × 5 =	1 × 6 =	2 × 3 =
0 × 7 =	1 × 4 =	3 × 4 =	5 × 3 =	6 × 4 =
4 × 2 =	1 × 7 =	8 × 6 =	9 × 7 =	1 × 1 =
7 × 5 =	9 × 5 =	1×10 =	7 × 1 =	10×8 =
3×10 =	10×4 =	1 × 2 =	10×0 =	4 × 5 =
8 × 4 =	8 × 0 =	2 × 0 =	4 × 9 =	8 × 2 =
7 × 3 =	0 × 3 =	0 × 5 =	9 × 1 =	4 × 0 =
6 × 2 =	3 × 1 =	6 × 0 =	10×2 =	0 × 9 =
10×6 =	2 × 9 =	5 × 6 =	9 × 3 =	5 × 1 =
0 × 3 =	10×5 =	3 × 7 =	0 × 1 =	6 × 7 =

Appendix D

Shows the format of and equations used in the Stability Test.

Name: _____ Test 2

10×7 =	2 × 0 =	5 × 3 =	2 × 9 =	3 × 1 =
4 × 2 =	4 × 1 =	7 × 6 =	0 × 1 =	8 × 6 =
2 × 6 =	3 × 4 =	4 × 8 =	5 × 6 =	6 × 1 =
7 × 8 =	8 × 3 =	0 × 4 =	10×8 =	9×10 =
10×5 =	2 × 3 =	3 × 7 =	1 × 5 =	2×10 =
0 × 8 =	4 × 5 =	7 × 5 =	5 × 9 =	6 × 7 =
3×10 =	6 × 3 =	3 × 2 =	8 × 5 =	7 × 2 =
5 ×2 =	4×10 =	6 × 2 =	2 × 8 =	9 × 8 =
5 × 4 =	7 × 7 =	8 × 9 =	4 × 9 =	1 × 0 =
9 × 9 =	9 × 4 =	7 × 3 =	10×0 =	3 × 3 =
8 × 4 =	8 × 8 =	1 × 4 =	6 × 6 =	2 × 4 =
10×6 =	9 × 5 =	3 × 0 =	5×10 =	5 × 1 =
0 × 0 =	1 × 2 =	10×10=	3 × 6 =	4 × 4 =
6 × 5 =	1 × 6 =	4 × 6 =	3 × 8 =	5 × 8 =
4 × 3 =	7 × 4 =	2 × 2 =	0 × 2 =	2 × 7 =
0 × 7 =	3 × 9 =	8 × 7 =	5 × 5 =	10×9 =
6 × 8 =	1 × 9 =	2 × 1 =	9 × 6 =	0 × 6 =
6×10 =	7 × 1 =	7 × 9 =	1×10 =	8 × 2 =
10×4 =	9 × 3 =	8×10 =	6 × 9 =	9 × 1 =
8 × 0 =	4 × 7 =	0 × 9 =	3 × 5 =	5 × 0 =
1 × 8 =	4 × 0 =	3 × 8 =	2 × 3 =	0 × 3 =
5 × 7 =	1 × 3 =	7×10 =	6 × 0 =	2 × 5 =
7 × 0 =	0×10 =	4 × 4 =	6 × 4 =	10×1 =
9 × 2 =	7 × 4 =	9 × 0 =	8 × 1 =	9 × 7 =
0 × 5 =	10×2 =	1 × 7 =	10×3 =	1 × 1 =

Appendix E

Shows the format of and equations used in the Endurance Test.

Name: _____ Test 4

3 × 3 =	4 × 9 =	0 × 5 =	2 × 7 =	6 × 3 =
1 × 6 =	7 × 6 =	2 × 8 =	9 × 6 =	8 × 5 =
9 × 5 =	8 × 7 =	5 × 5 =	6 × 2 =	1 × 0 =
10×7 =	6 × 6 =	3 × 8 =	8 × 6 =	4 × 2 =
8 × 4 =	2 × 1 =	7 × 2 =	9 × 4 =	7 × 7 =
3 × 9 =	0 × 4 =	3 × 7 =	4 × 4 =	5×10 =
7 × 4 =	9 × 9 =	10×6 =	2 × 6 =	3 × 1 =
1 × 8 =	7 × 3 =	5 × 9 =	7 × 1 =	0 × 8 =
2 × 9 =	1 × 4 =	3 × 6 =	0 × 0 =	5 × 8 =
8 × 3 =	2 × 5 =	8 × 8 =	9 × 1 =	6 × 9 =
6×10 =	2 × 2 =	7 × 0 =	9 × 3 =	5 × 4 =
1 × 1 =	5 × 6 =	5 × 0 =	0 × 1 =	7×10 =
4 × 7 =	2×10 =	8 × 9 =	3 × 2 =	8 × 1 =
7 × 8 =	10×1 =	4 × 5 =	1 × 2 =	1×10 =
0 × 9 =	5 × 6 =	2 × 0 =	10×4 =	9 × 2 =
6 × 7 =	0×10 =	7 × 8 =	2 × 3 =	10×3 =
1 × 3 =	6 × 7 =	1 × 5 =	1 × 9 =	3 × 0 =
6 × 4 =	10×0 =	5 × 3 =	3 × 4 =	2 × 4 =
0 × 2 =	0 × 7 =	9 × 0 =	4 × 5 =	6 × 0 =
4 × 8 =	9×10 =	8 × 0 =	10×10=	3 × 5 =
8 × 2 =	10×2 =	10×5 =	8 ×10 =	1 × 7 =
4 × 0 =	7 × 5 =	6 × 8 =	4 × 6 =	3×10 =
9 × 7 =	7 × 9 =	5 × 7 =	6 × 1 =	10×9 =
4×10 =	4 × 1 =	10×8 =	0 × 3 =	5 × 1 =
5 × 2 =	6 × 5 =	4 × 3 =	0 × 6 =	9 × 8 =

Name: _____ Test 4

2 × 3 =	4 × 6 =	5 × 8 =	2 × 4 =	1 × 2 =
5 × 7 =	6 × 0 =	4 × 8 =	8 × 2 =	10×5 =
7 × 1 =	5 × 9 =	7 × 7 =	6×10 =	9 × 3 =
9 × 2 =	0 × 6 =	4 × 1 =	5 × 2 =	7×10 =
3 × 1 =	7 × 4 =	6 × 3 =	1 × 7 =	8 × 8 =
4×10 =	9 × 5 =	8 × 4 =	2 × 8 =	2 × 0 =
8 × 5 =	10×6 =	4 × 2 =	7 × 3 =	3 × 9 =
9 × 6 =	5 × 3 =	2 × 1 =	6 × 2 =	5 × 1 =
6 × 4 =	9 × 8 =	3 × 6 =	5 × 4=	2 × 5 =
4 × 3 =	1 × 1 =	3 × 5 =	2 × 2 =	9 × 7 =
0 × 0 =	10×3 =	9×10 =	2 × 6 =	10×0 =
8×10 =	5 × 0 =	8 × 9 =	7 × 2 =	1 × 3 =
4 × 9 =	0 × 4 =	6 × 1 =	1 × 5 =	8 × 0 =
5×10 =	10×10=	0 × 2 =	3 × 7 =	9 × 9 =
1 × 0 =	3 × 2 =	4 × 7 =	1 × 6 =	3 × 8 =
6 × 5 =	0 × 5 =	10×1 =	2 × 7 =	8 × 6 =
6 × 4 =	8 × 7 =	3 × 3 =	10×9 =	2×10 =
4 × 0 =	9 × 3 =	7 × 6 =	4 × 2 =	1 × 8 =
2 × 9 =	0 × 8 =	10×8 =	6 × 9 =	0 × 9 =
3 × 0 =	1×10 =	0 × 7 =	7 × 5 =	8 × 5 =
6 × 6 =	3×10 =	3 × 5 =	1 × 9 =	4 × 4 =
7 × 0 =	4 × 1 =	0×10 =	10×7 =	8 × 1 =
2 × 5 =	9 × 0 =	5 × 5 =	9 × 1 =	10×4 =
6 × 8 =	1 × 4 =	10×2 =	0 × 3 =	8 × 3 =
3 × 4 =	7 × 9 =	6 × 9 =	9 × 4 =	0 × 1 =

Appendix F

Shows the format of and equations used in the Application/Adduction Test

Name: _____ Test 3

$3 \times \_\_ = 15$ $4 \times \_\_ = 12$

$4 \times \_\_ = 4$ $6 \times \_\_ = 36$

$10 \times \_\_ = 90$ $2 \times \_\_ = 0$

$9 \times \_\_ = 72$ $6 \times \_\_ = 12$

$3 \times \_\_ = 24$ $5 \times \_\_ = 20$

$6 \times \_\_ = 6$ $5 \times \_\_ = 30$

$20 \div 10 = \_\_$ $16 \div 4 = \_\_$

$33 \div 11 = \_\_$ $18 \div 3 = \_\_$

$18 \div 9 = \_\_$ $24 \div 6 = \_\_$

$49 \div 7 = \_\_$ $90 \div 9 = \_\_$

$15 \div 3 = \_\_$ $40 \div 8 = \_\_$

$72 \div 9 = \_\_$ $30 \div 5 = \_\_$

$14 \times 10 = \_\_$ $12 \times 11 = \_\_$

$3 \times 12 = \_\_$ $5 \times 12 = \_\_$

$10 \times 12 = \_\_$ $9 \times 11 = \_\_$

$10 \times 20 = \_\_$ $20 \times 40 = \_\_$

$4 \times 11 = \_\_$ $9 \times 12 = \_\_$

3	8	5	4	9	5
×5	×2	×9	×8	×8	×4
__	__	__	__	__	__

1	2	6	3	6	7
×7	×4	×6	×9	×5	×6
__	__	__	__	__	__

12	26	14	30	18	13
×3	×4	×5	×2	×8	×1
__	__	__	__	__	__

23	55	12	36
×11	× 34	×40	×10
____	____	____	____
____	____	____	____

Four friends brought four goldfish each, how many goldfish do they have all together? ____

If there are nine rabbits and they each have five baby rabbits, how many baby rabbits are there? ____

If three people go snorkelling, how many flippers will they need? ____

If there are ten Christmas cards in a pack, and Tom buys eight packs, how many Christmas chards does Tom have? ____

If a slice of cake cost two dollars, and Fred wanted to buy two slices, how much money will he need ? $ ____

Jane's Grandma will visit her in three weeks time, how many days dose Jane have to wait? _____

