Effects of a Working Memory Training Program on Secondary School Students' Mathematics Achievement

Wit Yee Ei[1], Cherry Zin Oo[2*]

[1]Taunggyi Education Degree College, Taunggyi, Myanmar,

[2] Yangon University of Education, Yangon, Myanmar

*cherryzinn@gmail.com

Abstract: This paper explores the impact of a tailored working memory training program on the mathematics achievement of secondary school students in Myanmar. While previous studies have investigated the relationship between working memory and mathematics, this study focuses on a context where computerized training programs are limited. Twelve Grade 8 students participated in a six-week program conducted via Zoom due to the pandemic. A Mathematics Achievement Test, aligned with the curriculum, assessed their performance before and after the program. Semi-structured interviews were conducted to gather insights into the students' experiences. Results showed significant improvements in mathematics achievement, particularly in geometry, after the training program. Working memory strategies such as chunking, visualization, and concentration were found to enhance problem-solving abilities. This study highlights the potential of working memory techniques for enhancing mathematics education, particularly in areas with limited technology access.

Keywords: working memory, mathematics achievement, secondary school students, teaching-learning process

INTRODUCTION

Working memory assumes a pivotal role in the acquisition of foundational educational competencies. It encompasses the cerebral capacity to retain, manipulate, organise, and shape information before its eventual integration into long-term memory for subsequent utilisation (Johnstone, 1984). Working memory capacity has been notably correlated with children's attainment across a diverse spectrum of mathematical proficiencies (Clair-Thompson & Gathercole, 2006; Elvet & Holmes, 2005), as well as their accomplishments in the fields of mathematics (Mumtaz et al., 2018).

Previous research has examined a comprehensive exploration of the relationship between working memory and mathematics ability (Holmes & Adams, 2006). These inquiries has conducted in different educational strata, including primary school students (Caviola et al., 2020), high school students (Batool et al., 2019), and university students (Clearman et al., 2017).

Now, a number of researchers, as well as, commercial companies, highlight the profound impact of working memory, with the overarching aim of enhancing academic outcomes, particularly in mathematics and other subjects, through the deliberate cultivation of subjects' working memory. Evidently, the cultivation of working memory has emerged as the requirements for optimising the teaching-learning process. Although numerous working memory training programs are available in commercial (e.g., Lumosity, Jungle Memory, CogniFit) or clinical (e.g., Cogmed) settings, these programs are in computerised formats.

In the context of numerous developing countries, including Myanmar, the locale of this study, the utilisation of computerised programs remains limited. Therefore, in this study, a working memory program tailored to the needs of secondary school students. In addition to extend beyond program development, this study investigates the impact of working memory program on the mathematics achievement of secondary school students.

Working memory and mathematics achievement

Using working memory tests, researchers have demonstrated that working memory plays an important role in mathematics calculations and achievement. Evidently, the correlation between working memory and mathematics is multifaceted and substantiated through diverse empirical observations. For instance, investigations have found the positive association between visual-spatial working memory and the mathematical performance of school-age students (Allen et al., 2019). Further insights reveal a noteworthy association between children's mental arithmetic capabilities and their capacity to retain verbal and auditory information (Jarvis & Gathercole, 2003), along with the indispensability of decision-making and information retrieval in fostering mathematical proficiency (Holmes & Adams, 2006).

This symbiotic relationship between working memory and mathematics emerges from the inherent demand of mathematical operations. Each mathematical calculation necessitates intricate working memory processes. When students grapple with mathematical problem-solving, their working memory is intricately woven into the fabric of the process. It aids in the retention of problem specifics, facilitates the retrieval of pertinent procedures, and orchestrates the transformation of these elements into tangible numerical outcomes (Dehn, 2008). Evidently, students with elevated working memory capacities tend to outperform their counterparts with limited working memory space (Alenezi, 2008), thereby underscoring the pivotal role of robust working memory in facilitating superior mathematical comprehension.

Need of working memory training program in the teaching-learning process

The importance and necessity of working memory in cognitive development is very prominent. This cognitive function not only plays a crucial role in academic achievement within the teaching-learning process but is also a strong predictor thereof (Peng et al., 2018). Working memory, representing the capacity for storing and manipulating information, exhibits a steady progression from infancy through childhood to adolescence (Cowan, 2016; Gathercole, Pickering, Ambridge, et al., 2004). This progression stems from both maturation and an expansion of knowledge (Cowan, 2016; Jones et al., 2007), is further enhanced through the implementation of working memory training programs (Sala & Gobet, 2020; Von Bastian & Oberauer, 2014). The potential impact of improving students' working memory through training is considerable, with implications reaching across various academic domains and extending to cognitive and real-life activities.

