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EFFECTS OF A DISTRIBUTED INTERLEAVED TEACHING STRATEGY ON AUTOMATICITY IN INTERMEDIATE PHASE MATHEMATICS

AYESHA ABDEROEF

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Supervisors: Dr. B. May (University of the Western Cape)

Prof. C. Julie (University of the Western Cape)

Contents

Abstract

The Trends in International Mathematics and Science Study (TIMSS) in 2015 indicate that South African learners fare poorly against their international counterparts. Results of these tests show that South African learners are not at the desired level of development in terms of mathematics learning. There is thus a need to find suitable teaching and learning strategies that can improve the status quo.

Mathematics learning is particularly sequential in nature and builds and progresses on the foundation of sound prior knowledge. It stands to reason, that the implications for teaching and learning would be to introduce better techniques and skills that improve retention of mathematics procedures and concepts. Retention of essential mathematics knowledge and skills will ensure that learners have a mental depository of prior knowledge to draw from when executing problems in tests and examinations in the higher grades.

Two teaching and learning strategies in the literature that shows promise is distributed and interleaved practice. Distributed practice is an approach to learning that spaces study material over extended intervals. This method contrasts with massed or blocked practice where study material is practiced over and over during a long practice session. Interleaved practice compliments distributive practice where multiple topics are intermingled in a session rather than just practicing one topic completely before moving to the next.

This study employed a descriptive, quantitative method in a pre-/post-test design to investigate the effects of a teaching strategy premised on distributed (spaced practice) and interleaved practice on automaticity in answering multiplication problems. It was also endeavoured, through our research, to determine to what extent automaticity in basic multiplication facts influence learners' performance in problems requiring them to recall multiplication strategies, in terms of speed and accuracy.

Learners practiced their multiplication tables (1 – 12) in a random order and at different difficulty levels over a period of 7 weeks on a computer application that collected the learner data in terms of accuracy and time taken to answer each question.

Consistent with expectations, the data has shown that the Grade 6 learners who participated in the intervention programme based on a distributed and interleaved practice, has shown statistically significant improvements in their test score results as well as improvements in the speed at which they completed a test. This research confirms previous findings and contributes to our understanding that spacing topics using an interleaved technique in mathematics teaching, enhances performance in mathematical procedures. It is apparent, through this research, that interleaved practice advanced learners' ability to discriminate between different problem types as well as enhance their ability to select the correct strategy to solve a problem. It was also determined that distributive practice enhanced information retention.

In a South African context, using a teaching and learning strategy premised on interleaved and distributive practice, shows great promise in enhancing learner competency and retention of foundational knowledge. This, in turn, will allow for improved results in high stakes examinations and allow for us, over time, to fare better on an international platform.

Key words: Distributive practice, Interleaved practice, Massed practice, intermediate phase, Mathematics learning, Learning skills, Long-term retention, Automaticity

Declaration

I declare that *Effects of a distributed interleaved teaching strategy on automaticity in intermediate phase mathematics* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Ayesha Abderoef Date: November 2022

Signed:

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CHAPTER 1 INTRODUCTION

1.1. Need for re-thinking strategies in mathematics teaching

Mathematics has a considerable influence on how we view and how we function in our lives. School learners' life opportunities are dramatically limited when they have a deficiency in certain mathematics skills. There is little dispute that there is a purpose to mathematics far beyond the classroom. The classroom, however, is still one of the most important sites where mathematical knowledge is cultivated. It would, thus, make sense to acquire mathematical knowledge and skills in the classroom, in such a way that the knowledge and skills learned could be drawn from memory and transferred when faced with authentic and natural mathematical problems or opportunities in real life.

It is often the case in primary school mathematics that knowledge acquisition is tiered in nature That is knowledge is acquired through concrete representations first followed by semi-concrete acquisition and then abstractly. A major expectation is that this knowledge and acquired skills should be transferable across disciplines. Therefore, there is an essential requirement for quality teaching and learning strategies in the early years of school, which will assist children to develop the necessary knowledge, reasoning, skills and confidence to do advanced mathematics programs.

South Africa's national and international literacy and numeracy results, though, provide for much trepidation about the outlook for our future mathematics problem-solvers. Reports, for grades five and nine, in the Trends in International Mathematics and Science Study (TIMSS) in 2015, showed that South Africa ranked 45 out of 48 countries (Letaba, 2017). The results of the Progress in International Reading Literacy Study (PIRLS) reveal that 78% of grade 4 learners cannot read for meaning (Spaull, 2017). These test results can be viewed as evidence that our country lags far behind, internationally, in terms of developing numerical and literacy skills in our learners.

Factors relating to poor performance include learners' socio economic and social settings, the preparedness of teachers to teach mathematics at all phase levels and learning and teaching environments. Learners attending independent schools, generally, fare well, followed by fee-paying public schools. Learners attending no-fee public schools delivered the poorest performance (Letaba, 2017). Another problem is that learners who experience difficulty with basic academic skills need interventions designed to support these needs (Pegg, Graham & Bellart). Often, these needs are not met because of lack of understanding and a lack of structured practice and repetition.

Also, the politically-historical realities of apartheid are embedded in the institutional DNA of our country and is among the contributing factors that directly affect South Africa's low internationally comparative academic performance. Historically, state schools in South Africa have also experienced a heavy political and racial divide; with most resources and durable infrastructure being afforded to 'white' or 'Model-C' schools and scarce resources allocated to schools in segregated areas; 'black' schools receiving the least.

These inequalities imposed by apartheid in the deliverance of education to the different race factions was addressed by our current government to remedy and restructure the education system by categorising South African public schools into five groups, called quintiles, primarily with the intention of allocating more financial resources to poorer schools. Quintile one schools are those schools classified as the most impoverished quintile, while quintile five is the least impoverished. Infrastructural factors as well as considering the socio – economic background of the community surrounding the schools would determine the quintile ranking of the school (Grant, 2013).

Regardless of governmental intervention, educational inequalities that existed then, still prevail and are reminiscent of the past political divide. According to Van den berg et. al. (2011), majority of South African children are located in schools where the institutional culture is established on a background of historical disadvantage. Learners within these schools characteristically exhibit low aptitude in reading, writing and numeracy.

1.2. Impact of Covid-19 on schooling

During the proposal stage of this study, at the end of the year 2019, an outbreak of COVID - 19 quickly spread around the world including South Africa. On the 11th March 2020, the World Health Organisation (WHO) announced the COVID-19 outbreak as a pandemic (World Health Organisation [WHO], 2020).

As a response to the pandemic and a way to mitigate the impact of the virus, the South African government declared a national state of disaster and on the 18th March 2020, all schools were closed followed by a 21-day country - wide lockdown 10 days later (Siegfried & Matthews, 2020). Due to the surge of infections, government, extended the lockdown by two more weeks on the 16th of April. The government implemented a risk – adjusted strategy to moderate economic and social activity; level 5 being the highest level, where extreme measures were taken to contain the virus and Level 1 being the lowest, where most economic and social activity can resume under precaution. Most schools were set to be open with the onset of Level 3, under considerable debate, on the 1st of June 2020. The Department of Basic Education (DBE) planned a staggered approach for the return of learners to school grade 7 and 12 being the first to return.

After much uncertainty and opposition by teacher unions, schools were reopened for grades 7 and 12 two weeks later, only to be closed again after 775 schools experienced COVID 19 infections (Powell, 2020). COVID 19 exposed the vast inequalities that lies within our school system. Protocols for schools reopening included social distancing, washing hands often, spacing desks further apart and wearing of masks. While these protocols are easy for schools in affluent areas to implement, schools in rural areas would again be handed the short end of the stick. Some schools were being left to deal with infrastructural challenges which includes the absence of running water, overcrowding and malnutrition.

Furthermore, in terms of curriculum delivery; while teachers and learners from affluent backgrounds were sending and receiving learning materials and lessons on online platforms, majority of South African learners had no access to learning resources during the lockdown period. Because of the phased – in approach, some learners were longer at home than others, causing frustrations on teachers, parents and learners, themselves. During this landscape of uncertainty, where curriculum delivery was halted, at most, for five months, a call for effective teaching and learning techniques was imperative.

The particular school where this study is carried out, is in an independent school which aims to provide affordable, quality education to a historically disadvantaged community in Cape Town, South Africa. During the lockdown period, because of the varied socio-economic backgrounds that the learners come from, it was decided that teachers would use the most affordable social media application, WhatsApp, to send and receive learning resources and work completed by learners. Teachers used Microsoft (MS) Office documents like MS Word and MS Excel, took a snapshot and sent the material in the form of pictures. Detailed and simplistic lesson plans were also sent on a weekly and daily basis to guide parents and caregivers on how to implement the lessons and MS PowerPoint presentations with voice –

overs were saved as MP4 videos to create on-line readers for Foundation Phase learners. It is acknowledged, though, that for a system described above, to work, a good parental teaching structure should be established at home. It can thus be foreseen that with the onset of COVID 19, curriculum activity has been halted for a few months, causing even more trepidation of the outcome of academic results.

The Western Cape Education Department (WCED) uses systemic tests to determine mathematics and literacy proficiency in the province. These tests are conducted each year and tests across all the content areas of mathematics and language in phase exit grades 3, 6 and 9.

In this way, schools can identify and focus on improving the areas in which they are performing weakest. Private schools apply to do these tests as well as a systemic test presented by the Joint Education Trust (JET). This study, will attempt to improve mathematical proficiency of a group of grade 6 learners, by using a teaching strategy premised on continuous revision.

1.3. Aims of the research

This study proposes to firstly determine what strategies intermediate phase mathematics teachers (grade 4-6) are currently employing to teach mathematics concepts to students and the revision strategies that these students and teachers use to review concepts taught. The aim of this study is to determine how a teaching strategy premised on interleaved and distributive practice will affect automaticity of research participants in integer multiplication problems and subsequently how attaining automaticity in multiplication, affects learner mathematical proficiency in tasks and algorithms requiring them to use multiplication.

1.4. Rationale

The distressingly low performance of South African students in the TIMMS study provide grounds that we should focus on the teaching and learning of mathematics (Letaba, 2017). Mathematics learning is hierarchical in nature and builds and progresses on the foundation of solid prior knowledge. This means that new mathematical knowledge is difficult to gain, should prior mathematical knowledge be forgotten.

I am of the opinion that one of the reasons for learners' low performance is that they forget (the forget problem) important procedures and concepts and that they do not develop the skill to distinguish between problem types as a result of the current dominant teaching strategies. The objectives of this study, therefore, is to investigate whether a continuous review strategy premised on distributed and interleaved practice will improve the forgetting and distinguishing problems. The main objective is to determine how distributive and interleaved practice influences the development of automaticity which ultimately improves speed and accuracy when solving algorithmic problems.

1.5. Research Question

The following is the research questions for the study:

i) How does a teaching strategy, premised on distributed and interleaved practice, influence learner automaticity in answering multiplication integer problems?

ii) How does automaticity influence learners' performance in problems requiring them to recall multiplication strategies, in terms of speed and accuracy?

CHAPTER 2 LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1. Introduction

Hart (1981, p. 205) described three hierarchies in school mathematics. These are as follows: learning sequence, teaching sequence and topic sequence. This hierarchical characteristic of school mathematics indicates that every new concept learnt in mathematics is built on the foundation of prior knowledge. Thus, when learners progress through each mathematical topic or even progress to the next grade, they need to be able to arrange the main points from new mathematics concepts into meaningful paradigms and then connect those paradigms to prior knowledge (Brown, Roediger & McDaniel, 2014). Often, the prerequisites for more advanced topics at school level mathematics rely on prior knowledge and being able to retrieve that knowledge swiftly from memory (Kang, 2016). For example, in order to execute problems with decimals and percentages, well developed knowledge of fractions will be helpful.