Appendix G

Shows the format of and equations used in the 100-Equation Test

Multiplication Total: _____

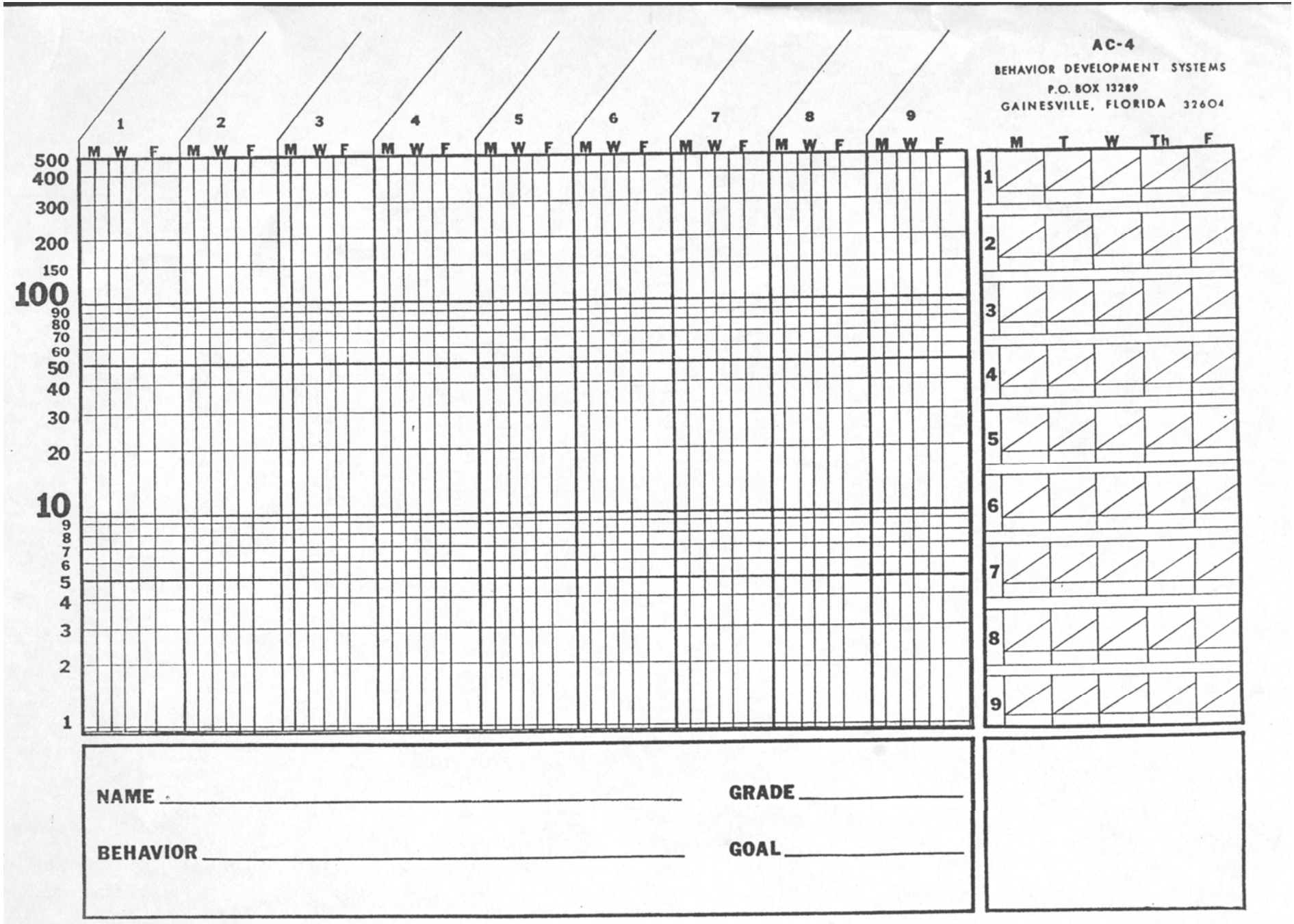
Date: _____ Name: _____

2 ×2	7 ×5	6 ×0	4 ×9	8 ×6	10 ×7	4 ×4	7 ×1	5 ×3	3 ×8	×
5 ×8	6 ×6	9 ×10	7 ×3	0 ×1	2 ×5	8 ×4	10 ×2	9 ×9	4 ×7	×
6 ×4	9 ×7	8 ×8	0 ×7	8 ×2	2 ×3	1 ×10	7 ×7	3 ×6	5 ×5	×
1 ×1	2 ×9	3 ×3	10 ×10	6 ×7	6 ×6	4 ×0	7 ×8	9 ×1	4 ×2	×
9 ×5	0 ×0	3 ×4	6 ×9	10 ×0	1 ×6	8 ×9	4 ×5	2 ×7	1 ×4	×

5 ×6	10 ×8	6 ×2	2 ×9	8 ×0	5 ×4	3 ×5	9 ×6	4 ×7	9 ×3	×
3 ×10	1 ×2	8 ×7	6 ×8	6 ×3	2 ×0	3 ×7	10 ×4	7 ×6	4 ×3	×
8 ×5	0 ×3	6 ×5	4 ×8	9 ×2	5 ×10	2 ×1	9 ×4	3 ×0	1 ×8	×
5 ×1	2 ×6	8 ×3	10 ×7	9 ×8	3 ×2	1 ×5	4 ×6	0 ×9	2 ×4	×
1 ×4	5 ×7	7 ×2	3 ×1	5 ×2	3 ×9	0 ×5	2 ×8	7 ×9	10 ×6	×

Appendix H

The standard celeration chart used by the students who received precision teaching in Experiment 1 and Experiment 2.



Appendix I

Example of the daily practice record sheet that the students in Experiment 1 used to record their practice results.

Daily practice record sheet

Week 1	Monday	Tuesday	Wednesday	Thursday	Friday
Test 1					
Test 2					
Test 3					

Week 2	Monday	Tuesday	Wednesday	Thursday	Friday
Test 1					
Test 2					
Test 3					

Week 3	Monday	Tuesday	Wednesday	Thursday	Friday
Test 1					
Test 2					
Test 3					

Week 4	Monday	Tuesday	Wednesday	Thursday	Friday
Test 1					
Test 2					
Test 3					

Week 5	Monday	Tuesday	Wednesday	Thursday	Friday
Test 1					
Test 2					
Test 3					

Daily practice record sheet

Week 6	Monday	Tuesday	Wednesday	Thursday	Friday
Test 1					
Test 2					
Test 3					

Week 7	Monday	Tuesday	Wednesday	Thursday	Friday
Test 1					
Test 2					
Test 3					

Week 8	Monday	Tuesday	Wednesday	Thursday	Friday
Test 1					
Test 2					
Test 3					

Week 9	Monday	Tuesday	Wednesday	Thursday	Friday
Test 1					
Test 2					
Test 3					

Week 10	Monday	Tuesday	Wednesday	Thursday	Friday
Test 1					
Test 2					
Test 3					

Appendix J

Example of the Visual schedule which outlined the procedure to be followed by the participants in Experiment 1.

Name: _____

A

Times table practice check list

		Monday		
Round 1	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐
Round 2	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐
Round 3	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐
		Tuesday		
Round 1	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐
Round 2	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐
Round 3	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐
		Wednesday		
Round 1	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐
Round 2	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐
Round 3	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐
		Thursday		
Round 1	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐
Round 2	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐
Round 3	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐
		Friday		
Round 1	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐
Round 2	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐
Round 3	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐

Name: _____

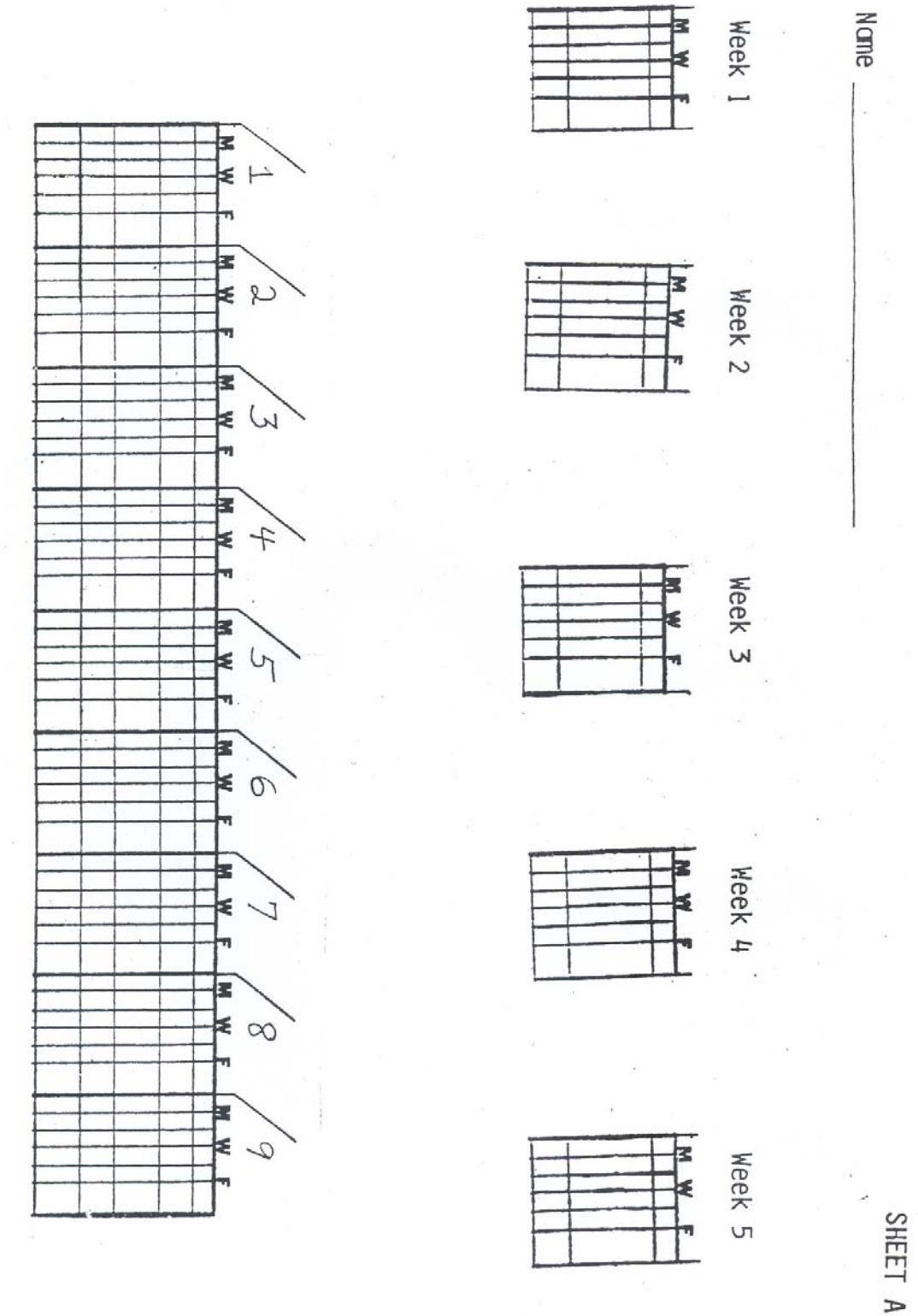
B

Times table practice check list

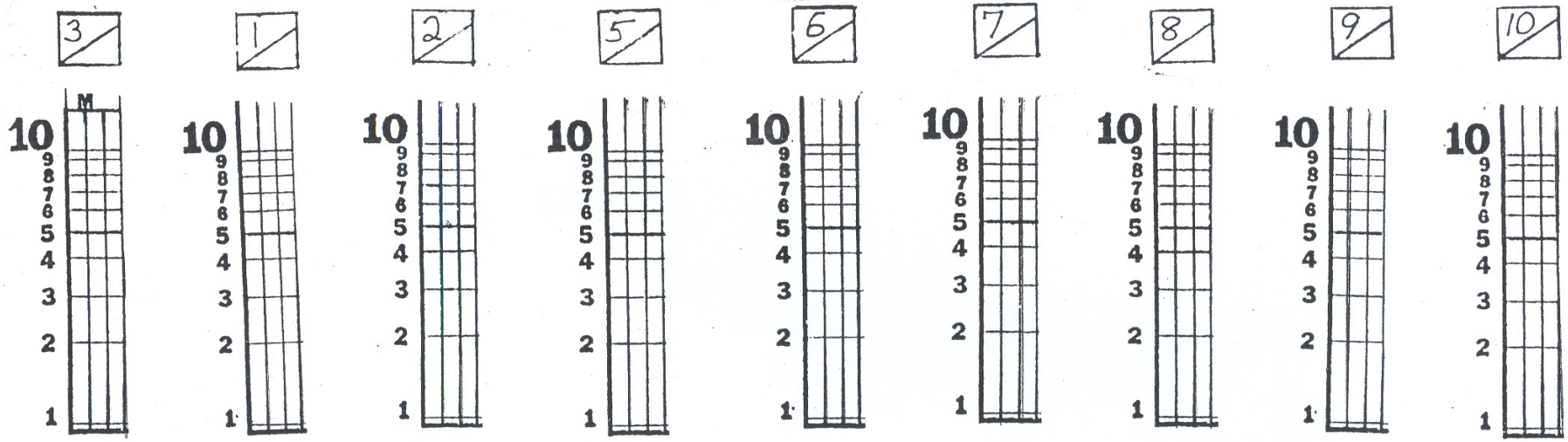
		Monday		
Round 1	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐
Round 2	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐
Round 3	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐
		Tuesday		
Round 1	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐
Round 2	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐
Round 3	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐
		Wednesday		
Round 1	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐
Round 2	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐
Round 3	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐
		Thursday		
Round 1	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐
Round 2	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐
Round 3	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐
		Friday		
Round 1	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐
Round 2	2 min practice	1 min speed trial	record results	monitor buddy
	☐	☐	☐	☐
Round 3	2 min practice	monitor buddy	1 min speed trial	record results
	☐	☐	☐	☐

Appendix K

Example of the Charting Worksheets used to teach the participants of Experiment 1 to chart.

