NUMBER SENSE DEVELOPMENT OF PRE-SERVICE MATHEMATICS TEACHERS: THE ROLE OF WORKING MEMORY CAPACITY

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ABSTRACT–The paper reports on the relationship between a group of pre-service mathematics teachers' working memory and number sense. South Africa's murky performance in the Trends in International Mathematics and Science Study (TIMSS) since 1995 instigated several interrogative reports. It was found that teachers' number sense influence their pedagogies and thus also learner achievement. Furthermore, too many teachers cannot teach quantities and how they feature in our lives properly. A number sense is an intuitive understanding of numbers, their magnitude and inter-relationships and arithmetic ability is a good indicator of number sense. A variable reported to relate to number sense, is working memory capacity. The 42 third year student-teachers wrote weekly mental arithmetic tests aimed at strengthening their number sense. Their working memory capacity was measured by the Working Memory Index of Wechsler's Adult Intelligence Scale. A linear regression ascertained that working memory capacity correlated strongly and positively (r=0.692) with arithmetic ability, predicting 48% of the variance. The nonparametric Mann-Whitney U test detected statistically significant arithmetic ability differences between participants with more or less working memory capacity. Working memory capacity development could be an important contributor to mathematics teachers' number sense and formal memory strategy training might positively enhance both.

Keywords: Number sense; Quantitative literacy; Working memory capacity; Arithmetic ability; Pre-service mathematics teachers.

1. BACKGROUND CONTEXT, RESEARCH PROBLEM AND PURPOSE

South Africa's dismal performance in the Trends in International Mathematics and Science Study (TIMSS), in which grade 4 and grade 8 learners participate every four years since 1995, led to several national interrogations over the years. The Human Sciences Research Council's (HSRC, 2011) TIMSS report, in which grade 8 learners from 42 countries participated, reveals that three countries (South Africa, Botswana and Honduras), administered the assessment at a grade 9 level. Despite this, their mathematics (and science) scores were still among those of the bottom six countries. Independent reports by Simkins and Spaull (both in 2013) speculate that an average South African Grade 9 mathematics learner seems to be two years behind the average grade 8 learner from 21 other middle-income countries. The question is: How can a country make up such a deficit?

Taylor, Head of the South Africa's Education Evaluation and Development Unit (NEEDU), (2011) points a finger to inadequate mathematics content knowledge and pedagogical competencies of teachers. McCarthy & Oliphant, on behalf of the Centre for Development and Enterprise (2013, p. 3), bluntly state: "The teaching of mathematics in South African schools is amongst the worst in the world". Henning (2014) advocates that many mathematics teachers have not been adequately trained to teach the fundamental principles of quantities and magnitude and how these feature in learners' lives. Her core message is that an insufficiently developed (or even a complete lack of a) number sense gave rise to mathematics teachers' inability to develop their learners' numerical abilities.

This unsatisfactory scenario and the author being co-responsible for delivering competent high school mathematics teachers instigated this research. The author postulates that mathematics educators who possess an adequate number sense and who can develop it in their learners, might be a fundamental key (one of many) to mathematics learner success in South Africa. This paper reports on a strategy that was employed during the formal education of a group of third year mathematics pre-service teachers at a South African university, aimed at the enhancement of their number sense. The potential relationship between participants' working memory capacity and their number sense, expressed via their arithmetic ability is the specific focus of the inquiry.

Within the context of this study, answers will be sought to the following research questions:
What is the nature of the relationship, if any, between pre-service mathematics teachers' working memory capacity and their number sense, as indicated by their arithmetic ability?
How does the arithmetic ability (and thus number sense) of participants with more working memory capacity compare to those with less working memory capacity?