Quality mathematics instruction should, accordingly, be structured in a way where learners can successfully advance in mathematics by developing an understanding of concepts. Developing an understanding of mathematics concepts requires learning strategies that facilitate long-term retention of those concepts. Once attained, mathematics students are equipped with a powerful tool to solve a multitude of problems across most scientific disciplines as well as in daily life. Teaching and learning strategies that maximise learning time and enhances long-term retention of mathematics procedures and concepts, should thus be of interest to all educators.

2.2. Strategies that optimise learning and maximise retrieval

Cognitive psychologists, Bjork & Kroll (2015) have studied how we learn and how to manage our learning in such a way that we optimize long – term retention of content learnt. Bjork, (1994) suggests "desirable difficulties" which are mechanisms that slow down the learning process, makes it harder for the learner but enhances long-term retention. Therefore, when instructing learners, teachers should set the challenges that are just beyond the reach of their learners. It may take longer to learn but this helps build long-term retention. The following is some learning strategies that have been identified in order to optimise learning:

- varying the conditions of learning (Bjork & Kroll, 2015)
- distributive learning/spaced repetition– the spacing of a given learning theme across more than one learning session (Rohrer, 2012);
- Retrieval practice by using tests (also called the 'testing effect') as learning trials (Larsen, Butler & Roediger, 2009; Soderstrom, Kerr & Bjork, 2016; Kang, 2016; Wheeler & Roediger, 1992, Roediger & Smith 2012)
- Interleaved practice i.e., interleaving of topics during the learning process (Bjork & Kroll, 2015; Rohrer, Dederick & Sterchic, 2014)

The general rationale of these techniques is that it optimises learning and maximises retrieval.

2.3.Interleaved and distributive practice

For the purposes of this study, as mentioned previously, we will concentrate on two of these teaching strategies namely interleaved and distributive practice.

In most cases, teachers' approach to studying mathematics is by focusing on one topic at a time (overlearning) for a short period of time (massed or blocked practice). For example, in the study of division, fractions and decimals, they would opt to study each topic separately, "master" it and then move to the next topic in one sitting.

Two main reasons why this method of study is so popular with teachers and learners is, firstly, because of time constraints. Secondly, because most teachers employ this practice where they would teach a skill and then have the students practice the skill which they have just learned in the same session or assign learners with exercise tasks that is dedicated to the same concept (Rohrer & Taylor, 2006; Rohrer, 2012). According to Kang (2016), this blocked-practice method is preferred in conventional education settings because it is 'convenient' to educators as the layout of most teaching materials, resources and textbooks is designed in a segmental or sectional style that support this kind of study. Practice problems in most textbooks cover problems relating directly to the preceding chapter. For example, a section on the addition of fractions is followed by a string of addition of fraction problems (Rohrer & Taylor, 2007 p.481; Rohrer, 2012 p. 358). Unfortunately, this blocking of concepts masks familiarity with mastery and deprives the learner of the skill of distinguishing between similar concepts (Rohrer, 2012).

Rohrer, Dedrick and Sterchic (2014) points out that to solve problems in mathematics, learners need to follow two steps: The first is to identify the problem type, choose an appropriate strategy to solve the identified problem and then to execute the strategy chosen.

The first is often more difficult for the learner to do, especially when there are no written clues or key terminology that indicates which strategy to use. The following example illustrates this point:

Our school has 325 learners. We are going on an excursion. A bus can hold 25 learners. How many buses do we need to accommodate all the learners?

This problem has no clues or key words to determine the strategy to be used. If, however, a learner was given a set of division questions, after completing a module on division, the learner would almost automatically divide 325 by 25 because all the problems in the homework assignment requires the learner to use division. This 'blocked method' way of practicing mathematics, limits the learner's thinking processes and removes the "desirable difficulties" of identifying the problem and choosing the strategy. Learners study or practice the same skill repeatedly until they feel that they have mastered it and then move on to the next topic or skill. According to Rohrer, Dedrick & Agarwal (2017), this feeling of mastery is an illusion. The illusion of mastery fades when writing an interspersed exam that requires the student to firstly identify the problem type and then choose a strategy to solve the problem.

Instead, Rohrer, Dedrick & Sterchic (2014) suggest tasks that include a variety of practice problems which would compel the learner to use different strategies. They call this method, interleaved mathematics practice. Problems of different kinds are mixed across exercises or assignments. Two benefits of interleaved practice are identified. Firstly, when problems are mixed it forces the learner to identify which strategy to use by making distinctions between concepts (discrimination learning) (Rohrer, 2012). Secondly when problems of the same kind are spaced, retention of concepts is improved (Rohrer, 2012).

2.3.1. Interleaved practice

Interleaved practice is a learning strategy where instead of concentrating on one concept at a time; related skills, topics and concepts are alternated (interleaved). When the learners are presented with practice exercises these are mixed in a way that switches from one topic to another. Similar concepts are thus sequenced in a way that is mixed up with other unlike concepts, rather than being consecutive. Learning gains are higher because each consecutive problem is different and results in a more variable and challenging task. In this way, interleaving requires the learner to constantly retrieve information from memory. Interleaved practice reinforces memory associations as it improves the ability to make distinctions between concepts (Rohrer, 2012).

In a study done by Rohrer, Dederick and Sterchic (2014), they compared interleaved and blocked mathematics practice with 126 grade 7 learners. Each learner was assigned to either a blocked method group or an interleaved practice group where they practiced graph and slope problems. Both groups were tested on day one or day 30. The learners in the interleaved group produced moderate results on test day 1 but showed better test scores on day 30.

In another study done by Rohrer & Taylor (2006), 116 students worked on practice problems that involved finding permutations for letter sequences. Practice problems were either spaced over two sittings, separated by a week or massed in one sitting. One or four weeks later, both groups were tested. Results showed that on test week 1, the students in the massed group, outperformed the spaced group slightly; but in week 4, the spaced group significantly outperformed the massed group. This data suggests that massed practice produces poor long-term retention and by contrast; spaced (distributed) practice enhances long term retention and in turn promotes the overall ability of students to problem solve.

As discussed above, learners doing mathematics must be able to select a strategy or method when problem solving. This selection of a strategy becomes difficult when an assessment or exam covers different problem types. In this case, interleaving not only helps learners to distinguish between the problem types but also, because learners need to shift between problems, association between categories of problems and the method needed to solve these problems is enhanced (Kang, 2016, pg 16). Among the benefits of interleaving is category learning and mathematics problem solving by eradicating discrimination errors (Rohrer, 2012; Kang, 2016). The benefit provided by interleaving such as improving problem solving skills is compelling, given that the primary way to assess mathematics competency is through problem solving.

Taylor & Rohrer (2009), asserts that there would be considerable difference in academic accomplishment if interleaving were commonly used in classrooms and if learning resources such as textbooks were designed to promote this practice.

The limitation of interleaved practice is that before interleaving can begin concepts and materials should be easily understood i.e., the learner should be familiar with the concepts or materials. This would imply that initial experiences to a topic or concept could be massed. Other limitations of interleaved study are outlined by Rohrer (2012). These are that the literature mostly covers non-classroom-based experiments, that there is a lack of studies that evaluates a combination of blocking and interleaving and that the benefits of interleaving are restricted to difficult discriminations.

2.3.2. Distributive practice

Even though distributive practice and interleaving are considered to be separate practices, they are often linked and used together. This is because interleaving intrinsically gives rise to the distribution of the same content (Taylor & Rohrer, 2009; Rohrer, 2009 in Kang, 2016). Rohrer (2012, p. 357), points out that there is a crucial nuance between interleaved and distributed practice. The arrangement of a single concept over time, is defined as distributed practice and the arrangement of multiple concepts over time, is defined as interleaving (Rohrer, 2012).

Distributive practice is when learning of concepts is spaced over time across more than a single session. When distributed practice is externally steered, it has been recognised to be a useful method for improving long-term retention of verbal information and straightforward mathematical procedural knowledge (Nazari & Ebersbach, 2018).

In a study done in Germany, Nazari & Ebersbach (2018) carried out a mathematical performance study on 95 grade 3 and 118 grade 7 learners. They intended to determine the impact that distributive practice had in two levels of mathematics schooling i.e., primary and secondary school which coincides closely with South Africa’s exit of foundation phase (grade 3) and entry into the senior phase (grade 7). Semiformal multiplication was introduced to the grade 3 class and stochastics (basic probability problems) was introduced to the Grade 7 class.

Students in both groups were split in half and each student was assigned to either the condition of practicing mathematical procedures massed on one day or distributed sequentially over 3 days. Findings of the study indicates that spacing effects in mathematics teaching enhances performance in mathematical procedures.

The overall benefits of distributive practice according to Kang (2016) is to improve various forms of learning including memory, problem solving and improving deductive reasoning in new contexts.

2.4.Automaticity

Automaticity in mathematics is achieved when a person can 'automatically' retrieve basic mathematics facts, procedures and concepts from the long-term memory with speed and accuracy without exertion of the conscious mind (Baker & Cuevas, 2018; DeMaioribus, 2011). Automatic recall in mathematics is important at all levels of mathematics. For example, learners in the beginning grades have to be able to develop the ability to recall certain addition facts. This has to be fairly automatic since it will slow down learning considerably if it is not. Developing automaticity is important for learners to accomplish further success in mathematics. We achieve automaticity with considerable, intensive practice over a period of time.

Criteria for automaticity, according to Posner and Snyder (1975) is:

- that a procedural task is done without intention
- that it is done without awareness, and
- that it does not interfere with other existing mental activity.

A study done by Baker and Cuevas (2018) focussed on automaticity when retrieving multiplication facts in the third to eighth grade. They interviewed a total of twenty-four learners; nine, ten and five students from third, fifth and eighth grade respectively. At each grade level, each learner was asked the same questions to determine whether they were using hybrid strategies to solve single-digit mathematics facts within a time frame that could be considered automatic. The duration of every interview did not exceed seven minutes. Each learner had to verbally answer fourteen questions. Basic information about the students and their current mathematics educator was covered in the first three questions of the interview.

The next seven questions required the learner to answer single-digit mathematics fact problems. The time it took for learners to answer the seven problems was documented. The remaining questions were open-ended and the answers were written down by the researcher as accurately as possible. Their findings indicate that almost all learners showed automaticity on the easier math facts but struggled when it came to the more difficult problems. In terms of automaticity, the fifth-grade participants were the highest performers i.e., they produced the most answers that fit into the automaticity range. They suggest that developing automaticity in single-digit addition, subtraction, multiplication and division problems is essential for the success of learners in the mathematics classroom.

Though the sample group was small and convenient in the study mentioned above by Baker and Cuevas (2018), it is consistent with another study done by Pegg, Graham & Bellert (2005). Their study focussed on 12 learners aged 11 to 14 who were constantly achieving low results for mathematics. In the study, the researchers used a theory-based intervention programme that supports basic skill development and focused on a variety of practice and recall strategies. The instructional intervention program ran for twenty-six weeks was specifically aimed to increase learners' speed of recall of basic number facts by freeing up working memory capacity. Learners were withdrawn in pairs from their normal class for five half-hour sessions each fortnight with the same instructor. The programme had three phases, i.e., pre-test, intervention and post-test. The post-test results of the study, showed a significant improvement in learners' performance in standardised tests.

