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COGNITIVE STRATEGIES IN LEARNING: SELF-REPORTED WORKING MEMORY STRATEGY USE AMONG UNIVERSITY STUDENTS

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Abstract:

Working memory supports higher-order learning and information processing, particularly attention control, information retention, visual-spatial processing, and verbal rehearsal. Although prior studies have largely examined working memory capacity, training, or performance in controlled cognitive tasks, less is known about how university students report using distinct working memory components as learning

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strategies in routine academic settings, especially across disciplines and educational levels in Malaysian higher education. Guided by Baddeley's multicomponent working memory model, this study examined the dominant strategies used by university students and whether self-reported scores differed by gender, education level, and academic discipline. A quantitative cross-sectional survey was conducted with 212 tertiary students from diverse academic fields. Data were collected using a seven-item self-report questionnaire derived from established memory frameworks, reviewed by subject-matter experts, and pilot-tested with 30 participants. The overall scale showed strong internal consistency (Cronbach's α = .923). The items represented the Central Executive, Visuospatial Sketchpad, and Phonological Loop. By examining these components as self-reported learning strategies in routine university contexts, the study extends the educational application of Baddeley's framework beyond controlled assessments of working memory capacity. Descriptive and inferential analyses identify patterns of strategy use and demographic differences. The Visuospatial Sketchpad recorded the highest mean (M = 3.95), followed by the Central Executive (M = 3.73) and Phonological Loop (M = 3.55). At the item level, recalling visual appearance had the highest mean (M = 4.00), followed by recalling object location (M = 3.90). No significant differences were found by gender, $t = -0.634$, $p = .527$; field of study, $t = -0.205$, $p = .838$; or education level, $F = 0.462$, $p = .764$. The findings suggest that diagrams, visual mapping, spatial organization, structured task planning, and goal-setting prompts may align with students' dominant visual-spatial and executive strategies, supporting effective learning in higher education.

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Keyword:

Cognitive Strategies, Higher Education, Self-Reported Learning Strategies, Visuospatial Sketchpad, Working Memory

Introduction

The mental workspace that holds and manipulates information for a brief period is known as working memory and plays a crucial role in effective learning and academic achievement (Oberauer,2019; Chai, Abd Hamid, & Abdullah, 2018; Linares & Pelegrina, 2023). In addition to supporting task performance in the present moment, working memory is a key mechanism that supports the transfer of newly learned information to long term-memory, which is important to continuous learning and has implications for cognitive development (Forsberg, Adam & Cowan, 2021). In higher education, particularly in applied learning settings, students are often assigned tasks that require prolonged concentration, goal setting, and information processing (Kim et al., 2020; Champod & Petrides, 2010; Ryan et al., 2021). Such demands are greater in subjects requiring problem solving, visual-spatial reasoning, and technical reasoning. Thus, understanding the functions of working memory can greatly improve

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instructional practices. While various studies have examined cognitive processing in their respective experimental setting, few investigations have investigated how working memory functions in the real-world academic settings, especially for tertiary students with varying educational backgrounds (Amin & Mohamad, 2021; Karim et al., 2010). This deficiency in context-related evidence restricts teachers' capacity to develop context sensitive instructional design which is inclusive and context sensitive to learners' processing strategies (Zainal Abidin et al., 2015; Shamila et al., 2023). Guided by Baddeley's multicomponent model, the present study examines students' self-reported use of the central executive, visuospatial sketchpad, and phonological loop in university learning contexts.

Extensive research has been conducted on the role of working memory in various stages of information processing. However, there are some areas that need to be improved which are not yet covered, especially the learners' perspectives. Most of the literature, like that of Cowan (2022) and Swanson, Zheng, & Jerman (2009), deals with the relationship between working memory and performance on a single task (e.g., reading comprehension, mathematical problem solving). However, the research to date lacks in-depth investigations of how learners use their working memory capacities in the wider education context, particularly within the context of varying learner profiles and learning contexts. Holmes et al. (2020) have demonstrated, for example, the promise of WMTs to improve cognitive functions. But the long-term impacts and applications of such interventions in mainstream schools have been little explored. While studies such as that of Sutterer et al. (2019) focus on the neural correlates of working memory, there is a need for more interdisciplinary research that ties together neuroscience, psychology, and educational methods to gain a greater understanding of how these neural processes relate to actual education outcomes.

Moreover, prior research has mainly focused on working memory as an isolated cognitive process, lacking attention to how it is related to other cognitive processes like attention, executive control and long-term memory in real world learning settings. Maezawa & Kawahara (2023) investigated the symmetry of processing between visual and auditory spatial representation in the context of updating working memory. Their results suggest that modality dependence has a significant effect on updating of spatial information in working memory, and thus that different modalities may have different effects on cognitive processes. This reinforces the notion that these modality effects can be considered in educational strategies to improve the learning outcomes. Auditory modalities can improve veridical memory performance than visual modalities (Olszewska et al., 2015), which implies that the modality of information presentation may affect working memory capacity and efficiency. This finding is corroborated by Greenberg et al., who have shown that individual differences in visuospatial memory capacity can significantly impact modality effects, and that educational strategies should be catered to accommodate differences among learners (Greenberg et al., 2021).