The functional role of working memory is intrinsically linked to academic outcomes (Bull et al., 2008; Gathercole, Pickering, Knight, et al., 2004). It facilitates the development of intricate cognitive skills such as language and mathematical proficiency (Bull & Scerif, 2001; Colmar & Double, 2017), as well as the acquisition of new information and novel concepts (Pickering, 2006). The potential effectiveness of a training program encompassing diverse working memory strategies holds particular interest, considering the substantial body of evidence attesting to the trainability of working memory (Chein & Morrison, 2010; Jaeggi et al., 2008; Klingberg et al., 2002, 2005).

Examining the varied outcomes of working memory training, certain investigations have focused on its impact on mathematics (Gray et al., 2012; Holmes & Gathercole, 2014; Nutley & Klingberg, 2014). In 2008, Torkel Klingberg conducted a study on working memory training, employing a specific set of computerized tasks with dynamically adjusted difficulty levels based on an algorithm. This training regimen spanned five days a week for five weeks, with each daily session lasting approximately 30-40 minutes. The results revealed improvements in cognitive tasks demanding working memory and attention, translating into enhanced attention in daily life (Klingberg, 2008). In the study of Swanson et al. (2013), it became evident that working memory capacity significantly interacts with treatment outcomes, which is to improve children's experiencing difficulties with mathematics.

The training programs utilised in previous studies are not applicable within the scope of the present research due to contextual discrepancies. Thus, this study aims to develop a tailored working memory training program that aligns with the specific needs of secondary school students.

MATERIALS AND METHODS

Participants

A total of 12 Grade 8 students (5 males and 7 females) from Magway, Myanmar participated in this study. This study was approved by the institutional ethics board at the second author's university. Participants were recruited by using purposive sampling because of the nature of qualitative study. Delivered over five days a week, each classroom session spanned forty-five minutes, with a comprehensive duration of six weeks. Due to the prevailing pandemic circumstances, these sessions were facilitated through the Zoom platform.

MEASURES

Mathematics Achievement Test

In the present study, a Mathematics Achievement Test was developed to examine students' mathematics achievement. The test was developed based on a typical Grade 8 Mathematics curriculum textbook in Myanmar (Ministry of Education, 2019). To validate the alignment of the test with the curriculum, ten experts from the Department of Methodology (Mathematics) and the Department of Educational Psychology, Yangon University of Education, alongside three secondary school Mathematics teachers teaching Grade 8, participated in an item review process. An initial pilot study, involving 210 Grade 8 students (100 boys and 110 girls), was conducted for the 72-item mathematics achievement test. Given the relatively modest sample size, Classical Test Theory (CTT) was employed to scrutinize the pilot test outcomes. Items for the final mathematics test were selected using the same inclusion criteria as the working memory test, factoring in DI range and DP values. This meticulous curation resulted in the retention of 12 items out of the original 72. The test exhibited a commendable reliability score of 0.87, attesting to its robustness.

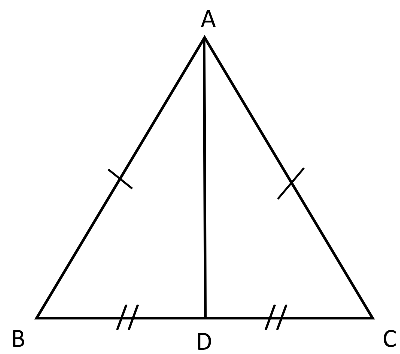
Mathematics achievement test was in line with the typical examination format in schools, Myanmar (i.e., type of questions and the number of items in each topic such as algebra and geometry). A total of 754 Grade 8 students engaged with this mathematics achievement test, each afforded 45 minutes for its completion. The test's scoring methodology allocated a maximum of 25 marks for its entirety. The test comprised four distinct sections, each carrying a designated scoring scheme. In Part 1, encompassing five items, which included both arithmetic and geometric components, the multiple-choice format with four options was employed, warranting one mark for accurate responses and zero marks for incorrect ones. Part 2 featured three arithmetic items, each attracting a score of 2 marks based on the precision of calculation steps. Part 3 incorporated a blend of two arithmetic and one geometric item, each deserving a score of 3 marks contingent upon the meticulousness of calculation steps. In Part 4, a singular geometric item was assigned 5 marks, reflecting a step-wise assessment approach. For instance, students' scores were contingent upon the correct sequence of steps, with each step meriting one mark. The following two items are the sample items that include mathematics achievement test:

Arithmetic item (1): "Calculate the problem $\frac{x^2y^3}{x^2y}+\frac{6xy^5}{-3xy^3}$ in the simplest form by using the properties of exponents."