2.5.Theoretical Framework

Long-term retention is crucial in all almost all areas of learning. Human memory encrypts, decodes, preserves, and evokes sensory input data which comprises of facts, practices, thoughts, skills, and behaviours (Velez-Pardo & Jimenez-Del-Rio, 2015). To know how we can retain information successfully, we need to know how human memory works.

The most prominent pioneering figure in the literature about memory, was a German psychologist, Hermann Ebbinghaus, in his straightforward, yet revolutionary study that he undertook on himself in the 19th century (Rubin & Wentzel, 1996; Velez-Pardo & Jimenez-Del-Rio, 2015; Cowan, 2017). He tested his own memory by learning nonsense words over various periods of time and plotted it on a graph, known today as the 'forgetting curve'. The graph shows how rapidly information is lost over time with an eventual tapering-off or flattening of the gradient. The curve, however, changes dramatically after every interaction with the information. The relevance and accuracy of the information of Ebbinghaus' study has been demonstrated by Murre, & Dros, 2015 when they replicated the study with similar results.

The Ebbinghaus forgetting curve is shown in figure 1. The y-axis indicates the strength of memory with 100% being the maximum value. When you review the information on the second day, the gradient flattens and it flattens even further when the information is reviewed on the seventh day. The broken line shows how the forget is affected when spaced retrieval is done.

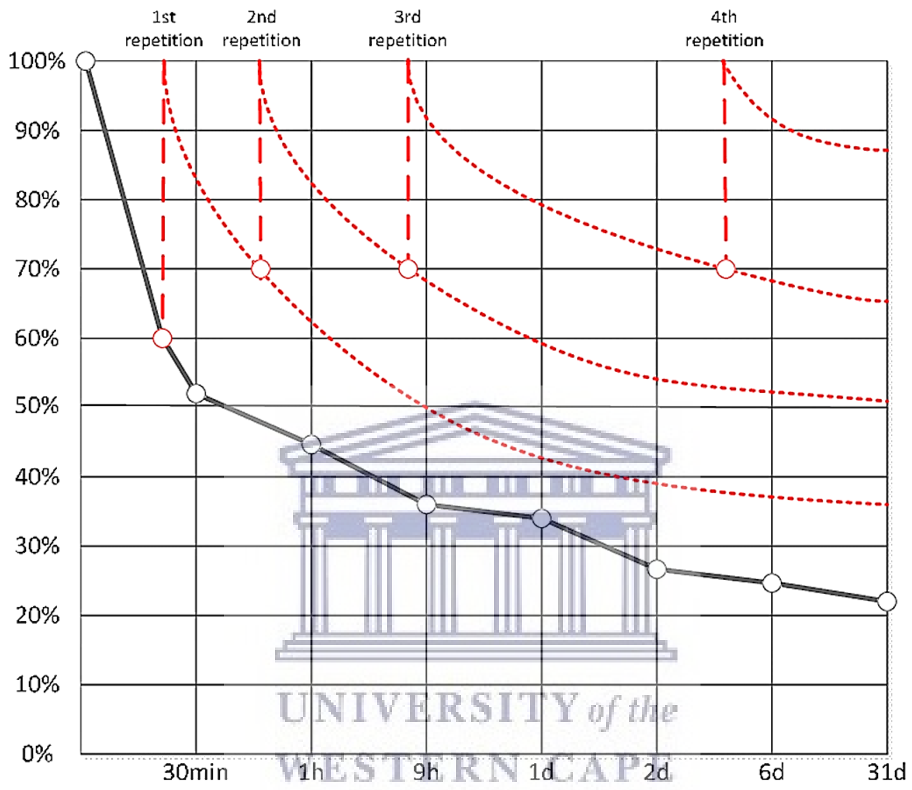


Figure 1: Ebbinghause Curve, Shimanke, Mertens, Hallay, Enders & Vornberger. (2015).

Memory can generally be classified into three types, namely short–term memory, working memory and long-term memory (Cowan, 2008; Velez-Pardo & Jimenez-Del-Rio, 2015). The ability to retain a small quantity of infomation for a brief stretch of time is known as short term memory. Existing conceptions and inferences substantiate the construction of new concepts and inferences in the short–term memory (Camina & Güell,2017). Working memory, according temporarily supports the processing of these new concepts and inferences by manipulating the information to facilitate rational thought (Aben, Stapert, & Blokland, 2012; Camina and G Güell, 2017)

A complexity arises when trying to differentiate between short–term and working memory; whether both are essentially the same thing or whether they are inherently and conceptually different (Cowan, 2008; Aben, Stapert & Blokland, 2012). One persistent definition, however, is that short-term memory is the unreceptive, "non – attention based", subdivision of "attention – based" working memory (Cowan, 2017). Most researchers agree that both short – term memory and working memory preserve input data (stimuli via our senses) over a short period of time (Brem, Ran & Pascual-Leone, 2013; Camina & Güell,2017).

Long – term memory refers to acquired input that has been strengthened and consolidated and which has become resistant to interference over a long period of time (Camina & Güell,2017; Velez-Pardo & Jimenez-Del-Rio, 2015). There are two types of long-term memory described in the literature. The first is declarative or 'explicit' memory which includes episodic memory (memories of autobiographical events) and semantic memory i.e., concepts and facts e.g., the sum of angles on a straight line is 180° . The second is non-declarative or 'implicit' memory which includes procedural memory. Procedural memories include all memories that requires us to do something mechanical in such a way that it is almost unconscious or intuitive (Camina & Güell,2017). In a mathematical sense an example would be to follow the sequence in a mathematical algorithm. An adjustment of input between testing and retesting is how reinforcement of input is assessed (Brem, Ran, & Pascual-Leone, 2013).

2.6.Conclusion

In summary, the aim of all learning is to successfully transfer information from the short – term or working memory, to the long – term memory structures. According to Brem, Ran and Pascual – Leone (2013), the pathway to successful storage of information in the long-term memory commences with the encoding and manipulation of sensory information. When information that is stored in the short – term memory is consolidated and reconsolidated, it subsequently gets stored in the long – term memory structures. Effective consolidation is when information can be retrieved swiftly and accurately (Brem, Ran & Pascual-Leone, 2013; Camina & Güell, 2017). This fluency in retrieving mathematical information is referred to as automaticity.

CHAPTER 3 RESEARCH DESIGN AND METHODOLOGY

3.1. Introduction

This study analysed the mathematical performance of a group of grade 6 learners engaged in practising their multiplication tables on a computer application in the school's computer laboratory. Learners practised at least once a week over a seven-week period.

3.2. Design

A quantitative research method has been employed in this study. Additionally, a non-experimental design has been used to gather data and therefore we did not use control and experimental groups. Furthermore, to investigate the effects of the intervention, a pre- post-test strategy has been used. The data gathered was the learners' responses to test items. Test scores obtained before the intervention constituted the pre-test. Whereas test scores obtained after the intervention was regarded as the post-test. The pre- and post-test scores was compared and analysed statistically to determine the effect of the intervention.

3.3. Sample

Convenience sampling has been adopted in the study, since learners that are accessible to the researcher will be study participants. Grade 6 Learners attending a comprehensive, combined school, situated in a suburb approximately 20 km from the centre of Cape Town city, South Africa has been recruited for the study. The students at this school generally come from a low -middle-income socio-economic dynamic. At this particular school, there is only one grade 6 class with 27 learners. The school is a fairly new school and has been established in 2018. The school has enough resources to afford learners opportunities to work on digital applications.

One learner did not submit a signed assent form and one learner left the study as a result of relocating. Four learners were absent on some days and thus the data of these six learners have not been included. All learners have experienced their grade 4 year during the pandemic and thus have a visible backlog in terms of basic concepts.

The school uses the Western Cape Education Department's (WCED) Centralised Education Management System (CEMIS) that acts as a registration and performance tracking. CEMIS also gathers term performance of specific classes and arranges it in manageable statistic formats. This particular grade 6 class performed at an average of 48.4 % in mathematics in the first term of the year 2022. The grade 6 class' results distribution for term 2 in mathematics was as follows: 18.5% of learners achieved between 0%-29%; 7.4% achieved between 30%-

39%; 22.2% achieved between 40% - 49%; 22.2% achieved between 50%-59%; 22.2% achieved between 60%-69% and 7.4% achieved between 70% - 79%. In the group of 27 learners, 5 were identified as having significant learning barriers and are currently on the school's intervention programme.

3.4. Discussion of the selected grade 6 topic for study

Multiplication has been selected as a topic for this study. Rapid and accurate recall of multiplication facts is important for success in the intermediate phase, as it builds the foundation to enable learners to do more complex tasks such as long multiplication, division, fractions, algebra etc. One needs to be mindful, however, that learners should first, have mastered the concepts of grouping and repeated addition, in the foundation phase, before memorising multiplication facts. An interleaved practice was implemented by having learners practice multiplication facts in a random order instead of having them practice one time – table at a time. Learners also practiced 1 – digit by 1 - digit up to 4 – digit by 3-digit problems in each sitting, rather than practice it and progressing through difficulty levels. Distributed practice was followed by having learners practice their multiplication facts weekly, instead of just once.

Consultation with the grade 6 Annual Teaching Plans (ATPs) as per the WCED, indicates that the multiplication number range for term one is at least 4-digit by 3-digit numbers, in term 1. Subsequently, it is projected that the pre-test and post-test will illustrate how accurately and with what speed learners can complete 4-digit by 3-digit multiplication problems.

After the pre-test, learners participated in an intervention programme using distributive and interleaved practice for learning multiplication facts as well as the 'column method' algorithm of solving 2-digit by 1 – digit progressively, to 4-digit by 3 – digit multiplication problems.

The "column method" is a formal, step by step written method of multiplying two- or three-digit numbers by another number of one, two or more digits. It is also often referred to as long multiplication. In the column method multiplication is performed vertically. The step-wise procedure is as follows:

- Step 1: Numbers are arranged in a column format according to their place value. The larger number is usually written on top. A multiplication sign is written on the left - hand side of the bottom number and the bottom number is underlined.

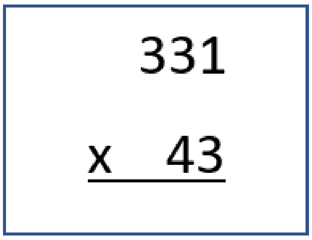


Figure 2: Step 1 of "column method" multiplication

- Step 2: Start by multiplying the unit value of the top number with the Unit value of the bottom number and continue to multiply the Tens and Hundreds place values of the top number with the Unit value of the bottom number, always remembering to start from the right to left. Write the answers from right to left below the line, keeping the digits arranged in its correct place values.

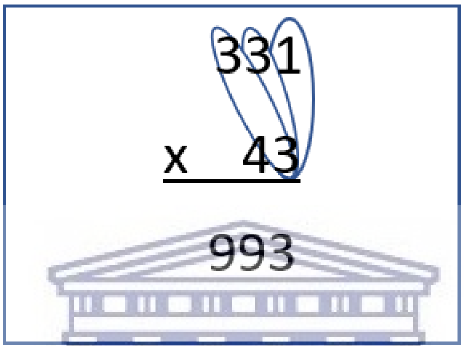


Figure 3: Step 2 of "column method" multiplication

- Step 3: Place a zero directly underneath the unit's digit of the previous result then start multiplying the top unit's digit with the tens digit in the bottom number. Arrange the result in the correct place value. Remember: When the result is more than the digit 9, we "carry" the unit over to the next top digit then add it to that result.