2. THEORETICAL PERSPECTIVES

2.1. Theoretical lenses through which the inquiry is viewed

Three complementary sets of literature perspectives are used as a theoretical lens through which *number sense* (also known as quantitative literacy), its manifestation and development are viewed in this inquiry. The first of the three is the interpretations of the National Council of Teachers of Mathematics (NCTM, 2000) on what it means to have a number sense, to be numerate or to possess quantitative literacy; secondly, the perspectives of the Australian Department of Employment, Education, Training and Youth Affairs (DEETYA, 1997), related to the use of mathematics in the 'real world', and thirdly the views of Wagner and Davis (2010) on the various sub-abilities that contribute towards having a number sense.

There are also two sets of literature perspectives that are used as a theoretical lens through which *working memory*, its definition, functioning and measurement, its relationship with number sense and its development, is viewed in this study. The first comes from the evergreen work of Miller, Galanter and Pribram (1960), discovering that people's daily functioning requires the execution of a hierarchy of plans, namely a master plan, supported by sub- and sub-sub-plans. Working memory is thus "the facility that is used to carry out one subplan while keeping in mind the necessary related subplans and the master plan" (quoted by Cowan, 2014, p. 201). The second view on working memory is that of Baddeley (2003), who has proven that it comprises four interrelated components all of them regulated by a central executive. These four working memory elements function in a coordinated manner, and underpin matters like vocabulary acquisition, reading, spelling and numeracy, while it is also a fair predictor of academic success (Alloway & Alloway, 2010). Literature perspectives, geared at number sense and working memory and how the two might be related, are reviewed in the following sub-sections.

2.2. Number sense

There are several delineations of what it means to have a number sense or to be numerate (Organisation for Economic Co-operation and Development (OECD), 2012; Steen, 2001; Willis, 1998; among others). The term *numeracy*, originally coined in the United Kingdom (UK Ministry of Education's Crowther report, 1959) is widely used in Australia, the UK and African countries (Bennison, 2015), while the concept *quantitative* or *mathematical literacy* (OECD, 2013) are popular in Europe, the USA and elsewhere. Muir (2012, p. 21) suggests that "it involves having a good intuition about numbers and their relationships, including the ability to have a 'feel' for the relative size of numbers and to make reasonable estimations." Shumway (2011) believes that people with a number sense have quantitative 'wisdom' to, for example, know when 100 is a lot or when it is not much. Muir (2012, p. 22) adds that such knowledge can then be used to "make comparisons, interpret data, estimate and answer the question, 'Does that answer make sense?'" Having a number sense (or being numerate) can thus be defined as "moving from the initial development of basic counting techniques to more sophisticated understandings of the size of numbers, number relationships, patterns, operations, and place value" (National Council of Teachers of Mathematics (NCTM), 2000, p. 79). It is regarded as a developing construct, made up of (at least) the following four abilities: (i) fluidity and flexibility with numbers, (ii) a sense of what numbers mean, (iii) to perform mental arithmetic relatively swiftly and accurately and (iv) to make quantitative comparisons in a real world context (Jordan, Kaplan, Locuniak, & Ramineni, 2007 and Wagner & Davis, 2010).

For the purpose of this inquiry, the Australian Department of Employment, Education, Training and Youth Affairs (DEETYA, 1997) provides an appropriate theoretical lens through which number sense can be viewed. Having a number sense or being numerate involves the capacity to "use mathematics effectively to meet the demands of life at home, in paid work and for participation in community and civic life" (p. 15).

2.3. Working memory

Working memory is regarded as the information that can be stored temporarily in a person's mind in a "readily accessible state" (Cockcroft, 2015, p. 2), for revival purposes and for subsequent use in performing simple and also more demanding cognitive tasks (Cowan, 2014, p. 197 and St Clair-Thompson, Stevens, Hunt, & Bolder, 2010). It is an omnipresent concept in psychological research, and increasingly so in the educational domain. According to Cowan (2014, p. 198), its origin dates back to three and a quarter centuries ago to John Locke (1690), who differentiates between meditation or "contemplation" (keeping an idea in mind), and memory ("the power to revive an idea after it has disappeared from the mind"). A more recent perspective has been generated by Miller, et al. (1960), who (as indicated in section 2.1 above) regard working memory as the intellectual-rational ('mental') ability to remember plans (and subplans) thereby enabling humans to function effectively on a daily basis.