Arithmetic item (2): "If $\frac{x+y}{y}=2.6$, find the value of $\frac{x}{y}$."

Arithmetic item (3): "Solve the problem $\frac{2x^2}{7y^2}\div\frac{4xy}{21}$ in the simplest form by using the properties of exponents."

Geometry item (1): "In the figure, ΔABC is an isosceles triangle and AB=AC, AD is the middle line of its triangle. Prove that (i) $\Delta ABD \cong \Delta ACD$ and (ii) $\angle ADB \cong \angle ADC = 90^{\circ}$.



Geometry item (2): If the angles of a triangle are 6x°, 4x° and 80° respectively, find the value of x by using the property of a triangle.

Geometry item (3): Write down the meaning and related properties of the following quadrilaterals. (i) Rectangle, (ii) Parallelogram (iii) Trapezoid

Semi-structured interview

In this study, we carried out semi-structured individual interviews following the intervention program to assess the impact of the working memory program. We chose to use semi-structured interviews because they offer flexibility, allowing us to tailor the questions to match each participant's responses, as recommended by Cohen et al. (2007). These interviews consisted of open-ended questions that sought insights into the students' perspectives on the working memory training program and any changes they experienced in their working memory and academic performance, particularly in mathematics, after participating in the program. It's worth noting that we conducted these interviews in the Myanmar language, given that both the researcher and participants shared the same language background. This approach ensured smooth communication and enabled participants to express their thoughts and understandings more clearly. To maintain the accuracy and quality of the data, we employed audio recording during each interview. This recording helped us precisely interpret the participants' opinions and perceptions, contributing to the overall reliability of our findings.

Intervention program

The initiation of the training program mandated preliminary consent from each participant's respective parents. Given the imperative utilization of the Zoom platform due to the pandemic context, the participants were granted permission to access their own handsets or laptops during the training period. Subsequently, the researcher conducted a comprehensive briefing session, elucidating the program's intricacies, intervention protocol, and potential benefits. Active participation was encouraged, and participants were prompted to seek clarifications as needed. This initiative aligned with the predefined lesson plans, which were systematically executed. Participants were duly informed of an impending post-training program test. Carried out over six weeks, comprising 30 sessions, each lasting 45 minutes, the program's comprehensive details were meticulously outlined and presented in each session (see Table 1). Following the culmination of the intervention, the post-training mathematics achievement test was administered.

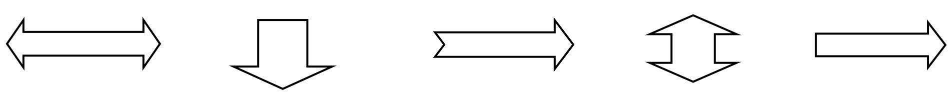
Week	Content	Topic
Week 1	Chunking Strategies	Session 1: explaining students working memory strategies, rules and regulations
		Session 2: practicing items by chunking method
		Session 3: practicing items by chunking method
		Session 4: practicing word sequence items
		Session 5: practicing items by repeating method
Week 2	Visualization Strategies	Session 6: memorizing photos and choosing the right one in pair of pictures
		Session 7: memorizing pictures and completing the blanks
		Session 8: memorizing pictures and answering the questions
		Session 9: memorizing pictures and choosing the right one in similar pictures
		Session 10: making the information change into images and memorizing
Week 3	Association Strategies	Session 11: applying the students’ imagination
		Session 12: applying the students’ creativities
		Session 13: memorizing the words without using association
		Session 14: memorizing the words using association strategies
		Session 15: differentiation the memorization level
Week 4	Concentration Strategies	Session 16: applying concentration

		Session 17: comparing among dependent factors such as size, shape, quantity
	Visual-spatial Memory Games	Session 18: applying different colours to be concentrated more
		Session 19: practicing “symmetry games”
		Session 20: practicing “symmetry games”
Week 5	Memory Games	Session 21: practicing “colour challenges”
		Session 22: practicing “colour challenges”
		Session 23: practicing “right square”
		Session 24: practicing “right square”
		Session 25: practicing “risky road”
Week 6	Memory Games	Session 26: practicing “risky road”
		Session 27: practicing “shopping list”
		Session 28: practicing “shopping list”
		Session 29: practicing “Find the new’
		Session 30: practicing “Find the new”