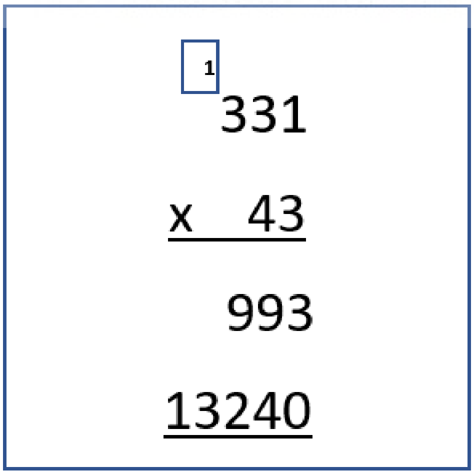


Figure 4: Step 3 of "column method" for multiplication

- Step 4: Use the method of column addition to arrive at the final solution.

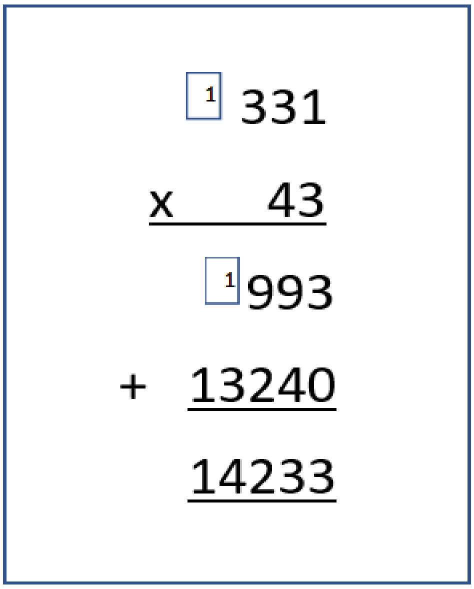


Figure 5: Step 4 of "column method" for multiplication

It has been established that learners in this particular class have been taught multiplication using the column method in grade five and in grade six as per the ATPs. *The Math Games Application* allows for the multiplication method explained above to be carried out by learners on the Application.

3.5. Procedures

The study was done in three phases – an initial assessment (pre-test), the intervention program using the *Math Games Application*, and a final assessment phase (post-test).

3.5.1. Pre-Test

The pre-test was administered on the first day under test conditions. Learners had to answer 15 multiplication questions within a 30-minute time frame. When learners completed, they would raise their hand and the researcher would record their time. Typically, the questions increased in degree of difficulty with the easier questions at the beginning of the test and the more advanced questions towards the end of the test. The first 6 questions were single digit by single digit, the next three were 2-digit by 1-digit; then 1 question was 2-digit by 2-digit and the next was 3-digit by 2-digit; a 3-digit by 3-digit follows and lastly, three 4-digit by 4-digit questions.

3.5.2. Intervention After the Pre-Test

During the lockdown period, teachers relied on technology to communicate curriculum content to learners. Certain assessments were also issued online. However, the reliability and integrity of the data received could not be assured. Educational applications have thus become popular during this period and when learners came back to school, these applications still played a role in classrooms. Applications have since been developed or improved to ensure data reliability. Having learners seated in a controlled environment where the researcher and the mathematics teacher are present facilitators, has ensured the integrity of the data. The school where the study took place has a computer lab with fifteen functioning computers. Learners had to share computers during sessions.

The application used in this study is an electronic application called *Math Games*, developed by *RV AppStudios LLC*. *Math Games* was created to help learners improve their basic arithmetic skills (addition, subtraction, multiplication, division, fractions, squares and roots). It has multiple game types and levels and enables step – by – step solving. The application is insights – driven and is a useful data collection tool. It has a reports section that helps researchers collect important assessment analytics. The report summary in *Math Games* allows the researcher to gain an overview of the main statistics e.g., number correct, how many equations they solved, how many equations they solved on average per day and how much time, on average, they took to solve per equation. The data updates each time the learner uses the application. The researcher, for example, can determine how a learner performed in a particular question and identify any knowledge gaps.

The intervention stage ran for seven weeks from the 8 of April 2022 to the 25th of May 2022. Prior to the first session, the researcher uploaded the application to each computer and created two profiles on each *Math Games Application*, starting from *Learner 1 to Learner 27*. Based on the class list, each learner was issued a number from 1 – 27 which became the profile that they worked on in each session. Sessions were distributed in the following way: The pre-test was done on day 1 of the first week and the first session was on the first day of the first week. The second session occurred on the first day of the third week; the third session on the third day of the third week; the fourth session on the first day of the fifth week; the fifth session on the third day of the sixth week and the last session, on the first day of the seventh week. The post – test was done on the same day of the last session. Learners were withdrawn from their main classes and worked in the computer lab for one 30 - minute lesson weekly spread across seven weeks. As the school only has 15 computers, 2 learners were assigned to each computer which meant that each learner only had approximately 15 minutes per session to practice their multiplication facts. For the first two sessions learners were instructed to practice their one-digit by one-digit multiplication facts to practice recall and develop some fluency. The application was set to randomly output multiplication facts from the 1-times table to the 12-

times table. This was done to assist learners with automaticity in retrieving basic multiplication facts. In the next four sessions, learners were encouraged to practice two-digit by one digit, two-digit by two-digit up to four-digit by three-digit multiplication problems. This ensured that an interleaved approach was followed instead of having them mass practice one times table at a time and one type of multiplication problem a time. The application recorded whether the learners responded correctly, which facts they were answering incorrectly and which facts they were correctly and how many times they were they were answering a particular fact correctly or incorrectly. It also recorded how fast learners responded to each question and the average time taken to answer a question. These timed-performance strategies were used to develop automatic recall.

3.6. Post-Test

Learners completed the post – test in class under test conditions within a 30-minute time-frame. The test was done after learners completed the six intervention sessions. The test also had 15 questions and was set up the same as the pre-test with different digits. When learners were completed their test, they would alert the researcher to record their time and to collect their scripts.

3.7. Data Collection

For the purposes of this study, we used the *Math Games App* over six sessions. For the multiplication game play option, the application allows learners to either punch in the correct answer or to use a multiple choice. It also gives the option for learners to manually punch in the answer from right to left or left to right. We set all learners devices to manually answer from right to left. We found that this was best as it required them to "carry" the tens or hundreds where applicable.

The program is completely learner-centered and this presents a limitation to its use in that it does not allow for data collection for an entire group or class. The data also could not be exported from the application and had to be collected by the researcher on a weekly basis by taking screen shots of the reports and then manually entering each learner's results onto a spreadsheet.

Interleaving happened in two ways; firstly, multiplication facts has been practised including all multiplication tables from 1 to 12, randomly, instead of practicing one multiplication table at a time. Secondly, multiplication has been practised along with other topics in the curriculum.

A distributive practice has been followed by having practice sessions over a period of seven weeks i.e., it took seven weeks to conduct the pre-test, implement the intervention programme and to conduct a post-test.

3.8. Ethical Considerations

Seven ethical principles are listed in Bhandari (2022): voluntary participation, informed consent, anonymity, confidentiality, potential for harm and results communication. Every effort has been made to ensure that all of these principles has been honoured. The directors of the school granted permission for this study to be conducted. The learners were informed of the purpose and scope of the study and they volunteered to be participants in the study by signing an assent letter. A letter requesting consent was sent to the parents of the learners involved in the study. This letter explained the purpose and details of the study and all the parents of participants in the study signed the letter giving permission for their child to participate in the study. The study was conducted at school in a familiar setting and the researcher is a teacher at the school with whom the learners are acquainted. Thus, the apprehension of being placed in an unfamiliar setting with an unknown researcher was reduced. The participants were informed that they could withdraw from the study at any time and the names of the participants and the name of the school would not be mentioned in the study. To further ensure confidentiality with regard to data collection, each learner was given a learner number and used that number to log into the mathematics application on the computers. It can, thus, be accepted that ethical principles were keenly considered to ensure that the participants and their parents or guardians were fully informed of the extent and purpose of the study and it was ensured that participants will not be exposed to harm; neither physically, emotionally or otherwise as a result of their participation in the study.

An ethics clearance certificate has been awarded to the researcher by the University of the Western Cape with an approval period from the 16th July 2021 – 16th July 2024.

3.9. Validity, Reliability and Relevance

Both validity and reliability refer to the quality of a study. A test result is considered reliable when the same result can be invariably achieved by using the same processes under the same circumstances. Validity refers to the accuracy of the study and it should measure that which it claims to measure. According to Queirós; Faria & Almeida (2017), the objective of quantitative research is accumulating accurate and reliable results that allow a statistical analysis.

The statistical analysis of this study was done with IBM SPSS (version 28) which is statistical software that allows the researcher to thoroughly analyse data, making it a much more effective tool than spreadsheets, databases or standard multi-dimensional tools. SPSS Statistics helps to make sense of complex patterns and associations, enabling users to draw conclusions and make predictions and handle tasks like data manipulation and statistical procedures. IBM SPSS Statistics features reliable and multi-faceted functionality and procedures that address the entire analytics lifecycle.

Relevance of the study refers to the suitability of the study in practice. This research has considerable relevance. Since memorisation of multiplication facts is necessary to increase automaticity in n algorithms such as long multiplication, long division within the mathematics curriculum as well as in real – life scenarios; the study is relevant within this context. Also, exploring strategies for learners to memorise mathematics facts and teaching them methods of retaining and being able to apply and transfer these facts in a meaningful way, will help to bridge the gaps that we find in mathematics teaching and learning in a South African context.

CHAPTER 4 DATA PRESENTATION AND STATISTICAL ANALYSIS

4.1. Introduction

As mentioned previously the statistical analysis that follows was done with IBM SPSS (version 28). Originally the number of research participants was 28. However, 4 students missed some tests and were excluded from the analysis. Hence only 24 students were used.

The objective of this research was to determine how a distributed interleaved teaching strategy will affect learner performance in terms of speed and accuracy during problem solving sessions. This information in turn will provide information on levels of automatization of cognition during problem solving sessions.

It is customary to investigate the data with descriptive statistics for violations of statistical parameters before one starts the statistical analysis.

Following presentation of the descriptive statistics a paired-samples t-test was used to determine how the teaching strategy affected learners' time taken to complete a test. Similarly, a paired-samples t-test was used to determine how the teaching intervention would influence learners' test scores pre- and post-intervention.

4.2. Descriptive Statistics

It is common practice that prior to doing statistical analysis one explores the data by means of descriptive statistics and graphs as a thorough description is essential to understanding the data. Another important reason is that one needs to check for violation of underlying assumptions in statistical tests. For example, one needs to check if the data is normally distributed and if outliers exist, since both of these might influence correlation coefficients. Table 1 below shows the descriptive statistics for the variables score pre, time pre, score post and time post.

Descriptive Statistics												
	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
SCORE-PRE	24	86.3	6.7	93.0	43.796	4.5813	22.4439	503.729	.628	.472	-.339	.918
TIME PRE	24	1142	658	1800	1301.29	73.378	359.477	129223.520	-.037	.472	-.967	.918
SCORE -POST	24	93.0	.0	93.0	57.975	4.3737	21.4266	459.098	-.796	.472	.926	.918
TIME-POST	24	1380	516	1896	1028.67	61.542	301.492	90897.536	1.116	.472	1.815	.918
Valid N (listwise)	24											

Table 1: Descriptive Statistics

A normal distribution has a bell-shaped curve, which has the greatest number of scores in the middle with smaller frequencies towards the extremes. To investigate the normality of the data we will use the skewness and kurtosis statistics. Positive skewness values suggest that scores are clustered to the left at the low values. Negative skewness values indicate a clustering at the high end. Positive kurtosis values indicate that the distribution is peaked (or clustered in the centre) with long, thin tails. Negative kurtosis values indicate a distribution that is relatively flat.