There is ample evidence (Baddeley, 2003 and others) that working memory comprises four interdependent components (or processes) that store and deploy information in a synchronised manner. The four components (Cockcroft, 2015, p. 2–5) are the:

verbal sub-system, known as the *phonological loop*, which converts auditory information into comprehensible sounds, words and sentences

visuospatial subsystem, known as the *sketchpad*, which integrates (visual and spatial information are stored separately in working memory) and interprets visual-spatial information

central executive, which has oversight of the verbal and visuospatial components, can access information from long-term memory and regulates functions like "paying attention, planning, inhibiting automatic behaviours, and simultaneously holding and processing information" (Cockcroft, 2015, p. 4) and

episodic buffer, which connects verbal, visual and spatial information, and fuses long- and shorter term memory into coherent episodes (Baddeley, 2000, p. 421–422).

2.4. Working memory capacity

There is considerable evidence (Alloway & Alloway, 2013; Cockcroft, 2015; Cowan, 2014) that links working memory capacity and performance to vocabulary, reading, mathematics, comprehension and eventually also to academic achievement. These working memory-academic performance links are, according to all the above-mentioned authors, based on a relatively firm connection between working memory and fluid intelligence, suggesting that working memory capacity determines someone's ability to reason and to solve problems. The exact relationship between working memory and academic ability is not fully understood yet, but Cowan (2014) strongly suggests that less working memory capacity would restrain learning.

Several researchers (Alloway, 2007; Cockcroft, 2015; Groth-Marnat & Baker, 2003; Hornung, Brunner, Reuter & Martin, 2011; Wechsler, 1998 and 2009) suggest that working memory capacity is typically measured via one or a combination of the reading, listening, word, digit and computational span subtests of Wechsler's Adult Intelligence Scale (WAIS). Higher scores on simple span tasks indicate greater short-term memory capacity, while higher scores on complex span tasks indicate greater working memory. Kane and Engle (2003) reveal that participants are unaccustomed with the various span tests (simple or complex), which implies that working memory ability is relatively unaffected by factors such as feedback, support and input from the home front, rural or urban origins and living conditions or socio-economic status (SES) (compare Cockcroft, 2015, p. 6).

2.5. Strategies aimed at enhancing number sense

Number sense is long considered a vital prerequisite for arithmetic proficiency (Gersten & Chard, 1999; Griffin, Case & Siegler, 1994; Hinton, 2011), but the relationship is mutual, because arithmetic exercises, especially without calculators have been shown (Yang & Li, 2013) to develop learners' numeric flexibility and thus their number sense. Van Luit and Schopman (2000) find that underdeveloped numeracy does interfere with the acquisition of mathematical abilities, while Clarke and Shinn (2004) discover that magnitude comparisons and quantity discrimination strongly relate to mathematical proficiency. Yang and Li (2013) cite several studies that have shown that mathematics learners at school, as well as pre-service mathematics teachers struggle mostly to solve number sense-related problems. They (p. 44) regard the user-hostile design of mathematics textbooks and "rule-based" pedagogies as reasons for these number sense inefficiencies.

Several strategies aimed at enhancing number sense have been employed with relative success over the past two decades, of which the following are noteworthy:

using spoken language by matching numbers with words (Gersten & Chard, 1999; Jordan, Kaplan, Locuniak, & Ramineni, 2007)

shying away from rules and finding the right answers towards discovering relationships between quantities (Griffin, 2004; Jordan, 2007)

collecting and charting data (Gurganus, 2004)

number sense and learning attitude exercises via interactive technology (Yang & Tsai, 2010), and via computer animation-based activities (Yang & Li, 2013)

estimation and discriminating between quantities exercises (Angier, 2008; Gurganus, 2004 and Muir, 2012)

playing a linear number or other board games (Ramani & Siegler, 2011)

mass, length, area, and volume conversion of units exercises (Galligan, 2011; Wagner & Davis, 2010)

the integration of the realistic use of numbers in the everyday world (Tsao, 2012)

mathematical diary writing (Yang, 2005) and

strategies aimed at working memory strengthening of pre-service mathematics teachers via arithmetic exercises without calculators (Ashcraft & Kirk, 2001) or a formal course on the meaning, magnitude, use of numbers and the effect of operations (Tsao, 2012).