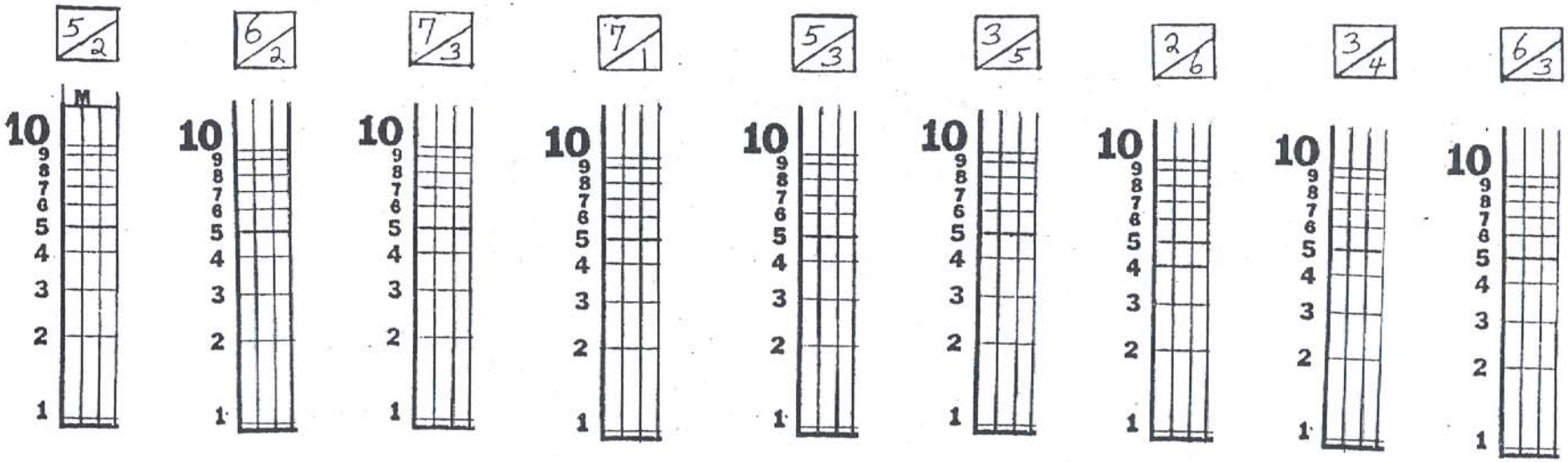


Name _____ SHEET B



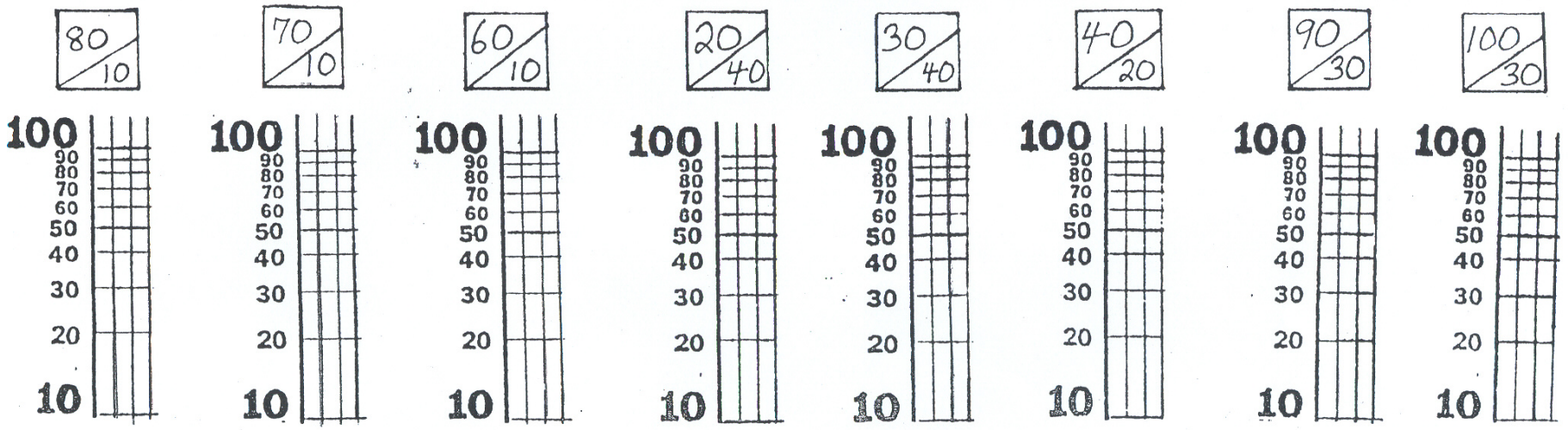
SHEET C

Name _____


5/2
M
10 9 8 7 6 5 4 3 2 1
6/2
10 9 8 7 6 5 4 3 2 1
7/3
10 9 8 7 6 5 4 3 2 1
7/1
10 9 8 7 6 5 4 3 2 1
5/3
10 9 8 7 6 5 4 3 2 1
3/5
10 9 8 7 6 5 4 3 2 1
2/6
10 9 8 7 6 5 4 3 2 1
3/4
10 9 8 7 6 5 4 3 2 1
6/3
10 9 8 7 6 5 4 3 2 1

Name _____

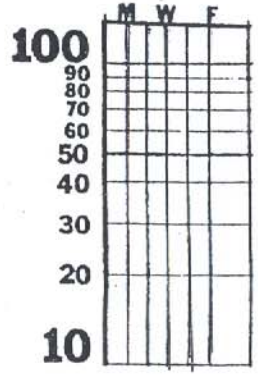
SHEET D


80/10
70/10
60/10
20/40
30/40
40/20
90/30
100/30
100
90
80
70
60
50
40
30
20
10

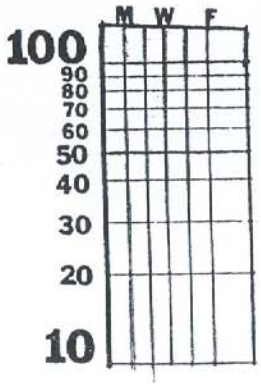
Name _____

SHEET E

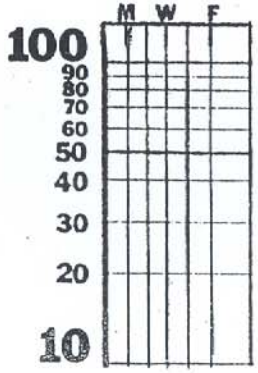
M	T	W	Th	F
34 / 21	42 / 21	42 / 22	51 / 30	63 / 10



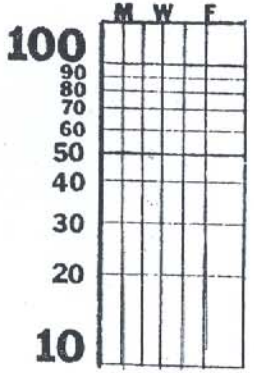
M	T	W	Th	F
31 / 15	45 / 16	55 / 17	65 / 19	75 / 20



M	T	W	Th	F
34 / 80	42 / 80	33 / 70	27 / 55	17 / 31



M	T	W	Th	F
100 / 41	78 / 43	88 / 50	90 / 27	60 / 43



Name _____

SHEET F

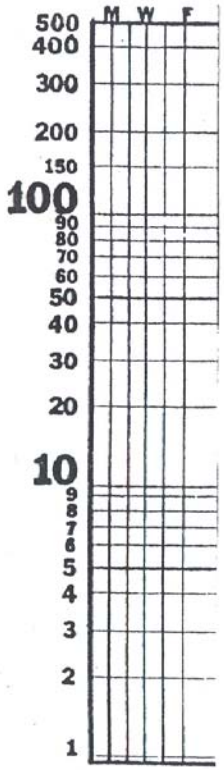
	M	T	W	Th	F
1	15 / 0	20 / 3		30 / 16	12 / 2

	M	T	W	Th	F
2	9 / 33	15 / 21	10 / 6	18 / 0	24 / 0

	M	T	W	Th	F
3	82 / 0	95 / 2	97 / 3		100 / 1

	M	T	W	Th	F
4	95 / 30	67 / 31	82 / 10	73 / 0	99 / 15

1



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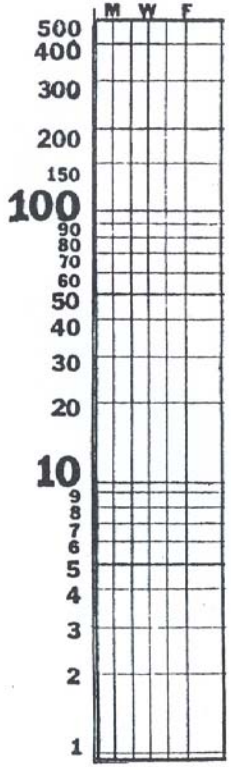

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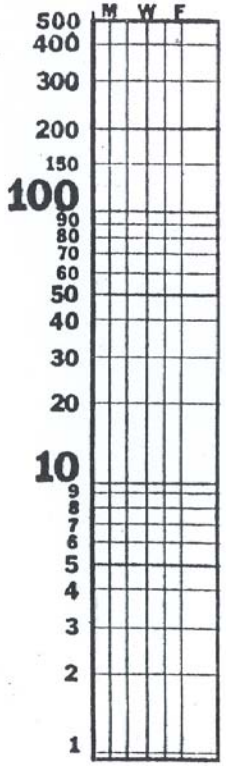

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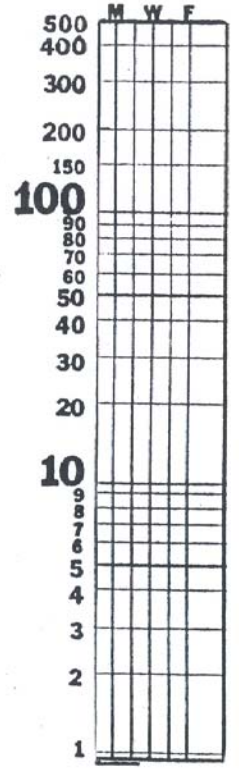
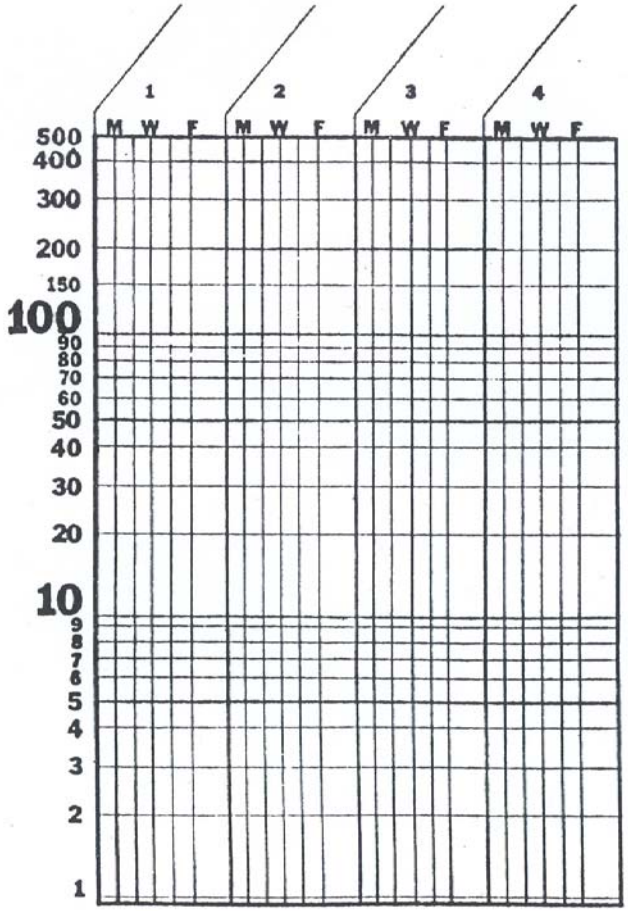


Name _____

SHEET G



	M	T	W	Th	F
1	9/0	17/3	/	27/0	30/2
2	34/5	42/4	27/2	36/0	40/0
3	90/2	95/2	97/3	/	100/1
4	80/9	86/8	75/7	93/7	98/5

Appendix L
The scripted used while teaching the participants of Experiment 1 how to chart.

Teaching children to chart

We are going to help you practice your times tables this term. Like last term, you are going to use flash cards to practice your times tables with a buddy, but from now on you will do some speed trials, as well as your usual practice. After the speed trials you will record how many cards you got right and how many you got wrong, and then you will chart your best score on this chart *hold up chart.* So before we start I'm going to teach you how to chart.
Hand out worksheets and make sure everyone has a pencil

1) "These lines (*point to the day lines)* stand for the days of the week. (*Highlight the Monday line*) What day do you think this is? (**Children answer**) This next line (*highlight the Tuesday line*) is for the day that comes after Monday. What day is that? (**Children answer**). (*Continue until the children can name the day you point to in random order twice in a row*).

2) If I wanted to put a dot on the Wednesday line should I put a dot here (*point to the gap between Tuesday and Wednesday*) (**Children answer**), … we have to put the dot on the line.

A1)
(*Hold up sheet A*) "Each of these boxes is for a week. Can you see the little numbers at the top? (*Point to week 2*) What week is this?

A2) "Now we are going to fill in week 1, so point to week 1 (*check everyone is pointing to week 1, correct if needed*). Good, now put a dot on the Monday line,….. and Wednesday. (*Make sure everyone got it right*). Ok, now point to week two (*check everyone is pointing to week 2, correct if needed.* That's right, now put a dot on Monday,….. and Tuesday. (*Make sure everyone got it right*).

Now I'm going to speed up, I will tell you the week and which days to put dots on. If you miss a day, don't worry, just listen for the next week and days.