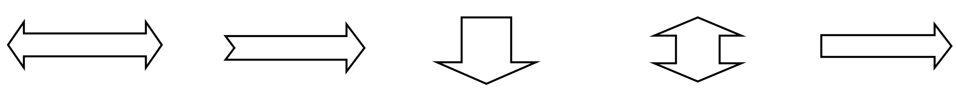
Table 1. Course content and structure of working memory strategies program

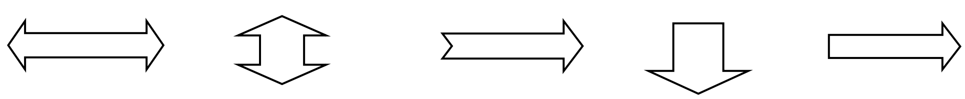
The sample items used in training for visualization and association strategies are as follows:

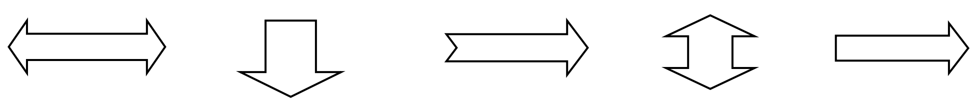
For visualization, the students are asked to memorize for the following picture for (20) seconds and then answer the question.

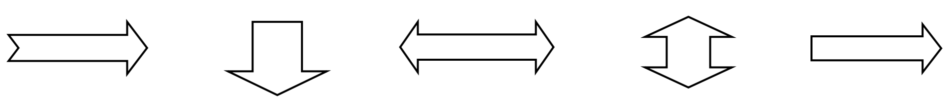


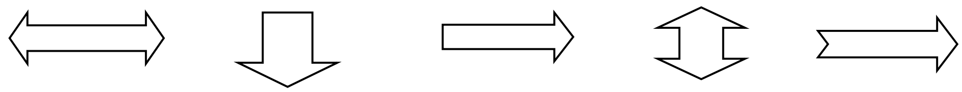
Which picture is the same as the above picture from the following ones?

(1) 

(2) 

(3) 

(4) 

(5) 

For association, the students are asked to memorize the following words for (5) minutes. Break (2) minutes and then write down these words in the same order.

(1) Wheel	(11) Train
(2) Children	(12) Holiday
(3) Orange	(13) Golf
(4) Honda	(14) Bicycle
(5) Cake	(15) Birthday
(6) Banana	(16) Nike
(7) Toyota	(17) Parents
(8) Bus	(18) Family
(9) Wife	(19) Car
(10) Apple	(20) Fruits

Analysis

In order to find out the effect of training program on secondary school students' mathematics achievement before and after the intervention, two types of data analysis, quantitative and qualitative data, were conducted. The quantitative data analysis using the IBM statistical package for the social science (SPSS) was used in the Mathematics achievement data analysis. In order to examine the changes of students' mathematics achievement, paired-samples *t* test was conducted. Regarding analysing the data of semi-structured individual interviews, thematic analysis was used. Three stages of thematic synthesis as highlighted by Thomas and Harden (2008) were used. These three stages are (i) coding text: the line-by-line coding that was done using NVivo software; (ii) developing 'descriptive' themes; and (iii) generating analytical themes. The first author developed descriptive and analytical themes that were reviewed by the second authors. The results of the thematic synthesis are presented in the following section.

RESULTS

Improving Mathematics Achievement

To investigate the changes in students' mathematics achievement before and after the training program, we conducted a paired sample t-test (see Table 2). Based on the results of our statistical analysis, the paired sample t-test indicated a noteworthy difference in the mean scores of mathematics achievement, with a significance level of $p < .001$ ($t\,(1,11) = -5.33$).

Diving into the subscales of algebra and geometry, we found a significant contrast between the pre-test and post-test scores in geometry mathematics, where $t\,(1,11) = -7.92$, and $p < .001$. In contrast, there was no statistically significant difference in the mean scores of algebra mathematics between the pre-test and post-test assessments.

	Intervention	Mean	Std. Deviation	Mean Difference	*t*	*df*	*p*
Algebra	Before After	10.08 10.33	2.23 1.49	-0.25	-.61	11	.555
Geometry	Before After	6.75 10.00	2.22 1.41	-3.25	-7.92***	11	.000
Mathematics Achievement	Before After	16.83 20.33	4.02 2.74	-3.5	-5.33***	11	.000

Note. *** The mean difference is significant at the 0.001 level.