The histogram for the variable score is shown in figure 6 below. The boxplot for the variable is shown in figure 7 below. The histogram, boxplot and skewness and kurtosis values will be used to assess the normality of the variable score pre. For the variable score pre-test the skewness value is $.63$ which is an indication that the data is clustered to the left. The kurtosis value is $-.339$ which is an indication that the distribution is relatively flat. However, an inspection of the histogram and the boxplot allows us to make an assumption that the distribution is not very far from normal.

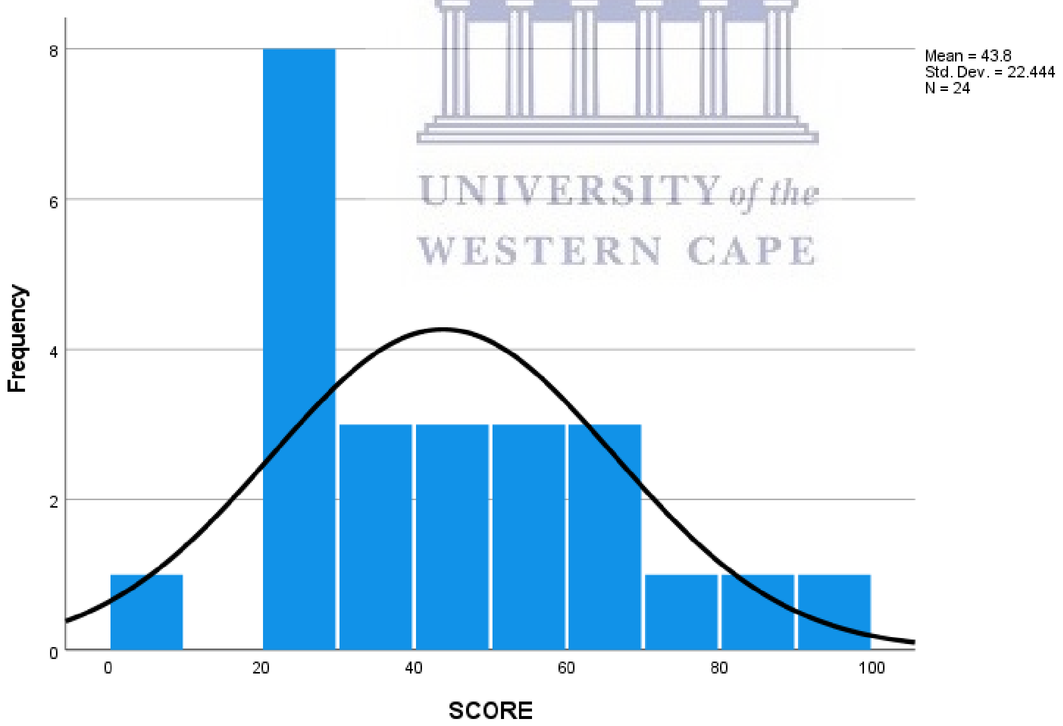


Figure 6: Variable Score Histogram

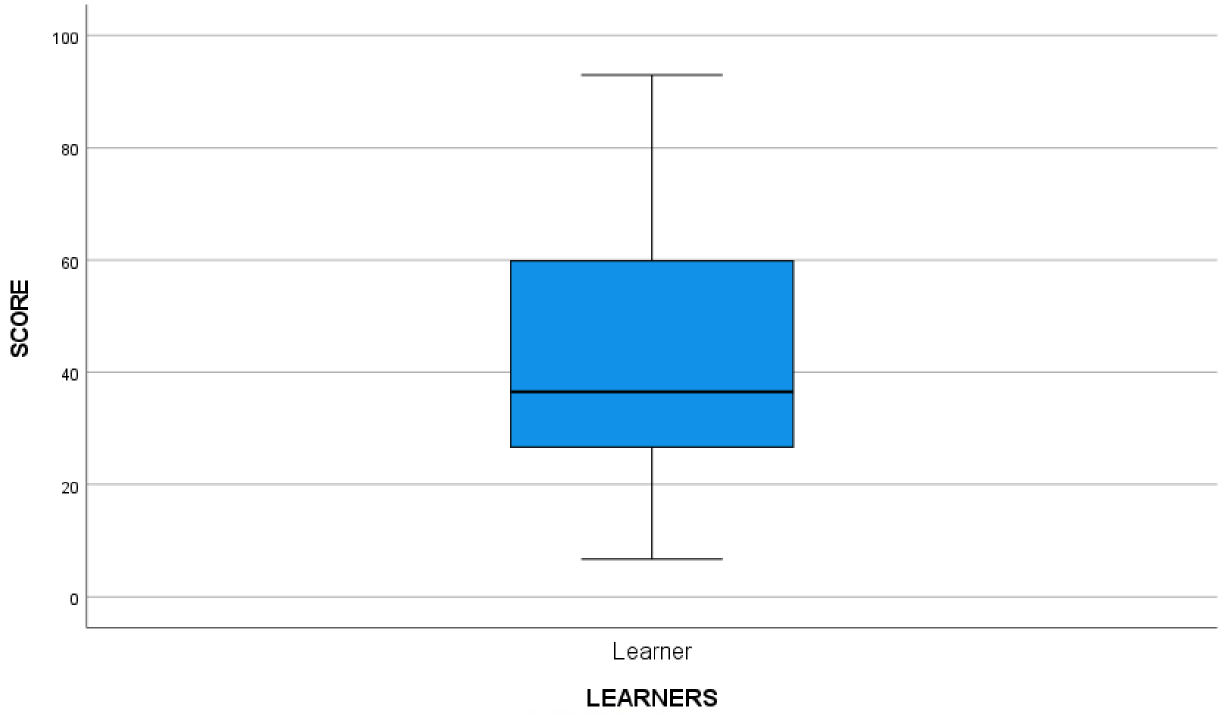


Figure 7: Variable Boxplot

The histogram and boxplot for the variable time pre - test is shown in figures 8 and 9 below. The skewness value for the variable time pre variable is −.37. This value indicates that the distribution is clustered at the high end. The kurtosis value is −.97 which suggests that the distribution is flat. An inspection of the histogram and boxplot however allows us to claim that violation of normality is not severe.

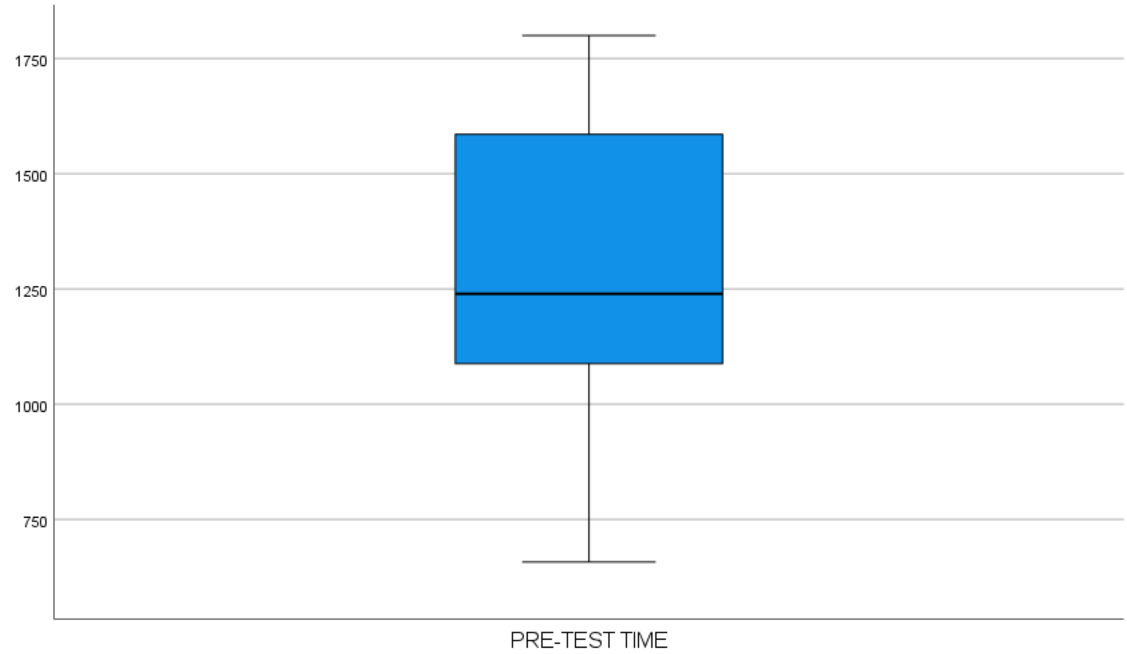


Figure 8: Boxplot for the variable time pre-test

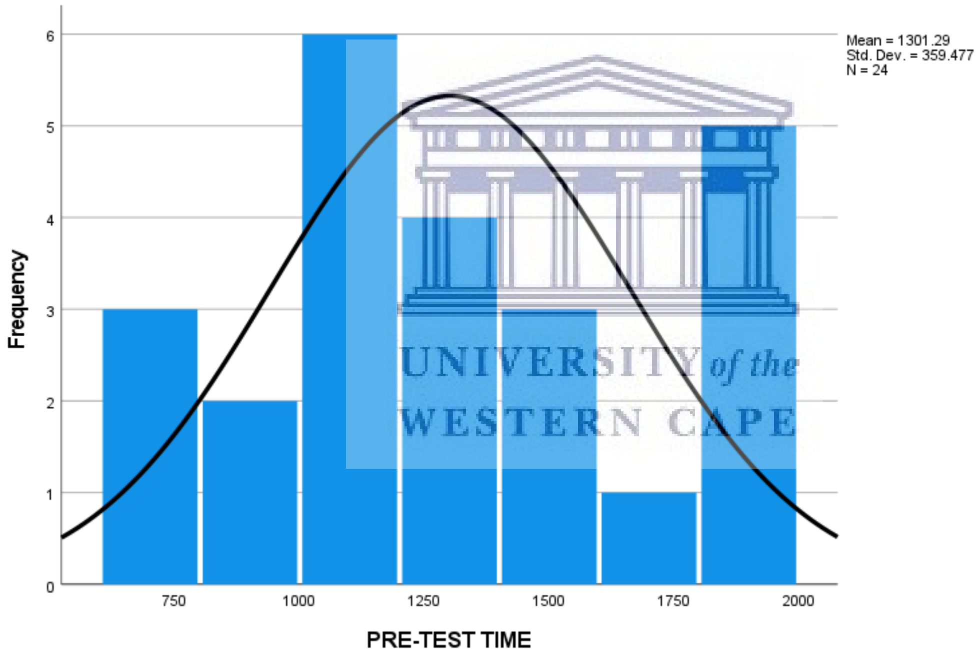


Figure 9: Histogram for the variable time pre-test

The histogram and boxplot for the variable score post-test is shown in figures 10 and 11 below. The skewness value for the score post variable is $-.796$ which suggests that the scores are clustered at the high end. The kurtosis value is $.93$ which is an indication that scores are clustered in the centre. An inspection of the histogram and boxplot however allows us to claim that violation of normality is not severe.