2.6. Working memory's connection to number sense

Salthouse and Babcock (1991) initially revealed the potentially powerful relationship between number sense and working memory. A functional working memory benefits mathematics learners in several ways, with arithmetic ability (accuracy & time taken), academic achievement, attention span, time on task, problem solving and reasoning the most prominent dividends (Ashcraft & Kirk, 2001; Ashcraft & Moore, 2009; Dehaene, 1997; Kane & Engle, 2003; Raghubar, Barnes & Hecht, 2010; St Claire-Thomson, Stevens, Hunt & Bolder, 2010; Unsworth & Engle, 2007).

Substantial international research connecting working memory capacity to arithmetical and mathematical performance, and hence to number sense, can be found. Dumontheil and Klingberg (2012, p. 1078) declare: "working memory capacity is highly correlated with mathematical reasoning abilities and can predict future development of arithmetical performance". Kane and Engle (2003) describe their experiment of how *staying on task* is tied to working memory capacity, by applying the so called Stroop effect. Participants are requested to name the colour of the ink in which various words (all of them colours) are written and sometimes the colour of the ink does not match the written colour, which often causes participants not to remain focused on the task at hand. The lack of staying on task effect, according to Cowan (2014, p. 211), often surfaces when mathematics learners are attempting to solve arithmetic problems, while they are also expected to remember words (descriptions or relationships between variables) interwoven with the problems.

3. RESEARCH DESIGN AND METHODOLOGY

3.1. Research paradigm and method

The research paradigm is the researcher's worldview, as portrayed by the matrix of beliefs, perceptions and underlying assumptions, which guides him in approaching this inquiry. The main paradigm underlying this study relates to an attempt to measure pre-service mathematics teachers' number sense (over a period of time), as well as their working memory (via a standardised psychological test). The investigation was thus conducted from a **post-positivist** stance. Post-positivism is a milder form of positivism, allowing for measurement, comparison and scientific engagement with the participants (Phillips & Burbules, 2000). The researcher accepts that reality cannot be known fully, but that measuring it objectively might reveal some of its elements.

3.2. Participants

The participants were a convenient sample (students in the researcher's class) of 42 pre-service high school mathematics teachers, in their third year of B.Ed. study during the second semester (July to November) of 2014. The majority are *male* (69%), *black* (83%), *indigenous* language speakers (81%) and *22 years or younger* (76%). The mean of their final marks for mathematics in Grade 12 was 66.1% and the median was 65%. Exactly a third (14) of the participants have scored less than 60% in Gr 12, while nine (21.4%) scored in the 70s, and seven (16.7%) obtained a distinction (80%+).

3.3. Arithmetic ability activities and their assessment

The pre-service teachers' arithmetic ability activities were carefully planned. It was based on the notion of '*30 second challenge*' on three levels, which is featured in the UK's Daily Mail newspaper. The newspaper claims (Lock, 2008) that the challenges effectively enhance mental arithmetic capacity development. Sixteen of these challenges were converted into activities for the participants, similar to the one portrayed in Figure 1 below. Participants were expected to follow the instructions, starting with the number on the left, attempting to reach an answer in the last cell on the right of each level. They were not allowed to use calculators, but written calculations, which utilised their working memory capacity in any case were permissible.

Participants engaged in one such activity per week during class time. Activities in the 2nd, 4th, 6th and every 2nd week from there onwards were seen as 'tests'. Participants knew that their 'test' marks counted towards their semester mark. The Daily Mail recommends that readers use maximum three minutes for a whole challenge, but the author (as lecturer) realised that most student-teachers would struggle to even complete the first two levels within three minutes and a time limit of *seven* minutes per 'test' activity was set. Activities during the 1st, 3rd, 5th and every 2nd week from there onwards, were seen as arithmetic ability exercising opportunities, and a time limit of *ten* minutes for each was set. Exercising activities were marked by peers and discussed in detail with the class directly afterwards. Test activities were marked by the author and participants received their marked activities and the memorandum back a week later.