Week 3- Tuesday, Friday
Week 4- Wednesday, Thursday
Week 5- Tuesday, Thursday

So for week 3, where did you put your dots? **children answer**, and for week 4, where did you put your dots? **children answer**, and for week five you put your dots on…. **children answer.** *Corrected/ prompted answers where needed.*

A3) (*Hold up sheet A again and point to the bottom chart*) Now this bit is the same as we just did, just that the weeks are all joined together. (*Point to a week*) What week is this? (**Children answer**). (*Continue pointing to random weeks till children have accurately*

identified 2 weeks in a row). Now I am going to say the week and the days that you have to put dots on, so listen carefully, because this time you might get tricked. If you get lost, listen for the next week and day, because I'm not going to stop till we get to week 9. Ready. **Children answer**

Week 1- Tuesday, Friday
Week 2 - Monday, Thursday
Week 4- Wednesday, Thursday
Week 5- Monday, Tuesday
Week 7 - Wednesday, Friday
Week 8 - Tuesday, Wednesday
Week 9 - Monday, Friday

Now did you all manage to keep up? (**children answer**) Which days did you put dots on for week 1? **children answer.** Which days did you put dots on for week 2? **children answer.** Which days did you put dots on for week 3? **children answer.** Which days did you put dots on for week 4? **children answer.** Which days did you put dots on for week 5? **children answer.** Which days did you put dots on for week 6? **children answer.** Which days did you put dots on for week 7? **children answer.** Which days did you put dots on for week 8? **children answer.** Which days did you put dots on for week 9? **children answer.**

B1)
(*Hold up sample sheet B, point to the Monday*) What day is this? (**Children answer**) On the next sheet you are going to going to practice charting the number of flash cards that you answered right. (*Point to the number in the little box*) What number is this? (**Children answer**) If I wanted to put a dot for four on Monday, would I put my dot here? (*Point to 1*) (**Children answer**), here? (*Point to 5*), how about here? (*Point to 4*)

B2)
Ok everyone, turn over the page. What number is in the first little box? (**Children answer**) Place your dot on the Monday line next to 3 (*check that everyone got this right*). Ok now what number is in the next little box? (**Children answer**) place you your dot. (*Check that everyone got this right*). Did you all put a dot on 1? **Children answer** When I say go, finish the rest of the sheet, Go. (*check that everyone got this right, correct if needed).*

C1)
Everyone look this way, (*Hold practice sheet c*) Notice how there are two number in the little box this time. The number on top is the number of flash cards that were answered right, the number at the bottom is the number of flash cards that were answered wrong. When charting the number of right and wrong cards, they both go on the same day line. So how many questions were answered correctly? (**Children answer**). *Place the dot.* When charting the number of cards that were answered wrong, you place a x, like this (*draw a x on the bottom of the chart*) on the chart. How many questions were wrong? (**Children answer**). *Place the x.*

C2)
Turn over the page. (*Point to the first chart on sheet c*) How many correct? (**Children answer**), place your dot. (*check they did it right*) How many wrong? (**Children answer**), place your cross, did everyone place a cross on 2, under their dot on the Monday line? **Children answer**. When I say go, finish the rest of the sheet. Go. (*check they did it right*).

D1)
Turn over your page. This sheet is the same as the last one, only that instead of the chart going from 1 to 10, it now goes from 10 to 100. How many corrects are there? (**Children answer**), mark that on the chart (*check this was done correctly*) How many incorrect? Mark that on the chart,… did you put your x on 10? When I say go, I want you to finish the rest of the sheet. Go. (*check for accuracy*)

E1)
Ok everyone turn over the page. (*Hold up sheet, point to the Monday box*), What day is this? (**children answer**) That's right, so chart these on the Monday day line. (*point to the Monday line*) (**Children answer**). How many corrects? (**Children answer**) (*point to the 20 line*) do I put the dot here? (**Children answer**) how about here? *point to 23* **Children answer.** Ok and how may wrong? (**Children answer**) *place the x*. *Point to the Tuesday box,* How many correct? **Children answer**, *place the dot,* how many wrong? **Children answer** *place the x.* (*Point to the Wednesday box*), now what is wrong with this box? (**Children answer**), there's noting to chart, so we'll just skip this day, and chart Thursday and Friday. *Point to Thursday,* How many right? *Continue with Thursday and Friday.* Now you guys have a go. *Check charting*

F1)
Everyone turn over the page, (*Hold up the sheet*) Now on this sheet is the same as the last one just that the chart goes from 1 to 500. *Point to the first box*, when there is a 0, you put a ?, like this (*demonstrate*) at the bottom of the day line, instead of a cross. Have a go charting, you can ask for help if you need it.

G1)
Everyone turn over the page, *Hold up the sheet*. This sheet is almost the same as the last one, just this time all the weeks are joined together, and the boxes for each week are on the side instead of above each week. Have a go charting, you can ask for help if you need it.

Appendix M

The check sheet used to check testing integrity.

Assessment Integrity Check

- Students were told
  - that they are racing the clock ☐
  - to write down as many answers they could before the timer goes ☐
  - to skip any questions they can't answer ☐

- Each test was handed out and completed separately

  Test 1 ☐ Test 2 ☐ Test 3 ☐ Test 4 ☐

- Each test was handed out face down

  Test 1 ☐ Test 2 ☐ Test 3 ☐ Test 4 ☐

- Students all started at the same time

  Test 1 ☐ Test 2 ☐ Test 4 ☐

- Students all stopped work when the timer went

  Test 1 ☐ Test 2 ☐ Test 4 ☐

- Students got 1 min to work on test 1 ☐ and test 2 ☐

- Students got 3min to work on test 4 ☐

- Test 3 was not timed ☐

Equipment used:

- 2x 26 1min tests ☐
- 26 5min tests ☐
- 26 7min tests ☐
- timer ☐
- Distracter ☐

Test 1 - 1 min test
Test 2 - 1 min Stability Test
Test 3 - application and adduction test
Test 4 - Endurance Test (3min)

Appendix N

The Teaching-to-Chart Integrity Check used to check for procedural integrity while teaching to chart.

Teaching children to chart: check list

We are going to help you practice your times tables this term. Like last term, you are going to use flash cards to practice your times tables with a buddy, but from now on you will do some speed trials, as well as your usual practice. After the speed trials you will record how many cards you got right and how many you got wrong, and then you will chart your best score on this chart *hold up chart.* So before we start I'm going to teach you how to chart.
Hand out worksheets and make sure everyone has a pencil

1) "These lines (*point to the day lines)* stand for the days of the week. (*Highlight the Monday line*) What day do you think this is? (**Children answer**) This next line (*highlight the Tuesday line*) is for the day that comes after Monday. What day is that? (**Children answer**). (*Continue until the children can name the day you point to in random order twice in a row*).

1)
- Read script
- Did script actions
- Waited for students to answer

2) If I wanted to put a dot on the Wednesday line should I put a dot here (*point to the gap between Tuesday and Wednesday*) (**Children answer**), … we have to put the dot on the line.

2)
- Read script
- Did scrip actions
- Waited for students to answer

A1)
(*Hold up sheet A*) "Each of these boxes is for a week. Can you see the little numbers at the top? (*Point to week 2*) What week is this?

A1)
- Read script
- Did script actions
- Waited for students to answer

A2) "Now we are going to fill in week 1, so point to week 1 (*check everyone is pointing to week 1, correct if needed*). Good, now put a dot on the Monday line,….. and Wednesday. (*Make sure everyone got it right*). Ok, now point to week two (*check*

everyone is pointing to week 2, correct if needed. That's right, now put a dot on Monday,….. and Tuesday. (*Make sure everyone got it right*).

Now I'm going to speed up, I will tell you the week and which days to put dots on. If you miss a day, don't worry, just listen for the next week and days.

Week 3- Tuesday, Friday
Week 4- Wednesday, Thursday
Week 5- Tuesday, Thursday

So for week 3, where did you put your dots? **children answer**, and for week 4, where did you put your dots? **children answer**, and for week five you put your dots on…. **children answer.** *Corrected/ prompted answers where needed.*

A2)
- Read script
- Did script actions
- Checked that students were pointing to correct week
- Waited for students to answer
- Checked that charting was accurate

A3) (*Hold up sheet A again and point to the bottom chart*) Now this bit is the same as we just did, just that the weeks are all joined together. (*Point to a week*) What week is this? (**Children answer**). (*Continue pointing to random weeks till children have accurately identified 2 weeks in a row*). Now I am going to say the week and the days that you have to put dots on, so listen carefully, because this time you might get tricked. If you get lost, listen for the next week and day, because I'm not going to stop till we get to week 9. Ready. **Children answer**

Week 1- Tuesday, Friday
Week 2 - Monday, Thursday
Week 4- Wednesday, Thursday
Week 5- Monday, Tuesday
Week 7 - Wednesday, Friday
Week 8 - Tuesday, Wednesday
Week 9 - Monday, Friday

Now did you all manage to keep up? (**children answer**) Which days did you put dots on for week 1? **children answer.** Which days did you put dots on for week 2? **children answer.** Which days did you put dots on for week 3? **children answer.** Which days did you put dots on for week 4? **children answer.** Which days did you put dots on for week 5? **children answer.** Which days did you put dots on for week 6? **children answer.** Which days did you put dots on for week 7? **children answer.** Which days did you put dots on for week 8? **children answer.** Which days did you put dots on for week 9? **children answer.**

A3)

- Read script
- Did script actions
- Waited for students to answer
- Repeated week if needed
- Checked that charting was accurate

B1)
(*Hold up sample sheet B, point to the Monday*) What day is this? (**Children answer**) On the next sheet you are going to going to practice charting the number of flash cards that you answered right. (*Point to the number in the little box*) What number is this? (**Children answer**) If I wanted to put a dot for four on Monday, would I put my dot here? (*Point to 1*) (**Children answer**), here? (*Point to 5*), how about here? (*Point to 4*)

B1)
- Read script
- Did script actions
- Waited for students to answer

B2)
Ok everyone, turn over the page. What number is in the first little box? (**Children answer**) Place your dot on the Monday line next to 3 (*check that everyone got this right*). Ok now what number is in the next little box? (**Children answer**) place you your dot. (*Check that everyone got this right*). Did you all put a dot on 1? **Children answer** When I say go, finish the rest of the sheet, Go. (*check that everyone got this right, correct if needed).*

B2)
- Waited for students to turn over the page
- Read script
- Did script actions
- Waited for students to answer
- Checked that charting was accurate

C1)
Everyone look this way, (*Hold practice sheet c*) Notice how there are two number in the little box this time. The number on top is the number of flash cards that were answered right, the number at the bottom is the number of flash cards that were answered wrong. When charting the number of right and wrong cards, they both go on the same day line. So how many questions were answered correctly? (**Children answer**). *Place the dot.* When charting the number of cards that were answered wrong, you place a x, like this (*draw a x on the bottom of the chart*) on the chart. How many questions were wrong? (**Children answer**). *Place the x*.

C1)
- Read script
- Did script actions
- Waited for students to answer

- Demonstrated putting the dot and cross on the same day line

C2)
Turn over the page. (*Point to the first chart on sheet c*) How many correct? (**Children answer**), place your dot. (*check they did it right*) How many wrong? (**Children answer**), place your cross, did everyone place a cross on 2, under their dot on the Monday line? **Children answer**. When I say go, finish the rest of the sheet. Go. (*check they did it right*).

C2)
- Waited for students to turn over the page
- Read script
- Did script actions
- Waited for students to answer
- Checked that charting was accurate

D1)
Turn over your page. This sheet is the same as the last one, only that instead of the chart going from 1 to 10, it now goes from 10 to 100. How many corrects are there? (**Children answer**), mark that on the chart (*check this was done correctly*) How many incorrect? Mark that on the chart,… did you put your x on 10? When I say go, I want you to finish the rest of the sheet. Go. (*check for accuracy*)

D1)
- Waited for students to turn over the page
- Read script
- Did script actions
- Waited for students to answer
- Checked that charting was accurate

E1)
Ok everyone turn over the page. (*Hold up sheet, point to the Monday box*), What day is this? (**children answer**) That's right, so chart these on the Monday day line. (*point to the Monday line*) (**Children answer**). How many corrects? (**Children answer**) (*point to the 20 line*) do I put the dot here? (**Children answer**) how about here? *point to 23* **Children answer.** Ok and how may wrong? (**Children answer**) *place the x*. *Point to the Tuesday box,* How many correct? **Children answer**, *place the dot,* how many wrong? **Children answer** *place the x.* (*Point to the Wednesday box*), now what is wrong with this box? (**Children answer**), there's noting to chart, so we'll just skip this day, and chart Thursday and Friday. *Point to Thursday,* How many right? *Continue with Thursday and Friday.* Now you guys have a go. *Check charting*

E1)
- Read script
- Did script actions
- Waited for students to answer
- Waited for students to turn over the page

- Checked that charting was accurate

F1)
Everyone turn over the page, (*Hold up the sheet*) Now on this sheet is the same as the last one just that the chart goes from 1 to 500. *Point to the first box*, when there is a 0, you put a ?, like this (*demonstrate*) at the bottom of the day line, instead of a cross. Have a go charting, you can ask for help if you need it.