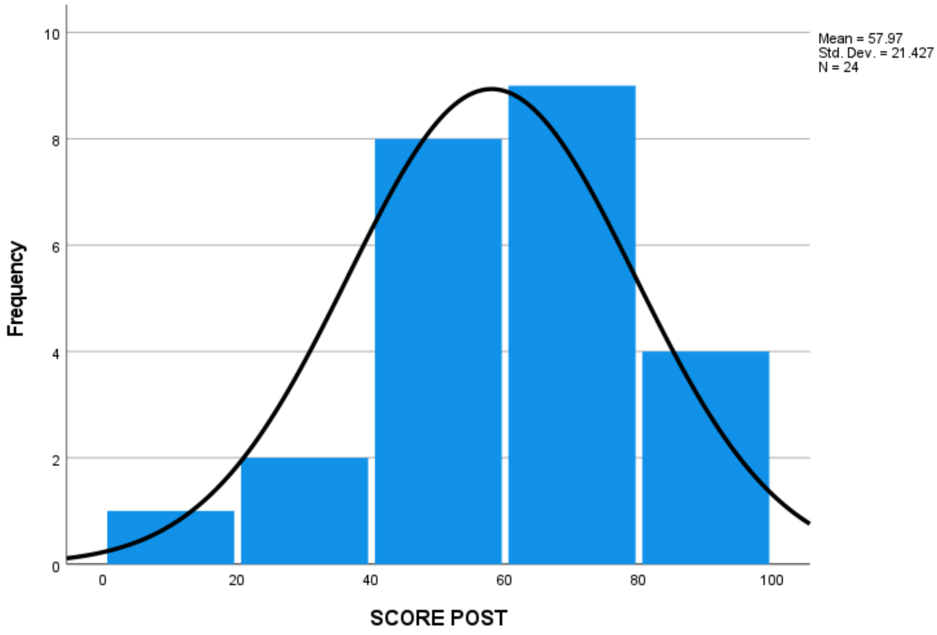


Figure 10: Histogram for the variable score post - test

Figure 11: Boxplot for the variable score post-test

The histogram and boxplot for the variable time post is shown in figures 12 and 13 below. The skewness value for the time post variable is 1.12 which suggests that the distribution is clustered at the left. The kurtosis value is 1.82 which is an indication that the distribution is clustered in the centre. An inspection of the histogram and boxplot however allows us to claim that normality is not too severely violated.

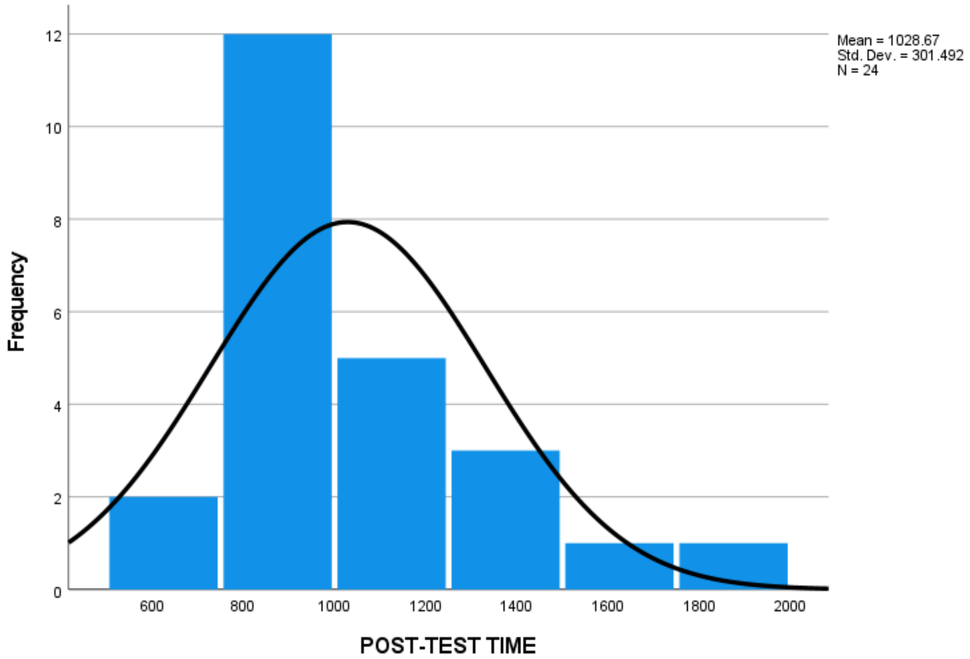


Figure 12: Histogram for the variable time post test

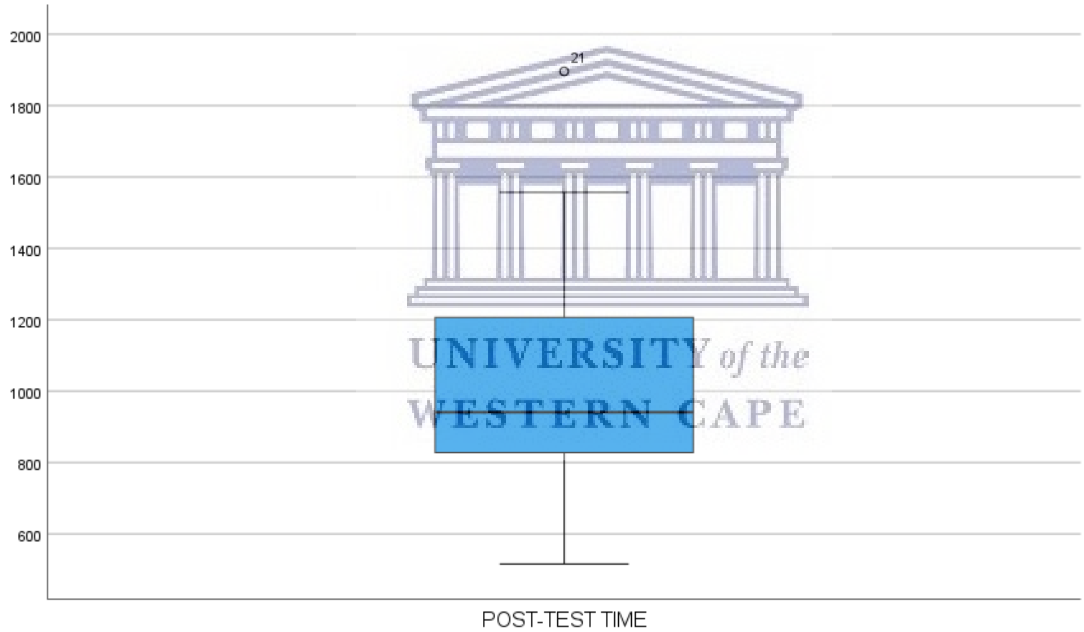


Figure 13: Boxplot for the variable time post-test

4.3 Time: Paired-samples t-tests

For the paired-samples t-test the null hypothesis was that there is no significant difference after exposure to the teaching strategy. In other words, the mean difference of the pre- and post-test time for the population is zero i.e.

$$H_0: \mu_D = 0$$

The alternative hypothesis is that the intervention caused the post-test time to be higher or lower than the pre-test time. In other words, the mean difference is not zero:

$$H_1: \mu_D \neq 0$$

The level of significance is set at $\alpha = .05$ for a two-tailed test.

The tables below provide the statistics for the paired samples-test for time pre and time post.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	TIME PRE	1301.29	24	359.477	73.378
	TIME-POST	1028.67	24	301.492	61.542

Table 2: Paired Samples Statistics for Time

Paired Samples Correlations

				Significance	
		N	Correlation	One-Sided p	Two-Sided p
Pair 1	TIME PRE & TIME-POST	24	.439	.016	.032

Table 3: Paired Samples Correlations for Time

Paired Samples Test

	Paired Differences					t	df	Significance	
				95% Confidence Interval of the Difference					
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1 TIME PRE - TIME-POST	272.625	353.473	72.152	123.366	421.884	3.778	23	<.001	<.001

Table 4: Paired Samples Test for Time

Paired Samples Effect Sizes

			Standardizer[a]	Point Estimate	95% Confidence Interval	
					Lower	Upper
Pair 1	TIME PRE - TIME-POST	Cohen's d	353.473	.771	.307	1.222
		Hedges' correction	359.370	.759	.302	1.202

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation of the mean difference.

Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

Table 5: Paired Samples Effect Sizes for time

A paired-samples t-test was conducted to evaluate the impact of a teaching intervention (based on distributed interleaved practice) on students' time taken to complete a test. There was a statistically significant decrease in time taken from pre- test time (in seconds) ($M = 1301.29$, $SD = 359.48$) to post-test ($M = 1028.67, SD = 301.49), t(23) = 3.78\ p < .001\ (two-tailed)$. The mean decrease in time was 272.63 with a 95% confidence interval ranging from $.307\ to\ 1.222$. The value for Cohen's d is 0.77 which is a medium effect size. The null hypothesis for the time variable is rejected that is $H_1: \mu_D \neq 0$. We conclude that the teaching intervention contributed to a decrease in time taken.

4.4. Scores: Paired-Samples t-test

The tables below indicate the paired-samples statistics for test scores pre and post intervention.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	SCORE POST	57.98	24	21.427	4.374
	SCORE PRE	43.80	24	22.444	4.581

Table 6: Paired - Samples t-test for Scores

Paired Samples Correlations

				Significance	
		N	Correlation	One-Sided p	Two-Sided p
Pair 1	SCORE POST & SCORE PRE	24	.769	<.001	<.001

Table 7: Paired Samples Correlations for scores

Paired Samples Test

		Paired Differences							Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	SCORE POST - SCORE PRE	14.179	14.946	3.051	7.868	20.490	4.648	23	<.001	<.001

Table 8: Paired Samples Test for Scores

Paired Samples Effect Sizes

					95% Confidence Interval	
			Standardizer[a]	Point Estimate	Lower	Upper
Pair 1	SCORE POST - SCORE PRE	Cohen's d	14.946	.949	.457	1.426
		Hedges' correction	15.195	.933	.450	1.402

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation of the mean difference.

Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

Table 9: Paired Samples Effect Sizes for Scores

A paired-samples t-test was conducted to evaluate the impact of a teaching intervention (based on distributed interleaved practice) on students' test scores. There was a statistically significant increase in test scores from pre- test $(M = 43.80,\ SD = 22.44)$ to post-test $(M = 57.98, SD = 21.43)$,

$t(23) = 4.65\ p < .001\ (two - tailed)$. The mean increase in scores was 14.18 with a 95% confidence interval ranging from $.46\ \ to\ 1.43$. The value for Cohen's d is 0.95 which is a large effect size. The null hypothesis for the score variable is rejected that is $H_1: \mu_D \neq 0$. We conclude that the teaching intervention contributed to an increase in scores.

4.5. Correlation Speed vs Accuracy (post intervention)

We were also interested to know whether there was a correlation between how fast the test was completed (speed variable) and correctness of responses (accuracy variable). We used scatterplots to do a preliminary analysis for the correlation (see figure 14). If one removes the extreme points, then it would seem that the distribution correlate to some degree. We therefore performed a correlation test for speed and accuracy.

Correlations

		TIME	PERCENTAGE
TIME	Pearson Correlation	1	-.123
	Sig. (2-tailed)		.568
	N	24	24
PERCENTAGE	Pearson Correlation	-.123	1
	Sig. (2-tailed)	.568	
	N	24	24

Table 10: Correlation Speed vs Accuracy (Post Intervention)

The tables (table 11 and 12) below show the correlation statistics for speed and accuracy. Since the data distribution does not violate the normality requirements too severely the Pearson correlation is the preferred statistic.