Table 2. Paired samples *t* test results of students' mathematics achievement before and after intervention

To support the analysis results of a paired sample *t* test, thematic analysis revealed two sub-themes arising from the overarching theme of changes in mathematics achievement: (i) algebra and (ii) geometry.

Algebra

The students who actively participated in the training program uniformly reported noticeable enhancements in their mathematics achievement. One student commented her experience, attributing the development of her mathematics abilities and improved memorization techniques to the intervention program. She shared that for mathematical operations, she ingeniously employed association strategies, facilitating easy problem-solving while extending retention over time:

> *"I think the level of memorization will be improved in calculating the arithmetic problems by using the working memory strategies. And also, I feel easier in solving mathematical operations. As an example, in handing the operations, there are the rules and principles to be followed. At that time, by using the association strategy, I remember the steps of operation into "PEMDAS" as an abbreviation. That is why, I never forget the steps of operation for a long time" (SS 1, L 61-69).*

Another student recounted his application of the association strategy to solve challenges related to the metric system in social arithmetic. He utilised various working memory strategies, aligning each to its corresponding context, thus enhancing his memorization capacity post-training. To illustrate, in the realm of mathematics, he memorized the metric system by adopting the association strategy, encapsulating it as "mili, centi, deci, mi, deca, heta, kilomi" for sustained recall.

> *"I am able to memorize mathematical concepts and facts by using the respective working memory strategy after the training programme. As a result, I rarely forget the information that I receive shortly" (SS 3, L 247-253).*

Similarly, another participant commented her dual utilization of chunking and association strategies to streamline operations involving algebraic and rational algebraic expressions. This approach yielded quicker, more accurate solutions, as well as an increased ease of tackling mathematical challenges.

> *"After attending the training program, I usually use both chunking and association strategies in solving the operations on algebraic expressions and rational algebraic expressions. Now, I know the strategies in order to memorize easily and not forget shortly in my memory. By applying these strategies, I think mathematics achievement will be improved to an appropriate level" (SS 9, L 801-809).*

This section verified the potential of working memory strategies to foster a deeper comprehension of algebraic concepts. This correlation between working memory strategies and enriched algebraic understanding hints at the prospective enhancement of overall mathematics achievement.

Geometry

During interviews, a predominant sentiment emerged among participants, highlighting the efficacy of visualization and concentration strategies when confronted with geometric problems. An interviewee candidly shared her prior difficulties with geometry, largely attributed to her struggle in translating textual descriptions into coherent visual constructs. Post-training, her proficient use of working memory strategies empowered her to navigate geometric puzzles with newfound ease.

> *"In the past, I did not know how to visualize the text into a figure or diagram and as a result I face difficulties in solving the geometric problems. Now, I am using both visualization and concentration strategies. After visualizing the text, the figures are coloured to see clearly. To prove the similarities of triangles, it is more prominently colouring the similar sides and similar angle" (SS 6, L 524-529).*

Another student confirmed that in proving congruence of triangles, it is necessary to find out the corresponding sides and angles. After the training, problems concerning the congruence of triangles was found easy by using both the visualization and concentration strategies.

> *"I always use colour to see clearly the sides and angles. I think visualizing or colouring matches with the geometric problems" (SS 7, L 602-605).*

One of the female students stated that visualization strategy is the most favourite one for her and she applied this strategy most in figuring out and solving many geometric problems like circle problems.

> *"I think visualization is very important in solving most of the geometric problems and this is also my favourite strategy. As an example, I can't find out the values if I can't figure out the circle problems" (SS 4, L 330-333).*

Hence, it becomes evident that employing working memory strategies, particularly visualization and concentration techniques, proves pivotal in resolving a majority of geometric problems. Engaging the mind in the process of visualizing textual content fosters the enhancement of students' creativity, leading to a consequent improvement in the process of memorization. This, in turn, elevates their working memory capacity to a certain degree. Additionally, the utilization of working memory strategies has already triumphed over the apprehensions related to geometry. Interestingly, it was observed that a larger number of students applied these strategies more in the domain of geometry than in algebra. As a consequence, the overall mathematics achievement of students will continue to ascend as they adeptly utilize working memory strategies in a suitable manner.

Through both quantitative and qualitative data analysis, the outcomes indicate that training secondary school students with a range of working memory strategies has resulted in improvements in their mathematics achievement compared to their state before the intervention.