F1)
- Read script
- Did script actions
- Waited for students to turn over the page
- Checked that charting was accurate

G1)
Everyone turn over the page, *Hold up the sheet*. This sheet is almost the same as the last one, just this time all the weeks are joined together, and the boxes for each week are on the side instead of above each week. Have a go charting, you can ask for help if you need it.

E1)
- Read script
- Did script actions
- Waited for students to turn over the page
- Checked that charting was accurate

Appendix O

Example of the Student Integrity Check.

Interobserver check for visual schedule

Name:
Round:

- ☐ Did practice
- ☐ Monitored buddies speed trial
- ☐ Made no mistakes while providing feed back
- ☐ Did speed trial
- ☐ Counted cards accurately
- ☐ Recorded the number of correct and incorrect answers

Name:
Round:

- ☐ Did practice
- ☐ Monitored buddies speed trial
- ☐ Made no mistakes while providing feed back
- ☐ Did speed trial
- ☐ Counted cards accurately
- ☐ Recorded the number of correct and incorrect answers

Name:
Round:

- ☐ Did practice
- ☐ Monitored buddies speed trial
- ☐ Made no mistakes while providing feed back
- ☐ Did speed trial
- ☐ Counted cards accurately
- ☐ Recorded the number of correct and incorrect answers

Appendix P

The precision teaching script.

First PT session: script

Tell them to sit with their buddies. Hand out the folders.

1)
From now on you will have 15 minutes each day to practice your times tables. As well as practicing your times tables you need to do three speed trials. A speed trial is where you have 1minute to say the answer out loud to as many flash cards as you can. After the speed trial you will count how many cards you got right and wrong and record this on the daily practice record sheet *hold up daily practice record sheet*. To help you remember what you should be doing there is a check list to tick of as you go in your folder. *Hold up the student check list.*

2)
Today we will go through the session together. Get out your times tables practice check list. What is the first thing that you have to do? **Students answer**. When you are doing your practice I want you to only say the answer out loud. Don't say the equation, as this will slow you down. So if you get a card that has 1x1, don't say one times one equals 1, just say one. Lets try a couple. *Practice this by holding up easy flash cards for the whole group, till the whole group only responded with the answer 3 times in a row*. Good, you can now do your two minutes practice, I will set the timer for two minutes, when the timer beeps, stop practicing.

3)
What did we just do? **Students answer**, so you can now tick that box. The next thing you have to do now is the speed trial. To do this I want you to sit opposite each other, *wait for students to get into position.* Have a look at the top corner of your check list sheet, if there is a B there you will do the speed trial first, if there is a A there you will monitor that your buddy is saying the right answer. If your buddy says a number that is different to the number on the back of the card, just say no, if your buddy says the same number, don't say anything, just keep watching and listening. When you are doing your speed trial and your buddy says no, just put that card in a different pile. People with sheet A, what do you say when your buddy says the same number as on the back of the card? **Students answer**. What do you say when your buddy says a different number? **Students answer**. People with sheet B, what do you do if your buddy says no? **Students answer**. You have 1minute to go through as many cards as you can, when the timer beeps, stop. *Set the timer*, ready set, go. *Start the timer*.

4)
Remember to tick the box of what you just did. Usually the person who just did the speed trial will count up their cards, and record the amount of cards that they got right, and the amount of cards that they got wrong on their daily practice record sheets, but because I want you to do this at the same time this time, just move your cards to the side, being careful to keep the right and wrong pile separate from each other.

Now the person with sheet A, can do their speed trial, and the person with sheet B will monitors the answers. People with sheet B, what do you say when your buddy gets the answer right? **Students answer**. What do you say when your buddy gets the answer wrong? **Students answer**. People with sheet A, what do you do if your buddy says no? **Students answer**. You have 1minute to go through as many cards as you can, when the timer beeps, stop. *Set the timer*, ready set, go. *Start the timer*.

5)
Remember to tick the box of what you just did. *Hold up the daily practice sheet*, What day is it today? **Students answer**, so under which day are you going to record your scores? **Students answer.** Write the number of cards that you got right in the top half of the box, and the number of cards that you got wrong in the bottom half. Do that now. *Check this is done correctly.*

6)
Now round 1 is finished. I'm going to get you to do round two and three on your own. *Hand out a timer to each pair.* Have a look on the right side of your timer, there is a red button that you can slide up and down, make sure it is pushed down, and that is says timer in the little red box on the front of the timer. To set the timer to one minute, press the 'min' button once, *demonstrate*. Then to set it going press the start/stop button once, *demonstrate.* If for some reason you want to reset the timer, press the start/stop button once, and then press clear, *demonstrate.* When the timer beeps, press the start/stop button. *Get each student to have a go*. Now that you know how to use the timers, you can start round 2, this time the person monitoring the speed trial sets the timer, so the person doing the speed trial can start as soon as the timer does.

While the students are working, move between the pairs, and check that they are doing it right.

Once everyone is finished,
7)
Now you have to pick your best score for today, record that in the boxes on the side of your chart, and chart that on your chart like we practiced yesterday. Your goal is to get 60 cards right in a minute. Sometimes Mel and I will place a line on your graph that you have to try to stay above.

For the rest of this week and next week, we going to be here to help you, if you need help. Sometimes we will sit down and watch you do your practices, when this happens, just keep practicing as usual.

Appendix Q

A copy of the information sheet provided to the principal of the school that participated in Experiment 2

Department of Psychology **The University of Waikato** **Private Bag 3105** **Hamilton,** **New Zealand**	**Phone +64 7 838 4466** **Ext 8400** **www.psychology.waikato.ac.nz**	THE UNIVERSITY OF WAIKATO *Te Whare Wānanga o Waikato*

As part of my Masters Thesis at the University of Waikato, I am undertaking a Experimentthat looks at whether the application of a teaching method called precision teaching, to teach maths will be successful in a New Zealand primary school. Research in the USA and UK has shown that this method of teaching has increased the speed with which students learn, in some cases between two and four times the national average. Furthermore a Experimentdone at a different school, in term four of 2008 resulted in the students, who had received precision teaching catching up with the rest of the class in their performance on times tables.

The aim of the last Experimentwas to determine whether the addition of precision teaching to the current strategy of practicing times tables (flash cards and a buddy system), would result in improved learning rates and out comes for the students involved. The precision teaching was the addition of timed practice, and the recording and charting of the results of the timed practice, combined with the setting of rate and learning rate goals.

As can be seen in figure 1, the rate that the PT group was able to write answers to the 0-10 times tables was slower than the rest of the class on the pre programme test. The graph also shows that the PT group made larger gains in their rate of writing correct answers than the rest of the class, and that on the post programme test the rate students in the PT group was able to write correct answers was much closer to that of the rest of the class.

Figure 1: The graph compares the rates year 5 students in the PT group achieved on the pre and post programme test to the rates that the rest of the year 5 students in the class achieved.

Despite the successfulness of the previous Experiment, it was disappointing to note that the rates achieved on the post programme tests by the students in the PT group were well below the rates achieved by the students during practice. A hypothesis for possible reason for this discrepancy between practice rates and test rates is that the skill practiced was see equation/ say answerer while the skill tested was see equation/ write answer.

To test this hypothesis, another Experimentis required where the skill tested before and after the precision teaching programme, is the same skill practiced during precision teaching. To do this ExperimentI would need to work with a teacher, who is interested in the research, is willing to administer two sets of timed maths tests to the whole class (one set at the start of the term and the other at the end of the term), and who is willing to have a group of about six children, receive precision teaching during the time the rest of the class is practicing the same skill. The teaching aims for the children will follow the teaching aims set out for the rest of the class by the teacher.

If you are prepared to participate, then we will provide the teacher with information about the Experiment. Also a meeting between the researcher and the teacher involved will be required before any tests are administered so that the researcher can prepare tests that will test the skill being practiced. Consent forms to be sent to the parents of all the children in the class will be provided by the researcher. Once consent is received, the children that receive precision teaching will be selected in one of two ways, depending on the teacher's preference. The teacher may choose to select the six children to be part of the precision teaching group, based either on them having difficulty with maths as compared to the rest of the class, or they may be randomly selected from those whose parents have consented to their participation.

The children in the group receiving precision teaching will be involved in, timed practice (using timers that count down, and sound an alarm), monitoring each others work and charting their results independently of the teachers help during their usual maths class. During the first two sessions the children will be taught how to use the practice material and how to graph their results. Based on the last Experiment, teaching the children to chart their results on a semi log graph should take no longer than an hour. Other than this, precision teaching should take the same amount of time as the teacher allocates for practice for the rest of the class. For the duration of the Experimentthe researcher will be present when possible, so that no extra burden will be placed on the teacher to help these children. The role of the researcher will be, to monitor the children's progress, provide motivation for good work and achievements (praise, or anything else the teacher usually uses), address any issues that may have arisen and to identify, based on the data how practice may need to be altered to better suit the students learning needs.

After the first set of timed maths tests have been administered, precision teaching will continue till the end of the term at which point another set of maths tests will be

given. From these two sets of tests it will be possible to compare the learning of the children who received precision teaching and those who did not.

At the end of the Experimentyou will be provided with a summary of the results, and are welcome to discuss developments during the course of the Experimentwith me or my supervisor at any time. My supervisor for this Experimentis Professor Mary Foster, from the Department of Psychology at the University of Waikato. She can be contacted at m.foster@waikato.ac.nz. This Experimenthas received ethical approval from the Psychology Research and Ethics Committee.

If this Experimentshows that precision teaching does result in improved learning outcomes, I would be happy to share these methods with any interested teachers. In accordance with ethical guidelines real names will not be used in my thesis so that neither the school, nor the teacher nor the children involved in the Experimentcan be identified. During the Experimentyou have the right to withdraw participation at any time.

So if want to know more please contact me by phone on 021 045 8638 or by email at djbh1@waikato.ac.nz.

Yours sincerely

Desiree Horlacher and Prof Mary Foster, DipPsychClin, PhD.

Appendix R

Example of the Practice test used in Experiment2 and Experiment3.

Name:_____ Date:_____

Practice test

1+4=	5+9=	5+5=	8+8=	2+5=	
5+7=	3+3=	2+3=	6+9=	3+1=	
8+2=	3+7=	4+5=	10+4=	9+10=	
4+9=	4+4=	3+10=	7+1=	3+3=	
5+1=	4+3=	2+9=	4+9=	9+1=	
9+3=	8+1=	3+7=	6+6=	7+8=	
2+3=	2+4=	6+6=	8+3=	2+6=	
6+8=	1+10=	9+2=	3+4=	5+4=	
7+2=	3+9=	3+5=	1+10=	7+7=	
4+3=	6+7=	8+9=	7+3=	2+4=	
9+2=	2+3=	6+2=	2+2=	6+9=	
6+4=	3+1=	9+1=	5+5=	1+1=	
8+9=	9+2=	4+2=	7+8=	5+6=	
7+1=	7+8=	8+8=	3+9=	2+6=	
9+3=	4+6=	2+6=	8+5=	7+9=	
2+5=	10+9=	4+7=	9+9=	3+5=	
9+1=	8+5=	3+9=	6+1=	1+7=	
3+8=	9+2=	10+5=	4+8=	5+2=	
9+8=	6+3=	2+7=	2+3=	8+1=	
5+6=	8+4=	4+6=	8+10=	3+4=	
8+2=	1+6=	9+9=	4+5=	5+5=	
7+5=	3+5=	2+5=	9+2=	10+2=	
9+4=	9+7=	7+4=	6+7=	9+8=	
4+5=	8+2=	5+1=	1+1=	7+3=	

Correct:

Incorrect:

Appendix S

Example of the Speed test used in Experiment2 and Experiment3.

Name:_____ Date:_____

Speed test

5×6=	5×8=	6×7=	7×10=	2×6=	
6×9=	4×7=	3×5=	4×8=	1×3=	
7×8=	6×1=	8×2=	3×7=	5×9=	
9×3=	2×2=	9×4=	3×3=	2×4=	
5×5=	4×4=	10×5=	8×7=	7×7=	
9×1=	9×8=	2×1=	4×2=	3×2=	
7×4=	8×5=	10×7=	5×1=	4×1=	
6×2=	10×3=	7×3=	5×2=	8×4=	
10×6=	3×8=	1×8=	4×9=	10×2=	
2×9=	1×9=	2×5=	2×10=	1×10=	
5×9=	8×2=	9×9=	5×4=	10×8=	
8×1=	9×7=	1×5=	3×1=	9×2=	
5×7=	9×6=	10×4=	9×5=	7×2=	
4×10=	5×7=	5×9=	2×7=	3×4=	
1×6=	2×3=	2×4=	6×4=	5×7=	
3×9=	10×9=	7×7=	5×4=	10×1=	
2×8=	9×8=	3×10=	1×2=	4×4=	
5×10=	1×7=	5×5=	10×10=	2×7=	
8×8=	7×5=	8×6=	6×3=	6×4=	
1×1=	5×3=	7×1=	4×3=	5×4=	
7×2=	6×10=	6×5=	6×6=	1×2=	
3×4=	8×3=	7×6=	7×9=	8×10=	
5×7=	4×6=	9×10=	1×4=	8×9=	
2×3=	6×8=	4×5=	3×6=	2×5=	

Correct:

Incorrect:

Appendix T

Example of the Standard worksheet used in Experiment2.