Nonparametric Correlations

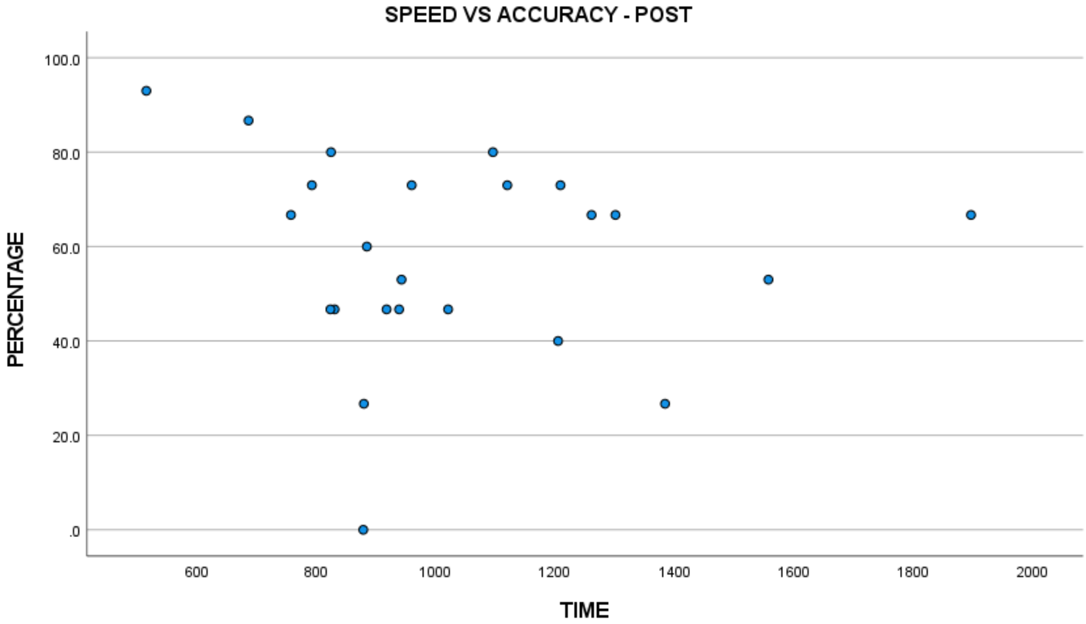


Figure 14: Speed vs Accuracy Scatterplots

Correlations

			TIME	PERCENTAGE
Kendall's tau_b	TIME	Correlation Coefficient	1.000	-.141
		Sig. (2-tailed)	.	.353
		N	24	24
	PERCENTAGE	Correlation Coefficient	-.141	1.000
		Sig. (2-tailed)	.353	.
		N	24	24
Spearman's rho	TIME	Correlation Coefficient	1.000	-.190
		Sig. (2-tailed)	.	.374
		N	24	24
	PERCENTAGE	Correlation Coefficient	-.190	1.000
		Sig. (2-tailed)	.374	.
		N	24	24

Table 11 and 12: Nonparametric Correlations Statistics for Speed and Accuracy

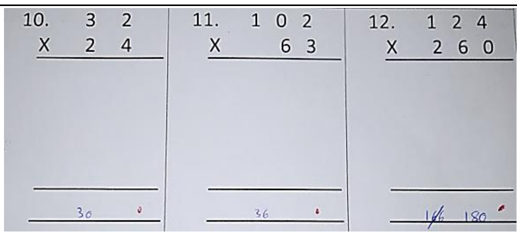
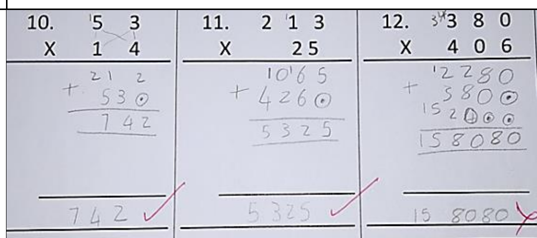
The relationship between speed and accuracy was investigated using a Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality and linearity. There was a weak negative correlation between the two variables, $r = -.12,\ n = 24, p = .57\ (two - tailed)$. Since the correlation is weak and not significant, we conclude that the intervention did not significantly enhance accuracy as speed increased.

CHAPTER 5 DISCUSSION OF RESULTS

5.1. Automaticity and Time

Findings in this study suggest that automaticity has been reached.

It is possible to hypothesise that learners gain confidence once automaticity is reached. Compatible with expectations, a paired-samples t-test revealed that there was a statistically significant decrease in time taken from pre- test time (in seconds) (see 4.3. above). The mean decrease in time was 272.63 seconds with a 95% confidence interval. This means that statistical data shows a positive impact of a teaching intervention, based on distributed interleaved practice, as the teaching intervention contributed to learners taking less time to complete the post – test than the pre – test. In table 12 below are examples of how learners answered the multiplication 2-digit by 2-digit, 3-digit by 2-digit and 3-digit by 3-digit question pre-test and post-test. Each of the three learners answered question 10 – 12 incorrectly in the pre-test and all three answered question 10 and 11 in the post-test correctly. This finding, while preliminary, would suggest that these results can be interpreted as support for the hypothesis that increased accuracy and automaticity in basic mathematic skills results in improvements in tackling procedural mathematics tasks that increase in difficulty.

<table>
<tr><th>LEARNER NUMBER</th><th>PRE - TEST</th><th>POST - TEST</th></tr>
<tr><td>12</td><td>
</td><td>
</td></tr>
<tr><td>TIME TAKEN TO COMPLETE</td><td>26 minutes 44 seconds</td><td>21 minutes 41 seconds</td></tr>
</table>

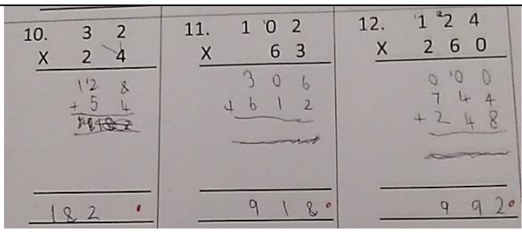
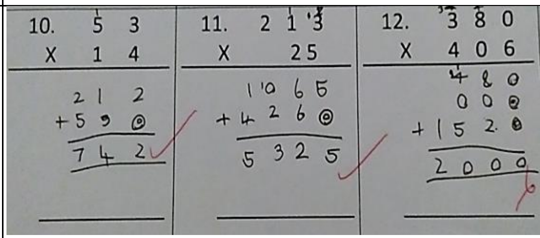
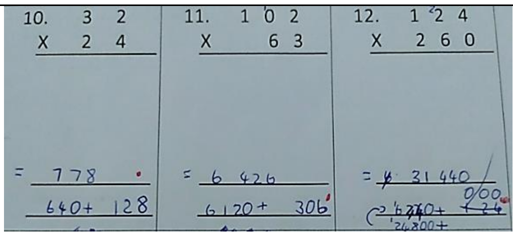
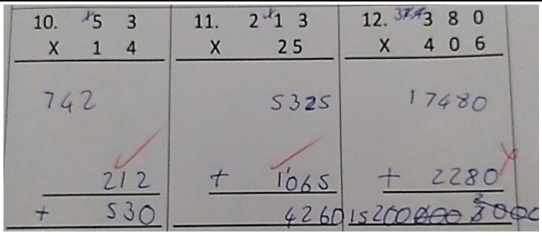
15 QUESTIONS		
13		
TIME TAKEN TO COMPLETE 15 QUESTIONS	18 minutes 08 seconds	30 minutes (Speed did not increase in this case, but accuracy and discrimination of problem type improved)
23		
TIME TAKEN TO COMPLETE 15 QUESTIONS	30 minutes	21 minutes 36 seconds

Table 12: Examples of learners' answers pre- and post-test

5.2. Learner Test Scores

Findings in the present study are consistent with the findings of Pegg, Graham & Bellert (2005). The teaching intervention based on distributed interleaved practice contributed to an increase in scores.

A paired-samples t-test (See 4.4. above) indicates that there was a statistically significant increase in test scores from pre- test with a mean aggregate of 43.80%, to post-test with a mean aggregate of 57.98% the mean increase in scores was 14.18% with a 95% confidence interval.

5.3. Speed and Accuracy

The relationship between speed and accuracy was investigated using a Pearson product-moment correlation coefficient. Since the correlation was found to be weak and not significant, contrary to expectations, it is concluded that the intervention did not significantly enhance accuracy as speed increased. There are several possible explanations for this result. For example, the small sample and the short duration of the study.

In summary, the intervention based on an interleaved, distributed practice improved learners speed, test scores as well as their automaticity. The multiplication test set with questions of varying difficulty levels required learners to be able to select the correct strategy when problem solving. In multiplication of different difficulty levels as explained in 3.4. above, the learner is required to use different strategies like 'carrying over' should the result of multiplying be a two-digit number; or inserting a place holder when multiplying a two or three – digit number with another two or three – digit. Should learners have only practiced one difficulty level at a time, it would be problematic for them to discern which strategy to use when an assessment covers different multiplication levels.

It is apparent that interleaving not only aided learners to distinguish between the problem types but also, because learners needed to shift between levels, association between difficulty levels of multiplication problems and the strategy needed to solve these problems was enhanced. We consider this in the progress made in learner 12 and learner 23 in table 12 above. In table 13 below we observe similar improvements in strategy selection for question 10 with learner 8, 9 and 18. In the pre-test both learner 8 and 18 only multiplied the unit of the first number with the unit of the second number. In the post test, they both remembered to 'carry over' the tens-digit of the product of the units of both numbers to the tens digit of the first number then add it to the product of the tens digit of the first number to the unit – digit of the second number. Examining learner 18, particularly, we note that this learner took longer to complete the post-test i.e., speed has not increased but identifying the problem type and remembering which strategy to use was enhanced. Learner 9 has also improved on problem discrimination and implementation of the correct strategy. So, among the benefits of interleaving is category learning and mathematics problem solving by eradicating discrimination errors.