DISCUSSION

This study demonstrates the positive impact of a working memory training program on the mathematics achievement of secondary school students. The results establish the program's effectiveness in enhancing their mathematical proficiency. These findings are in line with prior research (Ayoka & Akinyemi, 2014; Dahlin, 2013) that also observed improvements in mathematics following working memory training. Moreover, these results underscore the necessity of implementing working memory strategies to elevate secondary school students' mathematics performance, aligning with the findings of Holmes and Dunning (2017). Additionally, these improvements can contribute to a reduction in students' difficulties with mathematics, as indicated by Nur et al. (2018).

Within the training program, one specific working memory strategy, known as "chunking," emerges as an essential and practical technique for enhancing academic achievement, particularly in mathematics. Chunking minimizes the working memory space required by grouping information into easily remembered units. This approach aligns with the findings of Solopchuk et al. (2016) and Thalmann et al. (2019).

Many students derive significant benefits from visualizing the information they study. Visual aids such as photographs, charts, diagrams, and graphics in study materials capture their attention. When such visual cues are absent, especially when tackling geometric problems, students resort to creating their own. This underscores the importance of the visualization strategy, which aids in retaining information for extended periods. It serves as a foundational skill for comprehending and developing fundamental mathematical concepts and plays a pivotal role in superior problem-solving, as supported by Rabab'h and Veloo (2015).

Furthermore, this study reveals that students employ concentration strategies, including factors such as size and color, to enhance their mathematical problem-solving abilities. This finding corroborates existing literature, which posits that concentration is a trainable mental state wherein a student's senses and cognitive faculties are focused on a specific subject or information (Kumar, 2003).

However, it's important to acknowledge the limitations of this research, as is common in scientific inquiries. The sample size for the training program was constrained due to the unforeseen impact of COVID-19. Future research should prioritize larger sample size including various grades of secondary school students, to strengthen statistical power. Moreover, considering the evolving landscape of education, computer-based training programs should be considered, provided that students have access to the necessary technology and internet connectivity, to align with the changing educational needs and preferences in Myanmar.

CONCLUSIONS

In conclusion, this study brings out the positive potential of using working memory techniques in teaching secondary school students. Importantly, this training program is easy to implement as it involves classroom strategies, and it doesn't require computers or internet access, which means it's available in all local schools in Myanmar. By taking the time to understand the benefits of enhancing working memory and using strategies that suit each student, teachers can create a more engaging and effective teaching and learning experience. This not only benefits students but also makes our educational system more dynamic and fulfilling.

References

[1] Alenezi, D. F. (2008). *A study of learning mathematics related to some cognitive factors and to attitudes*. Ph.D, Thesis, University of Glasgow.

[2] Allen, K., Higgins, S., & Adams, J. (2019). The relationship between visuospatial working memory and mathematical performance in school-aged children: A systematic review.

Educational Psychology Review, *31*, 509–531. https://doi.org/10.1007/s10648-019-09470-8

[3] Ayoka, M. O., & Akinyemi, A. A. (2014). Memory training and academic achievement in mathematics among basic seven students in Lagos metropolis. *International Journal of Psychology and Counselling*, *6*(6), 84–88. https://doi.org/10.5897/ijpc11.008

[4] Batool, T., Habiba, U. e., & Saeed, A. (2019). The relationship between students' working memory capacity and mathematical performance at secondary school level. *Bulletin of Education and Research*, *41*(3), 177–192.

[5] Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology*, *33*(3), 205–228. https://doi.org/10.1080/87565640801982312

[6] Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children ' s mathematics ability : Inhibition , switching , and working memory. *Developmental Neuropsychology*, *19*(3), 273–293. https://doi.org/10.1207/S15326942DN1903

[7] Caviola, S., Colling, L. J., Mammarella, I. C., & Szűcs, D. (2020). Predictors of mathematics in primary school: Magnitude comparison, verbal and spatial working memory measures. *Developmental Science*, 1–19. https://doi.org/10.1111/desc.12957

[8] Chein, J. M., & Morrison, A. B. (2010). Expanding the mind's workspace: Training and transfer effects with a complex working memory span task. *Psychonomic Bulletin and Review*, *17*(2), 193–199. https://doi.org/10.3758/PBR.17.2.193

[9] Clair-Thompson, H. S., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *Quarterly Journal of Experimental Psychology*, *59*(4), 745–759. https://doi.org/10.1080/17470210500162854