Beginner level	8	x4	-15	x2	Reverse the digits	+ 17	÷ 4	+3	2/3 of this	Final answer
Inter-mediate level	206	-58	75% of this	-84	X 9	+ 37	3/10 of this	+252	7/8 of this	Final answer

Advanced level	330	Increase by 40%	+77	8/11 of this	-133	6/7 of this	+155	÷ 13	+181	Final answer

Figure 1: A typical mental arithmetic exercise or test activity

Each correct answer was worth one mark, implying a maximum mark of 24 per activity. Participants thus generated a cumulative mental arithmetic mark out of 192 for the eight activities.

3.4. Working memory capacity assessment

Halfway through the semester, each participant's working memory capacity was determined via the Working Memory Index (WMI) of Wechsler's Adult Intelligence Scale (WAIS), version III (Wechsler, 1998). The WMI is calculated by adding up participants' scores on three items, namely the *Digit Span* (measuring immediate memory), the *Arithmetic* (measuring concentration) and the *Letter–Number sequencing* (measuring freedom from distractibility) subtests (Ainsworth, n.d.). Assessments were conducted by two registered psychometrists, involving participants individually. Each participant's WMI (their working memory capacity) was expressed as a raw mark and as a percentage.

3.5. Data capturing and analysis

Collected number sense (arithmetic ability) and working memory capacity (WMI) data were captured in a Microsoft Excel worksheet and then analysed via the Statistical Package for the Social Sciences (SPSS, version 23). *Simple linear regression* was used to explore the 1st research question, namely the nature of the relationship between participants' working memory capacity and number sense. The *Mann Whitney U test* was used to find an answer to the 2nd research question, namely whether there are arithmetic ability differences between participants with more and those with less working memory capacity.

3.6. Ethical measures and participants' consent

After the goal of the inquiry, the nature of the working memory index instrument and their rights and responsibilities as respondents have been explained to them by the psychometrics, individual written consent was obtained from all participants to safeguard the confidentiality of collected data and their anonymity.

3.7. Validity and reliability measures

Groth-Marnat and Baker (2003) highlight that the WMI subscale displays face validity, content validity, moderate criterion validity (in connection of academic success) and construct validity in respect of the constructs attention span and concentration. The creator of the WAIS, Wechsler (1998) reports that reliabilities for sub-scales (e.g. the WMI) vary and that they are generally lower than the reliability of the full scale. By making use of test-retest and split-half methods, the internal consistency of the WMI subscale was found to vary from low .70s to low .80s (Groth-Marnat & Baker, 2003, p. 1212). The two psychometrists, both staff members from a leading African company of consulting psychologists, are frequently involved in validity and reliability testing in respect of the WAIS and its subscales, geared at South African respondents. They emphasised that Wechsler's working memory subscale displays acceptable validity and reliability features.

4. FINDINGS AND DISCUSSION

4.1. Relationship between participants' working memory capacity and number sense

The relationship between participants' working memory capacities (represented by their working memory indices) and their number sense (represented by their arithmetic abilities) are displayed in the scatterplot below in figure 2.