Name:_____ Date:_____

Worksheet 1

5×3=	7×5=	4×4=	3×10=	2×9=	
3×9=	8×4=	3×3=	4×9=	6×5=	
4×2=	5×5=	2×8=	6×2=	8×7=	
10×6=	4×3=	9×5=	3×8=	5×1=	
1×7=	2×7=	7×3=	8×8=	7×6=	
6×3=	10×9=	8×5=	4×1=	5×7=	
9×8=	5×4=	4×6=	6×8=	7×9=	
8×10=	3×4=	5×2=	6×6=	2×3=	
1×2=	2×4=	3×5=	3×2=	1×1=	
1×10=	9×6=	1×4=	2×5=	6×4=	
9×4=	3×6=	4×7=	9×9=	2×10=	
6×10=	5×9=	4×10=	4×8=	3×7=	
2×6=	9×7=	1×5=	8×6=	7×1=	
8×2=	8×1=	9×3=	9×2=	10×4=	
2×2=	9×1=	5×3=	10×3=	2×1=	
4×4=	2×9=	1×9=	6×5=	8×6=	
10×2=	3×7=	6×8=	7×7=	3×3=	
2×8=	2×2=	1×8=	7×5=	4×4=	
5×4=	10×8=	2×3=	8×4=	3×3=	
1×6=	8×4=	10×1=	10×7=	5×3=	
7×10=	7×4=	6×3=	7×2=	5×10=	
6×9=	5×8=	10×10=	6×1=	4×5=	
10×5=	8×3=	7×2=	8×9=	5×6=	
1×3=	6×7=	7×8=	3×1=	9×10=	

Correct:
Incorrect:

Appendix U
Example of a R 60 s worksheet used in Experiment2.

Worksheet _R

7×10=	5×6=	8×9=	6×5=	4×12=	
11×1=	2×9=	12×4=	3×2=	4×7=	
8×3=	9×11=	5×9=	11×7=	8×6=	
2×12=	12×4=	2×12=	5×5=	3×7=	
12×4=	6×12=	4×11=	11×9=	3×6=	
2×11=	8×4=	12×4=	2×7=	8×11=	
9×4=	7×6=	7×4=	4×5=	5×7=	
3×12=	5×2=	10×10=	7×2=	5×8=	
11×6=	11×5=	9×5=	4×8=	12×4=	
6×9=	5×12=	12×1=	12×5=	8×7=	
3×3=	8×8=	8×2=	9×3=	5×10=	
6×10=	3×12=	6×4=	12×3=	4×12=	
8×9=	6×5=	4×6=	8×5=	2×4=	
12×4=	3×12=	12×3=	6×7=	9×7=	
5×9=	11×7=	10×7=	4×12=	2×2=	
12×3=	5×5=	6×12=	6×11=	11×2=	
4×11=	11×9=	9×8=	4×3=	8×11=	
12×4=	2×7=	1×10=	2×5=	9×9=	
7×4=	12×5=	12×6=	9×6=	4×4=	
12×10=	7×2=	3×8=	7×8=	11×3=	
9×5=	4×8=	12×5=	11×2=	7×9=	
10×11=	7×5=	6×8=	6×6=	10×6=	
8×2=	12×3=	5×3=	3×9=	12×5=	
6×12=	11×3=	7×7=	9×2=	10×4=	

Time:60s
Correct:
Not yet:
Goal: 70

Appendix V
Example of a R 30 s worksheet used in Experiment2.

Worksheet _R

2×2=	10×6=	4×1=	2×6=	1×9=	
1×3=	4×3=	9×2=	8×1=	5×10=	
3×5=	1×5=	3×3=	7×10=	3×1=	
10×2=	10×4=	7×2=	5×2=	10×10=	
2×4=	2×10=	2×8=	1×7=	10×8=	
3×4=	10×3=	10×1=	2×7=	2×5=	
1×6=	4×10=	5×1=	2×2=	5×3=	
2×9=	1×1=	1×8=	6×1=	8×2=	
3×2=	1×4=	3×3=	2×1=	6×2=	
10×5=	2×3=	4×2=	1×10=	1×2=	

Time: 30s Correct: Not yet:
×2: ×2:

10×2=	10×4=	7×2=	5×2=	10×10=	
2×4=	2×10=	2×8=	1×7=	10×8=	
2×2=	10×6=	4×1=	2×6=	1×9=	
1×3=	4×3=	9×2=	8×1=	5×10=	
3×5=	1×5=	3×3=	7×10=	3×1=	
3×4=	10×3=	10×1=	2×7=	2×5=	
1×6=	4×10=	5×1=	2×2=	5×3=	
2×9=	1×1=	1×8=	6×1=	8×2=	
3×2=	1×4=	3×3=	2×1=	6×2=	
10×5=	2×3=	4×2=	1×10=	1×2=	

Time: 30s Correct: Not yet:
×2: ×2:

Best score:

Appendix W
Example of a R15 s worksheet used in Experiment.

Worksheet _R

2×6=	7×10=	1×8=	9×1=	5×2=	
10×1=	1×2=	7×2=	2×2=	1×10=	
9×2=	2×8=	3×1=	5×1=	5×10=	
1×4=	3×10=	2×4=	2×10=	3×2=	
2×1=	1×6=	1×1=	7×1=	9×10=	

Time: 15s Correct: ×4: Not yet: ×4:

4×2=	10×2=	1×5=	8×1=	2×5=	
10×3=	10×6=	6×1=	4×10=	8×10=	
1×3=	1×9=	10×8=	2×9=	10×4=	
8×2=	2×7=	10×5=	6×2=	2×3=	
1×7=	10×9=	4×1=	10×7=	10×10=	

Time: 15s Correct: ×4: Not yet: ×4:

9×2=	2×8=	5×1=	5×10=	3×1=	
1×4=	3×10=	2×10=	3×2=	2×4=	
2×1=	1×6=	7×1=	9×10=	1×1=	
2×6=	7×10=	9×1=	5×2=	1×8=	
10×1=	1×2=	2×2=	1×10=	7×2=	

Time: 15s Correct: ×4: Not yet: ×4:

2×7=	8×2=	10×5=	6×2=	2×3=	
10×9=	1×7=	4×1=	10×7=	10×10=	
10×2=	4×2=	1×5=	8×1=	2×5=	
10×6=	10×3=	6×1=	4×10=	8×10=	
1×9=	1×3=	10×8=	2×9=	10×4=	

Time: 15s Correct: ×4: Not yet: ×4:

Best score:
Goal:70

Appendix X

Example of an E60s worksheet.

Worksheet _E

16 20 24 28

4×4=	4×7=	5×4=	4×4=
4×6=	4×5=	6×4=	4×6=
7×4=	4×4=	4×6=	7×4=
4×7=	5×4=	7×4=	4×7=
4×6=	4×5=	6×4=	4×6=
4×4=	4×7=	5×4=	4×4=
4×6=	4×5=	6×4=	4×6=
7×4=	4×4=	4×6=	7×4=
4×7=	5×4=	7×4=	4×7=
4×6=	4×5=	6×4=	4×6=
4×4=	4×7=	5×4=	4×4=
4×6=	4×5=	6×4=	4×6=
7×4=	4×4=	4×6=	7×4=
4×7=	5×4=	7×4=	4×7=
4×6=	4×5=	6×4=	4×6=
4×4=	4×7=	5×4=	4×4=
4×6=	4×5=	6×4=	4×6=
7×4=	4×4=	4×6=	7×4=
4×7=	5×4=	7×4=	4×7=
4×6=	4×5=	6×4=	4×6=

Time: 60s
Correct:
Not yet:
Goal:60

Appendix Y

Example of an E 30s worksheet.

Worksheet _E

16 20 24 28

4×4=	4×7=	5×4=	4×4=
4×6=	4×5=	6×4=	4×6=
7×4=	4×4=	4×6=	7×4=
4×7=	5×4=	7×4=	4×7=
4×6=	4×5=	6×4=	4×6=
4×4=	4×7=	5×4=	4×4=
4×6=	4×5=	6×4=	4×6=
7×4=	4×4=	4×6=	7×4=
4×7=	5×4=	7×4=	4×7=
4×6=	4×5=	6×4=	4×6=

Time: 30s
Correct:
X2:
Goal:60

16 20 24 28

4×4=	4×7=	5×4=	4×4=
4×6=	4×5=	6×4=	4×6=
7×4=	4×4=	4×6=	7×4=
4×7=	5×4=	7×4=	4×7=
4×6=	4×5=	6×4=	4×6=
4×4=	4×7=	5×4=	4×4=
4×6=	4×5=	6×4=	4×6=
7×4=	4×4=	4×6=	7×4=
4×7=	5×4=	7×4=	4×7=
4×6=	4×5=	6×4=	4×6=

Time: 30s
Correct:
X2:
Goal:60

Appendix Z

Example of the times table chart provided to students for marking.

1×1=1	2×1=2	3×1=3	4×1=4	5×1=5
1×2=2	2×2=4	3×2=6	4×2=8	5×2=10
1×3=3	2×3=6	3×3=9	4×3=12	5×3=15
1×4=4	2×4=8	3×4=12	4×4=16	5×4=20
1×5=5	2×5=10	3×5=15	4×5=20	5×5=25
1×6=6	2×6=12	3×6=18	4×6=24	5×6=30
1×7=7	2×7=14	3×7=21	4×7=28	5×7=35
1×8=8	2×8=16	3×8=24	4×8=32	5×8=40
1×9=9	2×9=18	3×9=27	4×9=36	5×9=45
1×10=10	2×10=20	3×10=30	4×10=40	5×10=50

6×1=6	7×1=7	8×1=8	9×1=9	10×1=10
6×2=12	7×2=14	8×2=16	9×2=18	10×2=20
6×3=18	7×3=21	8×3=24	9×3=27	10×3=30
6×4=24	7×4=28	8×4=32	9×4=36	10×4=40
6×5=30	7×5=35	8×5=40	9×5=45	10×5=50
6×6=36	7×6=42	8×6=48	9×6=54	10×6=60
6×7=42	7×7=49	8×7=56	9×7=63	10×7=70
6×8=48	7×8=56	8×8=64	9×8=72	10×8=80
6×9=54	7×9=63	8×9=72	9×9=81	10×9=90
6×10=60	7×10=70	8×10=80	9×10=90	10×10=100

Appendix AA

Example of the Daily Practice Record Sheet used by the students in the PT group of Experiment 2, to record their correct and incorrect rates.