[10] Clearman, J., Klinger, V., & Szűcs, D. (2017). Visuospatial and verbal memory in mental arithmetic. *Quarterly Journal of Experimental Psychology*, *70*(9), 1837–1855. https://doi.org/10.1080/17470218.2016.1209534

[11] Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education*. https://doi.org/10.4324/9780203029053

[12] Colmar, S., & Double, K. (2017). Working memory interventions with children: Classrooms or computers? *Journal of Psychologists and Counsellors in Schools*, *27*(2), 264–277. https://doi.org/10.1017/jgc.2017.11

[13] Cornoldi, C., Carretti, B., Drusi, S., & Tencati, C. (2015). Improving problem solving in primary school students: The effect of a training programme focusing on metacognition and working memory. *The British Journal of Educational Psychology*, *85*(3), 424–439. https://doi.org/10.1111/bjep.12083

[14] Cowan, N. (2016). Working memory maturation: Can we get at the essence of cognitive growth? *Perspectives on Psychological Science*, *11*(2), 239–264. https://doi.org/10.1177/1745691615621279

[15] Dahlin, K. I. E. (2013). Working memory training and the effect on mathematical achievement in children with attention deficits and special needs. *Journal of Education and Learning*, *2*(1), 118–133. https://doi.org/10.5539/jel.v2n1p118

[16] de Vreeze-Westgeest, M. G. J., & Vogelaar, B. (2022). Cognitive training in the domain of mathematics for potentially gifted children in primary school. *Education Sciences*, *12*(2). https://doi.org/10.3390/educsci12020127

[17] Dehn, M. J. (2008). *Working memory and academic learning: Assessment and intervention*. Wiley, John & Sons, Inc., Hoboken, New Jersey.

[18] Elvet, O., & Holmes, J. (2005). *Working memory and children' s mathematical skills*. https://doi.org/http://etheses.dur.ac.uk/2205/

[19] Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology*, *40*(2), 177–190. https://doi.org/10.1037/0012-1649.40.2.177

[20] Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from national curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology*, *18*(1), 1–16. https://doi.org/10.1002/acp.934

[21] Gray, S. A., Chanban, P., Martinussen, R., Goldberg, R., Gotlieb, H., & Kronitz, R. (2012). Effects of a computerized working memory training program on working memory, attention, and academics in adolescents with severe LD and comorbid ADHD: a randomized controlled trial. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *52*(12), 1277–1284. https://doi.org/10.1111/j.1469-7610.2012.02592.x

[22] Harrison, T. L., Shipstead, Z., Hicks, K. L., Hambrick, D. Z., Redick, T. S., & Engle, R. W. (2013). Working memory training may increase working memory capacity but not fluid intelligence. *Psychological Science*, *24*(12), 2409–2419. https://doi.org/10.1177/0956797613492984

[23] Holmes, J., & Adams, J. (2006). Working memory and children's mathematical skills: Implications for mathematical development and mathematics curricula. *Educational Psychology*, *26*(3), 339–366. https://doi.org/10.1080/01443410500341056

[24] Holmes, J., & Dunning, D. (2017). Improving working memory to enhance maths performace. In A. M. John W. Adams, Patrick Barmby (Ed.), *The Nature and Development of Mathematics: Cross Disciplinary Perspectives on Cognition, Learning and Culture* (pp. 1–244). Routledge. https://doi.org/10.4324/9781315648163

[25] Holmes, J., & Gathercole, S. E. (2014). Taking working memory training from the laboratory into schools. *Educational Psychology*, *34*(4), 440–450. https://doi.org/10.1080/01443410.2013.797338

[26] Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Perrig, W. J. (2008). Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(19), 6829–6833. https://doi.org/10.1073/pnas.0801268105

[27] Jarvis, H. L., & Gathercole, S. E. (2003). Verbal and non-verbal working memory and achievements on national curriculum tests at 11 and 14 years of age. *Educational and Child Psychology*, *20*, 123–140. https://doi.org/https://psycnet.apa.org/record/2004-11157-010

[28] Johnstone, A. H. (1984). New stars for the teacher to steer by? *Journal of Chemical Education*, *61*(10), 847–849. https://doi.org/10.1021/ed061p847

[29] Jones, G., Gobet, F., & Pine, J. M. (2007). Linking working memory and long-term memory: A computational model of the learning of new words. *Developmental Science*, *10*(6), 853–873. https://doi.org/10.1111/j.1467-7687.2007.00638.x

[30] Klingberg, T. (2008). Training of working memory. *Cogmed Research Summary*, 1–8.