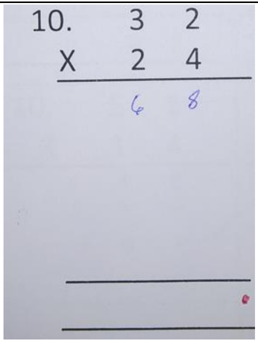
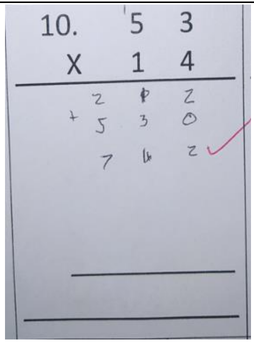
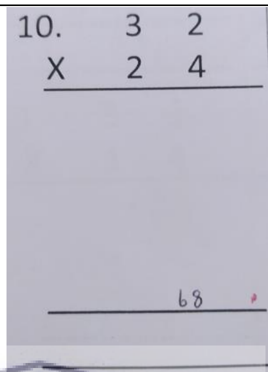
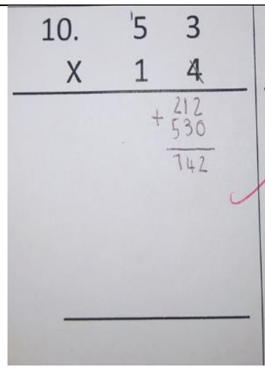
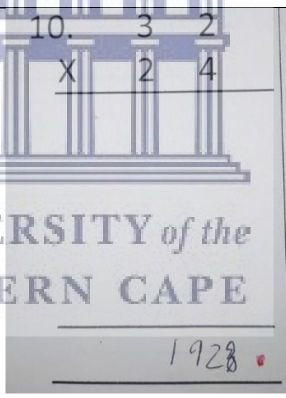
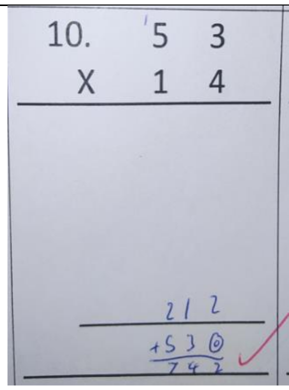
LEARNER NUMBER	PRE - TEST	POST - TEST
8		
TIME TAKEN TO COMPLETE 15 QUESTIONS	18 minutes 08 seconds	15 minutes 43 seconds
18		
TIME TAKEN TO COMPLETE 15 QUESTIONS	16 minutes 12 seconds	25 minutes 57 seconds
9		
TIME TAKEN TO COMPLETE 15QUESTIONS	24 minutes 25 seconds	13 minutes 51 seconds

Table 13:Examples of learner's answers pre - test and post - test to show discrimination of problem types and selection of strategy

CHAPTER 6: CONCLUSION

This research has investigated how a teaching strategy, premised on distributed and interleaved practice, influences learner automaticity in answering multiplication problems and consequently, how automaticity in basic multiplication facts influence learners' performance in problems requiring them to recall multiplication strategies, in terms of speed and accuracy. The study has shown that Grade 6 learners exposed to an intervention programme based on a distributed and interleaved approach to teaching basic multiplication facts, has shown statistically significant improvements in test score results as well as in the speed at which they completed a test. An important hypothesis to emerge in this study is that when automaticity is improved, confidence is increased. This research confirms previous findings and contributes to our understanding that spacing topics using an interleaved technique in mathematics teaching, enhances performance in mathematical procedures. It is apparent that interleaved and practice enhanced learners' ability to discriminate between different problem types and learners' ability to select the correct strategy to solve a problem.

Distributive practice enhanced information retention. This is since it requires learners to revisit a concept more than once over an extended period of time. Each time the information is recalled it is utilized in a different way and subsequently different recall 'hooks' is provided. Therefore, when subsequent recall is required, it is easier to recall since there are now more ways to access the information. Every recall also 'refreshes' the memory which enhances retention of the memory. In terms of procedural knowledge, it means that procedures become well ensconced in the memory which implies the information is recalled much easier and quicker. In other words, automaticity is improved. Furthermore, since retention is improved the forget problem is addressed.

The fact that interleaving of multiplication problem types presented to learners in the study, required learners to connect a problem type to a specific strategy enhanced ability of learners to distinguish between problem types. In other words, discrimination learning was enhanced. Discrimination learning is required in all high stakes mathematics assessments. Since for progression purposes a pass in mathematics is required, it means that a lack in discrimination ability therefore would have dire consequences for the learner.

This study also showed that the intervention based on a distributive, interleaved practice did not significantly enhance accuracy as speed increased. However, some limitations need to be acknowledged.

6.1 Limitations of the study

The sample size, being one class of 27 grade 6 learners, of which the data of only 24 was used, may not be large enough to generalize results. Time constraints and limited resources were also a factor. The study was undertaken over a period of 6 weeks with one or two half – hour sessions per week. With only 15 computers in the computer lab, learners had to share a computer, meaning that they would only have 15 minutes per session to practice their multiplication.

Further research should investigate how distributive, interleaved practice accommodates learning difficulties in mathematics and whether it leads to improved learning outcomes. Also, research could explore the correlation between automaticity of basic mathematics skills and working memory capacity.

In a South African context, much focus is needed on how to improve our mathematics teaching and learning. A distributed, interleaved approach seems an appropriate strategy to enhance learner performance in high – stakes mathematics tests and examinations. It shows great promise in terms of improving learner competency and retention of foundational knowledge.

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APPENDICES

Appendix A: Information letter

UNIVERSITY *of the* WESTERN CAPE

RE: Consent for your child's participation in research

Dear Sir/Madam,

I hope that this communique finds you in the best of health and spirits.

I, Ayesha Abderoef, am a Master's student registered in the School of Mathematics and Science Education (SSME) in the Faculty of Education at the University of the Western Cape. I am studying the effects of a mathematics teaching strategy based on a distributed, interleaved practice and whether this practice in teaching and learning mathematics will benefit learners while engaging with mathematics concepts.

The target group will be the grade 6 learners at your school.

The research title is: Effects of a distributed interleaved teaching strategy on automaticity in intermediate phase mathematics

The study will be guided by the following research questions:

1. How does a teaching strategy, premised on distributed and interleaved practice, influence learner automaticity in answering multiplication and division integer problems?

2. How does automaticity influence learners' performance in problems requiring them to recall multiplication and division strategies, in terms of speed and accuracy?

The research will take place during mathematics lessons at the end of the first term and throughout the second term of 2022. This study will not alter the prescribed curriculum outline as the teaching method only serves to rearrange the way in which learners' practise and study mathematics, in order to capitalise on the retention and comprehension of the content that they are already learning.

As stated above, the research participants will comprise of the grade 6 class. Data collection will be in the form of an assessment before and after the practice period. The participation in this study is completely voluntary. The participants may withdraw from the research at any stage without having to provide any justification. The utmost confidentiality is guaranteed for all participants regarding all information collected. Learners' identity will not be divulged. The identities of learners as well as the school will be kept confidential throughout the study.

I would like your permission to conduct my research in your child's class. A letter of consent from you as the parent as well as a letter of assent is attached to this letter. Kindly complete and sign the letter of consent and kindly ask your child to complete the assent letter.

Should you wish to find out more about the research, you are welcome to contact my supervisor, Dr Bruce May, whose contact details are provided below. Alternatively, you may contact me personally.

Kind Regards

Signature

____

Researcher: Mrs. A. Abderoef

Ph: 0718863039

E-Mail: ayesha.abderoef@gmail.com

Supervisor Details:

Dr. Bruce May (PhD)

Ph: 0219599545

Email: bmay@uwc.ac.za

Appendix B: Parent Consent Letter

Parental Consent form

RESPICE PROSPICE

UNIVERSITY *of the* WESTERN CAPE

Parental Informed Consent Form

I________________________________ (parent/guardian name and surname), hereby give permission for my child to be part of the research study conducted by Mrs. Abderoef, and I understand that my child's participation in this research study is voluntary. If I, for some reason, wish to withdraw my child from being a participant in this study, I am aware that I could do so without having to give any means of justification. I understand the purpose and goals of this study.

I am aware that the information will be used for a Master's thesis and a research paper. I have the right to examine, comment on, and/or remove my child's information prior to the paper's submission. The data gathered in this study is confidential and anonymous with respect to my child's personal identity, unless I specify or indicate otherwise. In the case of classroom participation, I have been ensured that my child's personal identity and the identity of the school will be protected.

I have read and understand the above information. I give my consent for my child to participate in the study.

____________________ ____________________

Parent/Guardian's signature Date

______________________ 09.03.2022

Researcher's signature Date

Appendix C: Learner Assent Letter

Participants: Assent Form

UNIVERSITY of the WESTERN CAPE

RESPICE PROSPICE

Participant's Informed Assent Form

I____ (participants name and surname), agree to be part of this research study and I understand that my participation in this research study, is voluntary. If I, for some reason, wish to withdraw from being a participant in this study, I am aware that I could do so without having to give justification. I understand the purpose and goals of this study.

I am aware the information will be used for a Master's thesis and a research paper. I have the right to examine, comment on, and/or remove information prior to the paper's submission. The data gathered in this study is confidential and anonymous with respect to my personal identity, unless I specify or indicate otherwise. In the case of classroom participation, I have been ensured that my personal identity and the identity of the school will be protected.

I have read and understand the above information. I give my consent to participate in the study.

____________________ ____________________

Participant's signature Date

____________________ 09 March 2022

Researcher's signature Date

Appendix D: Letter to the Directors and Principal

RE: Permission to conduct research at (school name)

Dear Principal and Directors

My name is Ayesha Abderoef. I am currently enrolled for my MEd study at the University of the Western Cape (UWC). I herewith wish to apply for permission to perform a research study at your school. I have chosen your school because of its diversity and commitment to instilling a growth mindset in your learners and also affords me convenience because of my relationship with the school.

The research study will include collecting and analysing data gathered by teaching and assessing a mathematics study method with grade 6-9 learners. All information gathered will be used for research purposes only. The name of the school and the learners will remain anonymous.

I will give a summary report of my findings to the school, at the end of my data analysis. For ethical consideration in data gathering, the stamp of the school and signatures will suffice for the purposes of proof of consultation and permission by school management.

The research that I will be conducting will depict the effects of a mathematics teaching strategy based on a *distributed and interleaved* practice.

The research title is: Effects of a distributed and interleaved teaching strategy on learner performance in high stakes exams in the intermediate phase.

The study will be guided by the following research question:

1. How does a teaching strategy, premised on distributed and interleaved practice, influence grade 6-9 learners' performance in a high-stakes exam?

The research will take place during mathematics lessons throughout the second term of 2022. This study will not alter the prescribed curriculum outline. This teaching method only serves to rearrange the way in which learners' practice and study mathematics and to capitalise on the retention and comprehension of content.

The research participants will comprise of two grade 6 classes. Data collection will be in the form of an assessment before and after the practice period. The participation in this study is completely voluntary. The participants may withdraw from the research at any stage of the research without having to provide any justification. The utmost confidentiality is guaranteed for all participants regarding all information collected. Learners' identity will not be divulged. The identities of learners as well as the school will be kept confidential throughout the study. I will give a summary report of my findings to the school, at the end of my data analysis. For ethical consideration in data gathering, the stamp of the school and signatures will suffice for the purposes of proof of consultation and permission by school management.

Should you wish to find out more about the research, you are welcome to contact my supervisor, Dr Bruce May, whose contact details are provided below. Alternatively, you may contact me personally.

Kind Regards

____

Researcher: Mrs. A. Abderoef

Ph: 0718863039

E-Mail: **ayesha.abderoef@gmail.com**

Supervisor Details:

Dr. Bruce May (PhD)

Ph: 0219599545

Email: **bmay@uwc.ac.za**

Appendix E: Written Pre – Test

Learner number______________ **Time: ______**

Pre - Test

Grade 6

1. 5 x 9 =	2. 6 x 8 =	3. 7 x 11 =
4. 3 x 4 =	5. 12 x 9 =	6. 8 x 7 =
7. 2 2 X 4 ________ ________	8. 7 2 X 6 ________ ________	9. 3 6 X 9 ________ ________
10. 3 2 X 2 4 ________ ________ ________	11. 1 0 2 X 6 3 ________ ________ ________	12. 1 2 4 X 2 6 0 ________ ________ ________
13. 2 1 6 8 X 4 0 3 ________ ________ ________	14. 3 7 9 0 X 5 0 6 ________ ________ ________	15. 5 4 9 8 X 6 4 6 ________ ________ ________

Appendix F: Written Post – Test

Learner number_______________ **Time: ______**

Post - Test

1. 6 x 9 =	2. 4 x 8 =	3. 9 x 11 =
4. 7 x 3 =	5. 12 x 7 =	6. 8 x 5 =
7. 1 2 X 4	8. 8 6 X 7	9. 4 2 X 5
10. 5 3 X 1 4	11. 2 1 3 X 2 5	12. 3 8 0 X 4 0 6
13. 3 2 7 9 X 5 1 4	14. 4 9 8 9 X 6 4 1	15. 6 2 5 3 X 2 1 2