Date:________________

	Worksheet	Time	Score
Round 1			
Round 2			
Round 3			

Date:________________

	Worksheet	Time	Score
Round 1			
Round 2			
Round 3			

Date:________________

	Worksheet	Time	Score
Round 1			
Round 2			
Round 3			

Date:________________

	Worksheet	Time	Score
Round 1			
Round 2			
Round 3			

Date:________________

	Worksheet	Time	Score
Round 1			
Round 2			
Round 3			

Date:________________

	Worksheet	Time	Score
Round 1			
Round 2			
Round 3			

Date:________________

	Worksheet	Time	Score
Round 1			
Round 2			
Round 3			

Date:________________

	Worksheet	Time	Score
Round 1			
Round 2			
Round 3			

Date:________________

	Worksheet	Time	Score
Round 1			
Round 2			
Round 3			

Date:________________

	Worksheet	Time	Score
Round 1			
Round 2			
Round 3			

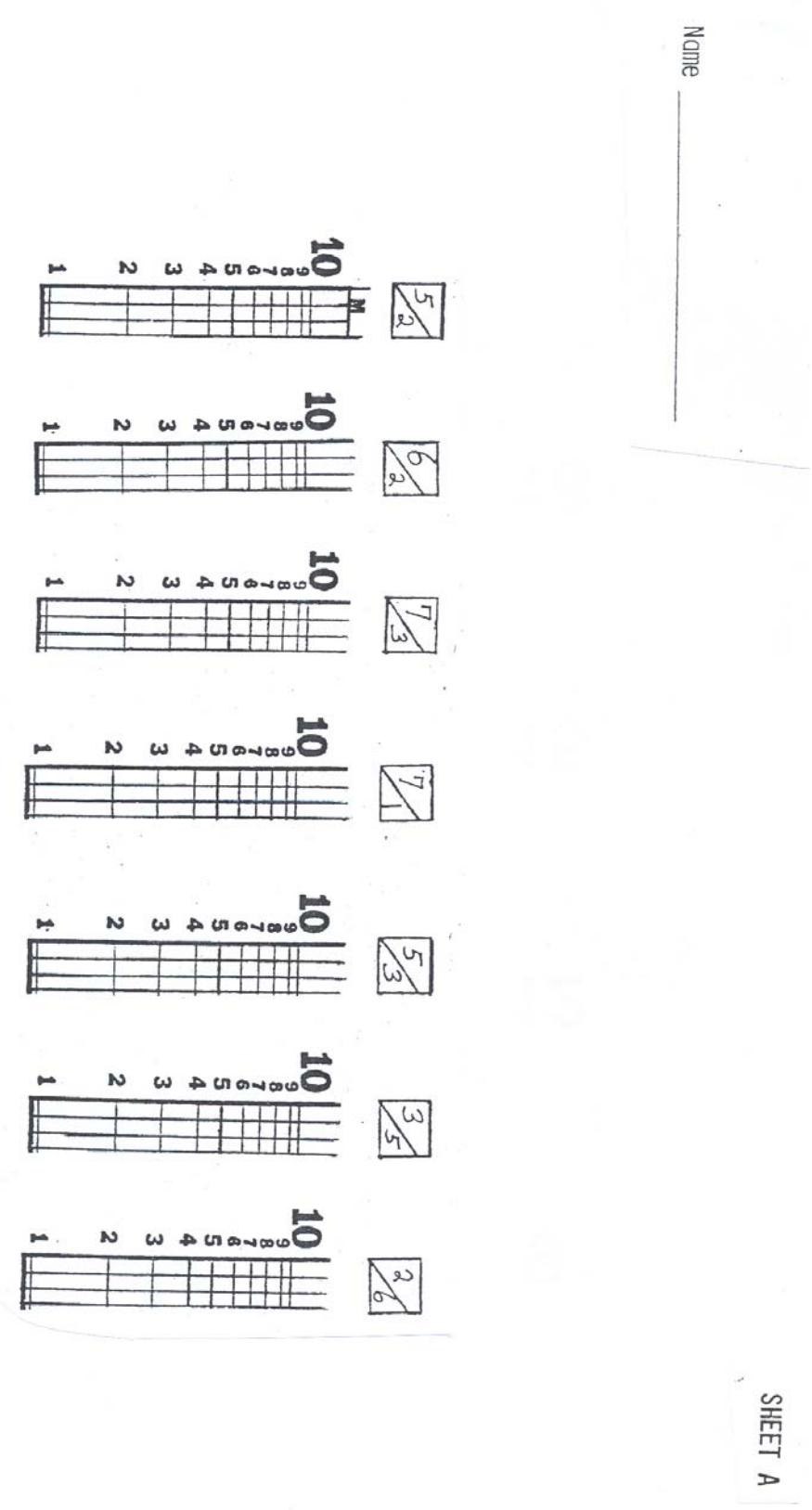
Appendix AB

Example of the Daily Practice Record Sheet used by the students in the Non PT group of Experiment2 to record their correct and incorrect scores.

Date	Worksheet	Score

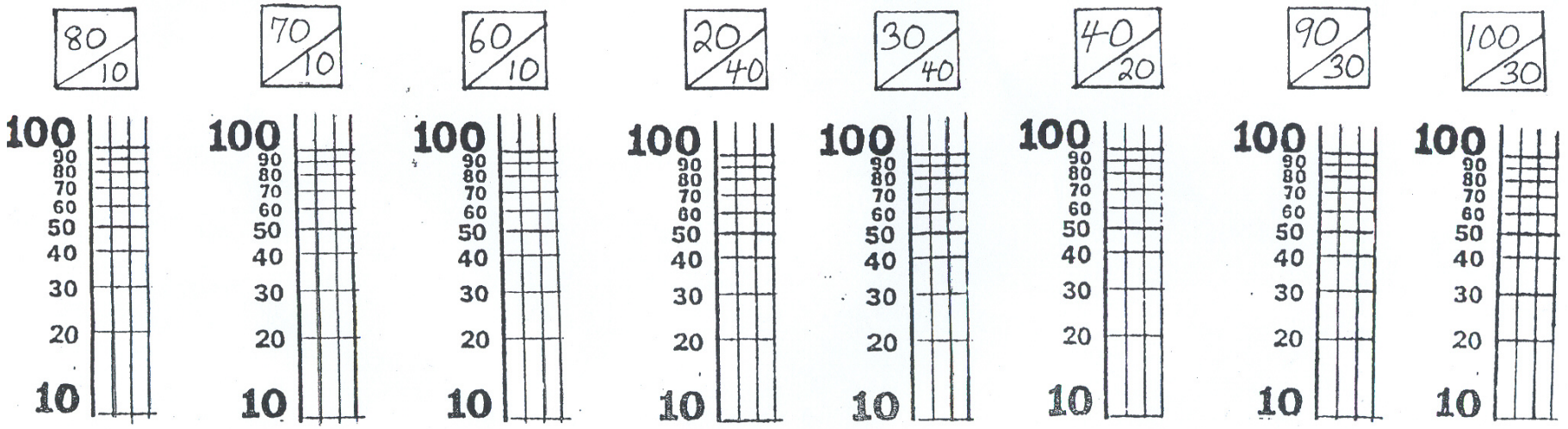
Appendix AC

Example of the charting worksheets used in Experiment2 to teach the students in the PT group how to chart their scores.



Name _____

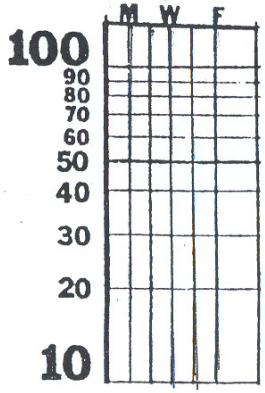
SHEET B


80/10
70/10
60/10
20/40
30/40
40/20
90/30
100/30
100
90
80
70
60
50
40
30
20
10

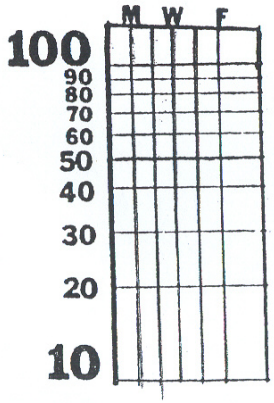
Name _____

SHEET C

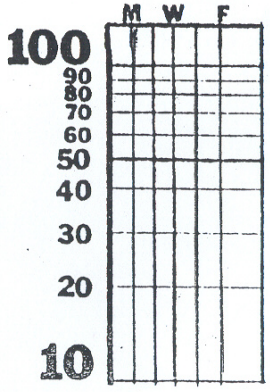
M	T	W	Th	F
34 / 21	42 / 21	42 / 22	51 / 30	63 / 10



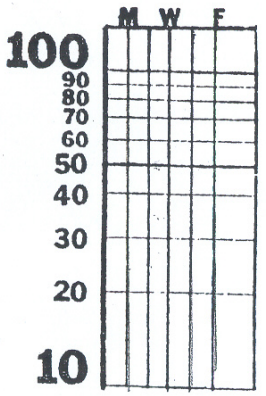
M	T	W	Th	F
31 / 15	45 / 16	55 / 17	65 / 19	75 / 20



M	T	W	Th	F
34 / 80	42 / 80	33 / 70	27 / 55	17 / 31



M	T	W	Th	F
100 / 41	78 / 43	88 / 50	90 / 27	60 / 43

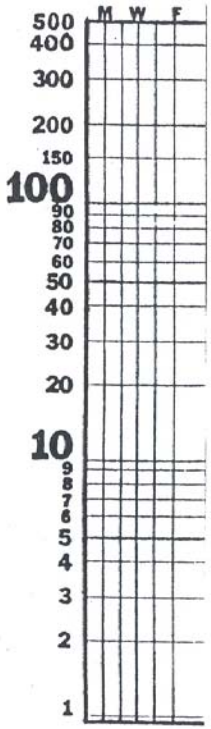


Name _____

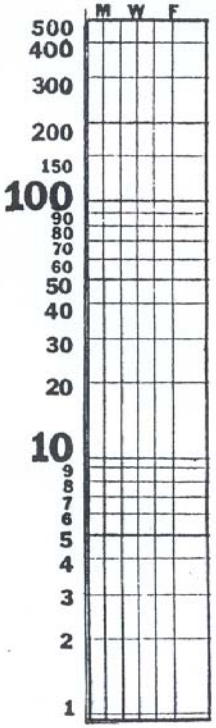
SHEET D

	M	T	W	Th	F
1	15 / 0	20 / 3		30 / 16	12 / 2
2	9 / 33	15 / 21	10 / 6	18 / 0	24 / 0
3	82 / 0	95 / 2	97 / 3		100 / 1
4	95 / 30	67 / 31	82 / 10	73 / 0	99 / 15

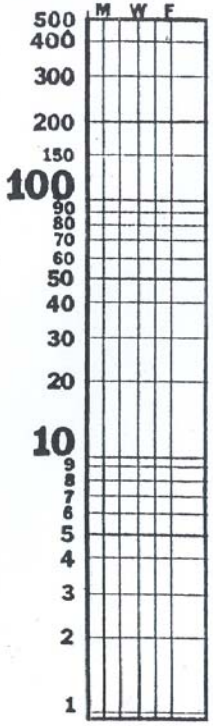
1



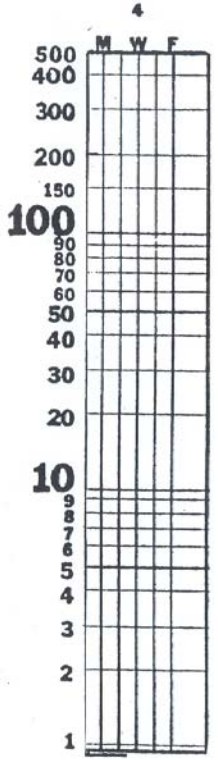
2



3



4



Appendix AD

The Teaching to Chart Script used in Experiment2 to teach the students in the PT group how to chart their scores.

Teaching children to chart: script

I'm going to help you practice your times tables this term. From now on when you practice you will have one minute to answer as many problems on a work sheet, like you did yesterday. After marking the work sheet, you will record how many questions you got right and how many you got wrong. Every day you will do three different worksheets, at the end of every practice you will chart your score from the three worksheets on this chart *hold up chart.* So before we start I'm going to teach you how to chart.

A1) (*Hold sheet a*) Notice how there are two number in the little box. The number on top is the number of problems that were answered right, and the number at the bottom is the number of problems that were answered wrong. When charting the number of right and wrong answers they both go on the same line, at the moment I don't mind which line, as long as there are two dots on the same line. So how many questions were answered correctly? (**Children answer**). *Place the dot.* When charting the number of problems that were answered wrong, you place a x, like this (*draw a x on the bottom of the chart*) on the chart. How many questions were wrong? (**Children answer**). *Repeat for next plot.* Try finishing the rest of the sheet, you can ask for help if you get stuck.

B) This sheet is the same as the last one, only that instead of the chart going from 1 to 10, it now goes from 10 to 100. How many corrects are there? (**Children answer**), *mark that on the chart*. How many incorrect? *Mark that on the chart*. Try finishing the rest of the sheet, you can as for help if you get stuck.

C1) This sheet is a bit different, as these lines stand for the days of the week. (*Highlight the Monday line*) What day do you think this is? (**Children answer**) This next line (*highlight the Tuesday line*) is for the day that comes after Monday. What day is that? (**Children answer**). If I wanted to put a dot on the Wednesday line should I put a dot here (*point to the gap between Tuesday and Wednesday*) (**Children answer**), we have to put the dot on the line.

C2) Now these boxes belong to each day of the week, *point to the Monday box,* what day is this? (**Children answer**). If I wanted to chart these scores, would I put the dots and crosses on this line? *Point to Friday, Why not?*

C3) How many corrects? (**Children answer**) (*point to the 20 line*) do I put the dot here? (**Children answer**) how about here? *point to 23* **Children answer.** Ok and how may wrong? (**Children answer**) *place the x*. *Point to the Tuesday box,* How many correct? **Children answer**, *place the dot,* how many wrong? **Children answer** *place the x.* Now you guys have a go.

D1)

Everyone turn over the page, (*Hold up the sheet*) Now on this sheet is the same as the last one just that the chart goes from 1 to 500. *Point to the first box*, when there is a 0, you

put a ?, like this (*demonstrate*) at the bottom of the day line, instead of a cross. Also when a box is empty, there's noting to chart, so just skip this day. Have a go, you can ask for help if you need it.

Appendix AE

The check list used to check for procedural integrity while teaching to chart.