[31] Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlström, K., Gillberg, C. G., Forssberg, H., & Westerberg, H. (2005). Computerized training of working memory in children with ADHD - A randomized, controlled trial. *Journal of the American Academy of Child and Adolescent Psychiatry*, *44*(2), 177–186. https://doi.org/10.1097/00004583-200502000-00010

[32] Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Increased brain activity in frontal and parietal cortex underlies the development of visuospatial working memory capacity during childhood. *Journal of Cognitive Neuroscience*, *14*(1), 1–10. https://doi.org/10.1162/089892902317205276

[33] Kumar, S. (2003). An innovative method to enhance interaction during lecture sessions. *Advances in Physiology Education*, *27*(1–4), 20–25. https://doi.org/10.1152/advan.00043.2001

[34] Le, H. V. (2021). An investigation into factors affecting concentration of university students. *Journal of English Language Teaching and Applied Linguistics*, *3*(6), 07–12. https://doi.org/10.32996/jeltal.2021.3.6.2

[35] Manning, J. R., & Kahana, M. J. (2012). Interpreting semantic clustering effects in free recall. *Memory*, *20*(5), 511–517. https://doi.org/10.1080/09658211.2012.683010

[36] Mashuri, S., Sarib, M., Rasak, A., & Alhabsyi, F. (2022). Semi-structured interview: A methodological reflection on the development of a qualitative research instrument in educational studies. *Journal of Research and Method in Education*, *12*(1), 22–29. https://doi.org/10.9790/7388-1201052229

[37] Ministry of Education. (2019). *Grade 8 Mathematics Text Book (1) and (2)*. Curriculum, Myanmar.

[38] Mumtaz, N., Khan, M. S., & Ayub, S. (2018). Working memory and mathematical performance: A correlational study. *Global Social Sciences Review*, *III*(IV), 156–172. https://doi.org/10.31703/gssr.2018(iii-iv).11

[39] Nur, I. R. D., Herman, T., Dahlan, T. H., & Umbara, U. (2018). The correlation between working memory and students' mathematical difficulties. *Journal of Physics: Conference Series*, *1132*(1). https://doi.org/10.1088/1742-6596/1132/1/012050

[40] Nutley, S. B., & Klingberg, T. (2014). Effect of working memory training on working memory, arithmetic and following instructions. *Psychological Research*, *78*(6), 869–877. https://doi.org/10.1007/s00426-014-0614-0

[41] Peng, P., Barnes, M., Wang, C. C., Wang, W., Li, S., Swanson, H. L., Dardick, W., & Tao, S. (2018). Meta-analysis on the relation between reading and working memory. *Psychological Bulletin*, *144*(1), 48–76. https://doi.org/10.1037/bul0000124

[42] Pickering, S. J. (2006). Working memory in dyslexia. In T. P. Alloway & S. E. Gathercole (Eds.), *Working memory and neurodevelopmental disorders* (pp. 7–40).

[43] Rabab'h, B., & Veloo, A. (2015). Spatial visualization as mediating between mathematics learning strategy and mathematics achievement among 8th grade students. *International Education Studies*, *8*(5), 1–11. https://doi.org/10.5539/ies.v8n5p1

[44] Sala, G., & Gobet, F. (2020). Working memory training in typically developing children: A multilevel meta-analysis. *Psychonomic Bulletin and Review*, *27*(3), 423–434. https://doi.org/10.3758/s13423-019-01681-y

[45] Solopchuk, O., Alamia, A., Olivier, E., & Zénon, A. (2016). Chunking improves symbolic sequence processing and relies on working memory gating mechanisms. *Learning and Memory*, *23*(3), 108–112. https://doi.org/10.1101/lm.041277.115

[46] Swanson, H. L., Lussier, C. M., & Orosco, M. J. (2013). Cognitive strategies, working Memory, and growth in word problem solving in children with math difficulties. *Journal of Learning Disabilities*, *48*(4), 339–358. https://doi.org/10.1177/0022219413498771

[47] Thalmann, M., Souza, A. S., & Oberauer, K. (2019). How does chunking help working memory? *Journal of Experimental Psychology: Learning Memory and Cognition*, *45*(1), 37–55. https://doi.org/10.1037/xlm0000578

[48] Von Bastian, C. C., & Oberauer, K. (2014). Effects and mechanisms of working memory training: a review. *Psychological Research*, *78*(6), 803–820. https://doi.org/10.1007/s00426-013-0524-6