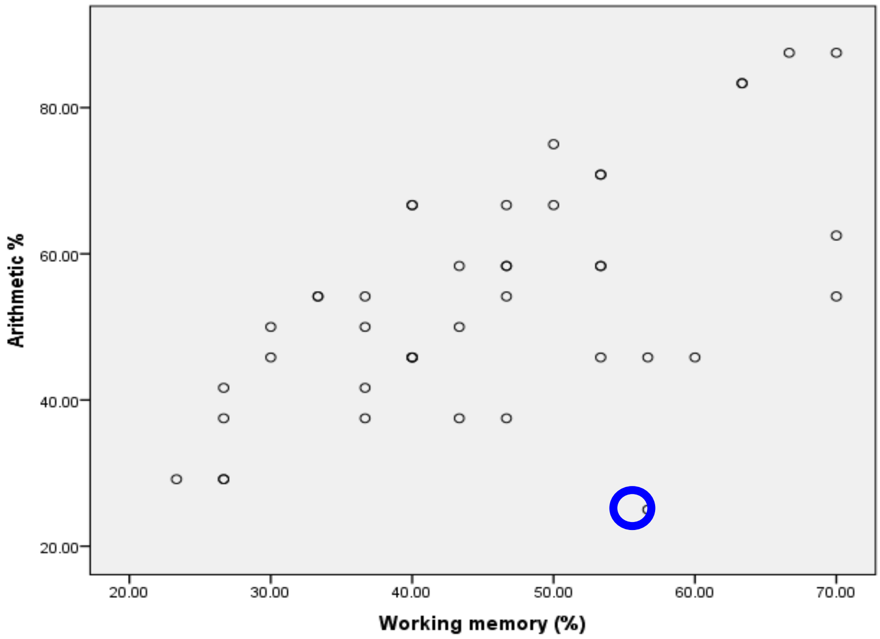

Figure 2: Scatterplot of participants' working memory capacities versus their arithmetic abilities

The scatterplot exhibits a positive correlation between participants' working memory and number sense. The data point marked by a blue circle is an outlier and was not taken into account in further correlation and regression calculations. The Pearson's correlation coefficient (r= .692) is strongly positive and it implies that working memory capacity accounts for almost 48% of the variance in arithmetic ability. The significance level (p< .001) means that there is a much less than 1% possibility that this difference may have occurred purely due to the nature of this specific sample.

A simple linear regression was carried out to ascertain the extent to which working memory capacity scores might predict arithmetic ability scores. This was done after ascertaining that all assumptions for a proper linear regression (Cook, 2005) were met. This includes that a linear relationship exists between the two variables, that the range of values is not restricted, that all outliers and potentially influential data points are discarded, that residual values are normally distributed and that homoscedasticity applies, which means that the residual values vary non-systematically (with no discernible pattern). A P-P plot was also used to check these assumptions. Tables 1, 2, 3 and 4 below present the key outputs of the linear regression.

Table 1: Descriptive statistics generated by the simple linear regression

	Mean	Std. Deviation	N
Arithmetic ability (%)	54.675	15.428	41
Working memory capacity (%)	45.203	12.975	41

Table 2: Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.692 [a]	.479	.466	11.27288

Predictors (constant), Working memory capacity (%)

Table 3: ANOVA [a]

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	4564.628	1	4564.628	35.920	.000 [b]
Residual	4956.036	39	127.078		
Total	9520.664	40			

Dependent Variable: Arithmetic ability (%)

Predictors: (Constant), Working memory capacity (%)

Table 4: Coefficients [a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	17.459	6.454		2.705	.010
Working memory capacity (%)	.823	.137	.692	5.993	.000

Dependent Variable: Arithmetic ability (%)

A strong positive correlation was found between working memory capacity and arithmetic ability scores (*r* = .692) and the regression model predicted 48% of the variance. The model was also a good fit for the data (*F* = 35.92, *p* < .001). From table 4, the equation of the regression line can be deduced, namely, $y = .823x + 17.459$. This means that a participant with a WMI score of 60%, is predicted to obtain an arithmetic ability score of approximately 67%.

The positive connection between working memory and number sense, confirmed by this study, echoes the views of several other researchers (compare Section 2.6 above) and endorses the sentiments of Dumontheil and Klingberg (2012, p. 1078) that working memory capacity can and does predict arithmetic ability and hence also number sense.