Teaching children to chart: check list

I'm going to help you practice your times tables this term. From now on when you practice you will have one minute to answer as many problems on a work sheet, like you did yesterday. After marking the work sheet, you will record how many questions you got right and how many you got wrong. Every day you will do three different worksheets, at the end of every practice you will chart your score from the three worksheets on this chart *hold up chart.* So before we start I'm going to teach you how to chart.

Explained why we are there

A) (*Hold sheet a*) Notice how there are two numbers in the little box. The number on top is the number of problems that were answered right, and the number at the bottom is the number of problems that were answered wrong. When charting the number of right and wrong answers they both go on the same line, at the moment I don't mind which line, as long as there are two dots on the same line. So how many questions were answered correctly? (**Children answer**). *Place the dot.* When charting the number of problems that were answered wrong, you place a x, like this (*draw a x on the bottom of the chart*) on the chart. How many questions were wrong? (**Children answer**). *Repeat for next plot.* Try finishing the rest of the sheet, you can ask for help if you get stuck.

Explained how the box relates to the chart

Demonstrated how to chart corrects and errors

Ensured the students charted accurately

B) This sheet is the same as the last one, only that instead of the chart going from 1 to 10, it now goes from 10 to 100. How many corrects are there? (**Children answer**), *mark that on the chart*. How many wrong? *Mark that on the chart*. Try finishing the rest of the sheet, you can ask for help if you get stuck.

Demonstrated how to chart

Ensured the students charted accurately

C1) This sheet is a bit different, as these lines stand for the days of the week. (*Highlight the Monday line*) What day do you think this is? (**Children answer**) This next line (*highlight the Tuesday line*) is for the day that comes after Monday. What day is that? (**Children answer**). If I wanted to put a dot on the Wednesday line should I put a dot here (*point to the gap between Tuesday and Wednesday*) (**Children answer**), we have to put the dot on the line.

Explained that the vertical lines represent days of the week

Explained that students have to place the dot on the line, not the gap between the line

C2) Now these boxes belong to each day of the week, *point to the Monday box,* what day is this? (**Children answer**). If I wanted to chart these scores, would I put the dots and crosses on this line? *Point to Friday, Why not?*

Explained how the boxes relate to the chart

C3) How many corrects? (**Children answer**) (*point to the 20 line*) do I put the dot here? (**Children answer**) how about here? *point to 23* **Children answer.** Ok and how many wrong? (**Children answer**) *place the x*. *Point to the Tuesday box,* How many correct? **Children answer**, *place the dot,* how many wrong? **Children answer** *place the x.* Now you guys have a go.

Demonstrated how to chart

Ensured the students charted accurately

D1)

Everyone turn over the page, (*Hold up the sheet*) Now on this sheet is the same as the last one just that the chart goes from 1 to 500. *Point to the first box*, when there is a 0, you put a ?, like this (*demonstrate*) at the bottom of the day line, instead of a cross. Also when a box is empty, there's noting to chart, so just skip this day. Have a go, you can ask for help if you need it.

Explained what to do if there is a 0

☐ Explained what to do if there is missing data

Demonstrated how to chart

Ensured the students charted accurately

Appendix AF
The testing integrity check used in Experiment2 and Experiment3

Integrity check for testing

Procedure

☐Explained to the students that they only get one minute to answer as many questions as possible

☐Instructed the students to skip equations they don't know

☐Handed out the tests face down

☐Handed out, and completed tests one at a time

Students

☐Students were all seated at a table

☐Students all started at the same time

☐Students all stopped work when the timer went

Equipment

☐addition test (practice test) ×12

☐multiplication tests × 12

☐Digital timer

Appendix AG

Shows an example of the Standard worksheet added in Experiment3 to accommodate a 30s timing.

Worksheet 1

2×2=	10×6=	4×1=	2×6=	1×9=	
1×3=	4×3=	9×2=	8×1=	5×10=	
3×5=	1×5=	3×3=	7×10=	3×1=	
10×2=	10×4=	7×2=	5×2=	10×10=	
2×4=	2×10=	2×8=	1×7=	10×8=	
3×4=	10×3=	10×1=	2×7=	2×5=	
1×6=	4×10=	5×1=	2×2=	5×3=	
2×9=	1×1=	1×8=	6×1=	8×2=	
3×2=	1×4=	3×3=	2×1=	6×2=	
10×5=	2×3=	4×2=	1×10=	1×2=	

Time: 30s Correct: Not yet:

×2: ×2:

10×2=	10×4=	7×2=	5×2=	10×10=	
2×4=	2×10=	2×8=	1×7=	10×8=	
2×2=	10×6=	4×1=	2×6=	1×9=	
1×3=	4×3=	9×2=	8×1=	5×10=	
3×5=	1×5=	3×3=	7×10=	3×1=	
3×4=	10×3=	10×1=	2×7=	2×5=	
1×6=	4×10=	5×1=	2×2=	5×3=	
2×9=	1×1=	1×8=	6×1=	8×2=	
3×2=	1×4=	3×3=	2×1=	6×2=	
10×5=	2×3=	4×2=	1×10=	1×2=	

Time: 30s Correct: Not yet:

×2: ×2:

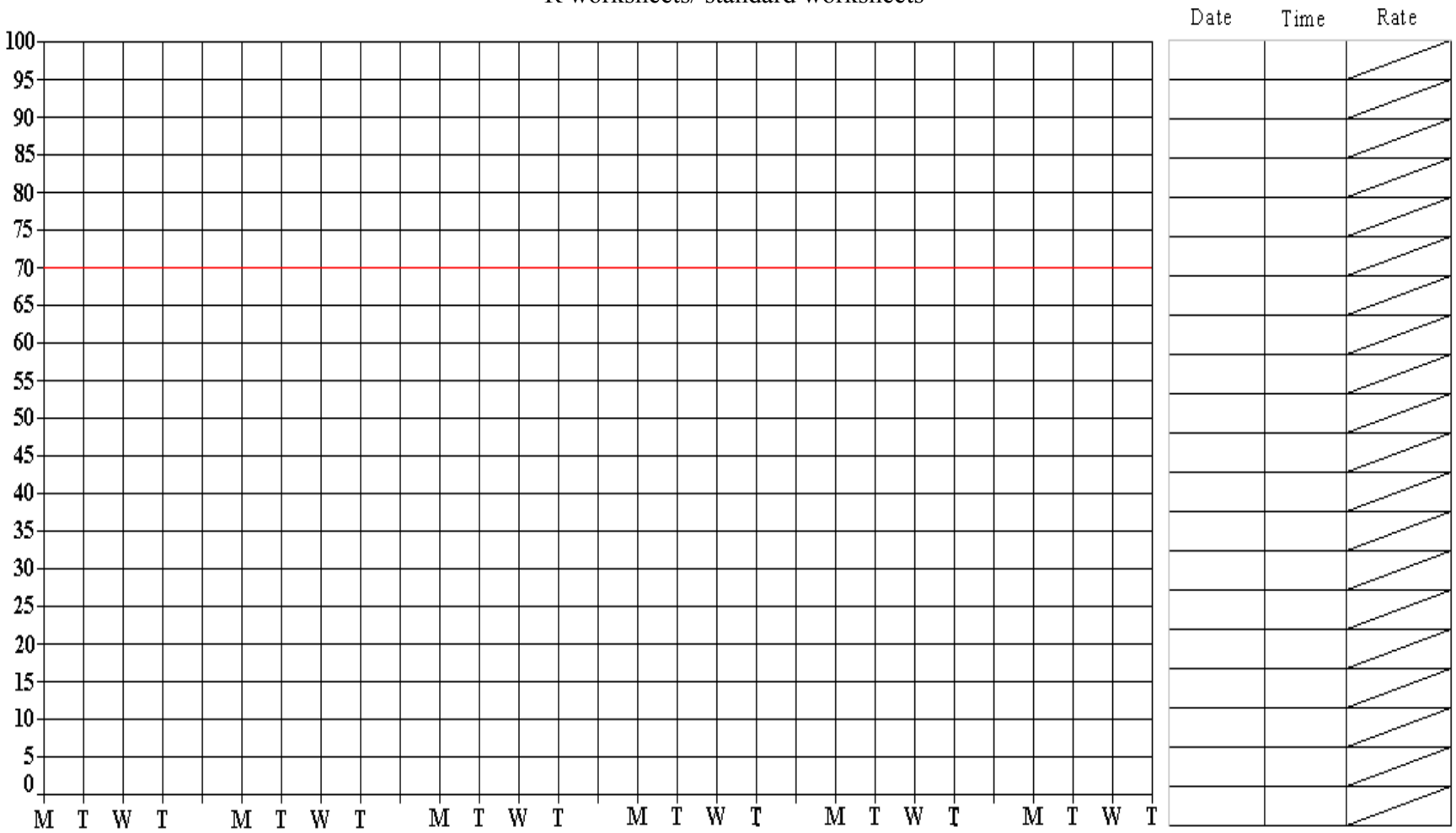
Best score:

Goal:70

Appendix AH

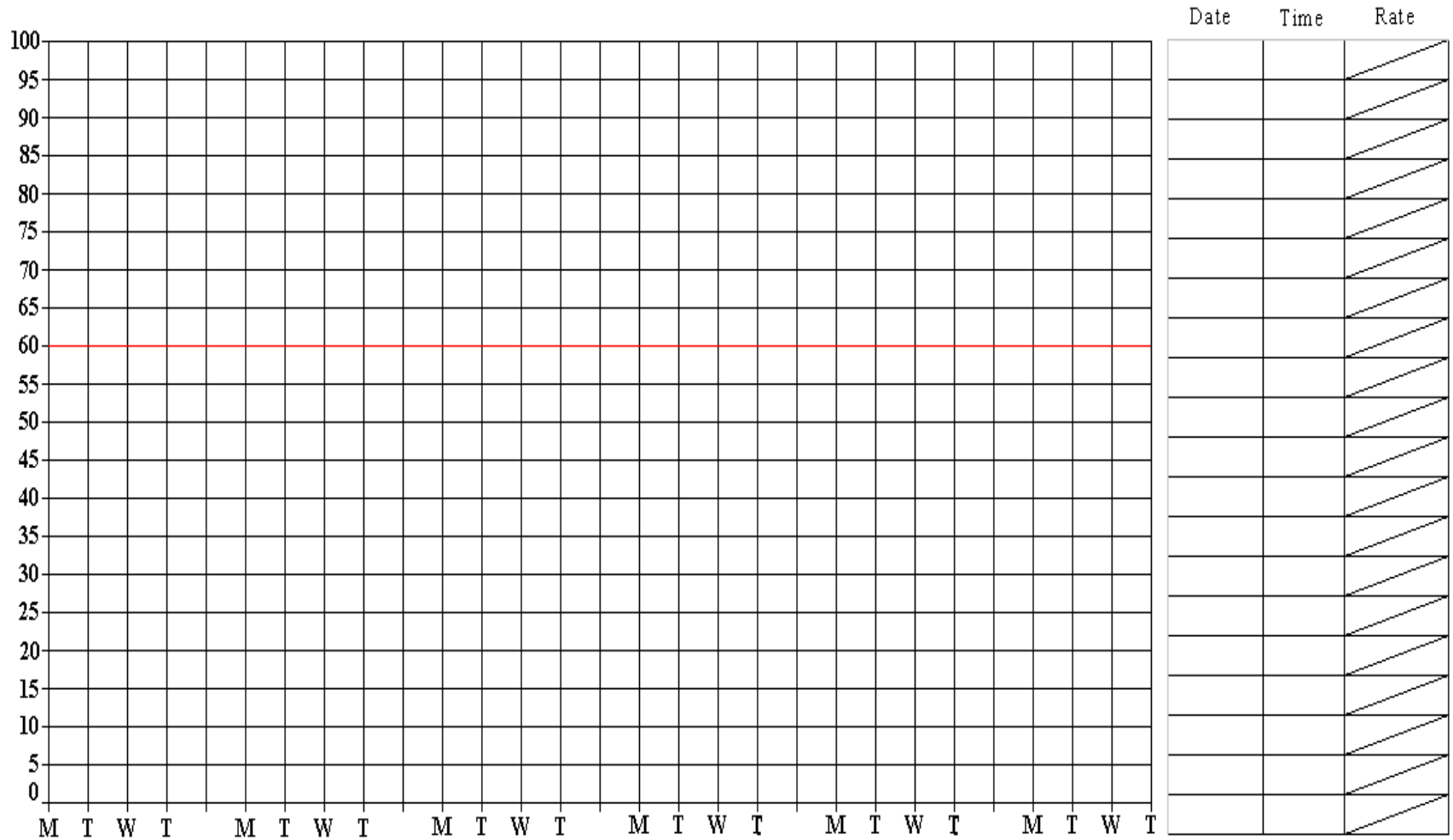
Example of the charts used in Experiment 3.

R worksheets/ standard worksheets



Name: _____

E worksheets



Name: _____