4.2. Differences between participants with more and those with less working memory capacity

The Mann-Whitney U test, as non-parametric statistical technique was used to analyse differences between the arithmetic abilities of participants with lower (less than 50%) and those with higher working memory indices (50% or more). Mann-Whitney is considered appropriate (Milencović, 2011, p. 74), because the participants' scores aren't normally distributed, are measurable on at least an ordinal scale, are comparable in size and independent (scores of the group with a lower WM capacity don't affect scores of the group with a higher WM capacity).

Tables 5 and 6 below present the ranks and test statistics in respect of pre-service teachers' number sense (represented by their arithmetic abilities), with working memory capacity (presented by their WM Indices) as the grouping variable.

Table 5: Ranks in respect of arithmetic ability

	Groups	N=	Mean rank	Sum of ranks
Working memory index categories [N=42]	Less than 50%	26	17.06	443.50
	More than 50%	15	28.72	459.50

Table 6: Test statistics [a] for pre-service teachers' arithmetic ability

	Arithmetic ability percentages [a]
Mann-Whitney U	92.500
Wilcoxon W	443.500
Z	-3.007
Asymp. Sig. (2-tailed)	.003 [b]

a The arithmetic abilities of pre-service teachers, who scored ***50% or more*** in respect of their working memory index are compared to the arithmetic abilities of pre-service teachers, who scored ***less than 50%*** in respect of their working memory capacity index

b Significant at the 99% level of confidence

The Mann-Whitney test findings indicate that the 26 mathematics pre-service teachers in this study with a working memory index of less than 50%, have a significantly lower (at the 99% confidence level) arithmetic ability (*Mdn* = 47.92) than the arithmetic ability (*Mdn* = 66.67) of the 15 pre-service mathematics teachers with a working memory index of 50% or more, $U = 92.50$, $p < .01$. The influence of the participants' working memory on their arithmetic ability ($r = .47$) is on the border of being classified as big (Milencović, 2011, p. 77), which implies that these findings have moderate to large practical significance.

5. IN CONCLUSION

The research questions that this study attempted to find answers to were two-fold, namely:

What is the nature of the relationship, if any, between pre-service mathematics teachers' working memory capacity and their number sense, as indicated by their arithmetic ability?

How does the arithmetic ability (and thus number sense) of participants with more working memory capacity compare to those with less working memory capacity?

The theoretical lens through which this inquiry is viewed, relates to the perspectives of Baddeley (2003), Alloway and Alloway (2010) and Cowan (2014), that working memory underpins matters like vocabulary acquisition, reading, spelling and number sense, while it also acts as a fair predictor of academic success. Forty two mathematics pre-service teachers were exposed to a series of mental arithmetic activities over a period of 16 weeks during one of their third year courses. This culminated into a cumulative arithmetic ability mark for each participant. Their working memory capacities were also formally detected via the Working Memory Index (WMI) of Wechsler's Adult Intelligence Scale (WAIS). A comparison of the two sets of scores revealed that there is a positive connection between working memory and number sense and that the former indeed predicts the latter. A further analysis indicated that there is a significant arithmetic ability (or number sense) difference between participants with a lower versus participants with a higher working memory capacity.

Mathematics pre-service-teachers' number sense could be further developed through the enhancement of their mental arithmetic abilities. In addition, the latter could be promoted via improving pre-service teachers' working memory capacity. Cockcroft's (2015) views on how working memory capacity could be improved are particularly relevant. Formal working memory training (St Clair-Thompson et al. (2010, p. 213) for example recommend a computerised program known as *Memory Booster*), preferably via an intensive and sufficiently rigorous and demanding program that stretches over a number of successive weeks is highly recommended. Such training, which could be computerised or not, which should be varied, and which should also entail daily feedback and reward (Cockcroft, 2015, p. 11), "may involve either explicit teaching of memory strategies or implicit training through the completion of appealing visuospatial and/or verbal tasks that place demands on working memory."

The view of Cowan (2014, p. 218) appropriately concludes the matter: “We are not yet at a point at which every task can be analyzed in advance in order to predict which tasks are doable with a particular working memory capability. It is possible, though, to monitor performance and keep in mind that failure could be due to working memory limitations, and adjust the presentation accordingly.”

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