The cognitive aspects such as working memory have been identified as being impacted by cultural factors. For instance, a study by Cockcroft (2022) tested working memory models with non-WER (Western, Educated, Industrialized, Rich, and Democratic) populations and found that working memory models are not necessarily robustly capturing the cognitive dynamics in other populations. They concluded that a four-component model of working memory – domain-specific storage and processing – was more appropriate for the data from these non-Western participants. This underscores the need to modify the models to fit in cultural differences in the way cognitive processing takes place. Furthermore, the role of cultural contexts in development of memory was stressed by Kolling et al. (2016), who pointed out that declarative memory and nondeclarative memory may have varying developmental trajectories in different cultures. Their research shows that there can be some similarities in their cognitive processing, but the mechanisms and contexts in which memory develops can differ greatly, and that the working memory models should be tested and perhaps adjusted accordingly (Kolling, Graf & Knopf, 2016). This further suggests that to be effective, educational interventions need to take account of cultural differences.

Previous research has established associations relationships between working memory capacity and academic tasks performance such as reading comprehension (Swanson, Zheng, & Jerman, 2009; Swanson et al., 2014); mathematical problem-solving (Oberauer, 2019); attention control (Mayer & Moreno, 2003); and multimedia learning. Working memory training, cognitive mechanisms, neural processes or modality effects have been studied under controlled or task-specific context (Holmes et al., 2020; Sutterer et al., 2019; Maezawa & Kawahara, 2023; Olszewska et al., 2015). Fewer studies, however, exist on self-reports of the utilization of the central executive, visuospatial sketchpad, and phonological loop as learning strategies during mundane academic tasks by university students. There are also some limitations in the existing studies that tend to focus on specific cognitive outcomes, individual processing modalities or to a lesser extent, specific learner groups, while comparative evidence in other disciplines and at other levels of higher education in Malaysia is still limited (Amin & Mohamad, 2021; Karim et al., 2010). As a result, teachers have little evidence to inform them of the working memory strategies that are commonly used by students and if there are differences across learner groups. Consequently, educators lack contextually grounded evidence about which working memory strategies students commonly rely on and whether these patterns vary across learner groups. Addressing this gap is important because working-memory-informed approaches may support the development of cognitively responsive and inclusive instructional practices (Soemer, 2016; Henry & Bettenay, 2010). Therefore, this study examines the dominant self-reported working memory strategies used by Malaysian tertiary students and investigates whether their use differs according to gender, education level, and academic discipline. The contribution of this study lies in shifting the application of Baddeley's framework from the conventional assessment of working memory capacity or task performance toward students reported strategic use of its components in authentic higher education settings. By comparing these strategy patterns across academic disciplines and educational levels, the study provides contextually grounded evidence that can connect cognitive theory with inclusive instructional design in Malaysian higher education.

The study focuses on how learners engage three core working memory components, namely the central executive, visuospatial sketchpad, and phonological loop, to support cognitive tasks such as problem-solving, comprehension, attention control, and information retention. Although the episodic buffer is acknowledged in Baddeley's broader model, it was not analysed as a separate component in this study because the questionnaire items most directly represented the three core components examined. Ultimately, the outcomes of this study may inform educational practices and pedagogical approaches by helping educators understand how students report using working memory strategies in learning. If a educator knows how working memory is used in learning, he or she might have a better chance of designing teaching strategies that help the employed use working memory in three ways such as to process visual-spatial information, to control attention, to organize tasks, and to rehearse verbal.

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Theoretically, this study is based on Baddeley's multicomponent model of working memory (Baddeley, 2003; Baddeley, 2012) which further states that working memory consists of three core subsystems: the central executive subsystem (involved in attentional control and coordination), the visuospatial sketchpad subsystem (involved in visual and spatial information processing), and the phonological loop (involved in verbal and auditory information processing). These parts work together to aid various learning processes and tasks, such as planning, comprehension, and information retention. This knowledge of how learners use these systems can also provide insight into cognitive diversity and the development of inclusive instructional strategies.

Accordingly, this study is guided by the following research questions:

1. What are the dominant working memory strategies used by tertiary students in Malaysian higher education?
2. Are there significant differences in working memory strategy use based on gender, education level, or academic discipline?

Figure 1 illustrates the conceptual framework guiding this study, based on Baddeley's broader multicomponent model of working memory and cognitive load perspectives in learning. The broader model includes the central executive, visuospatial sketchpad, phonological loop, and episodic buffer. However, the present study analyses only three core components: the central executive, visuospatial sketchpad, and phonological loop, as these were the components most directly represented by the questionnaire items. The framework indicates the interdependencies of these three components in processed during learning activities, especially those that involve controlling the attention, visual-spatial processing, verbal rehearsal, and goal maintenance as described by Baddeley (2003), Baddeley (2012), Sweller (1988), and Mayer & Moreno (2003). This visualization helps to understand the allocation of cognitive resources in real world learning tasks, especially in applied and cognitively challenging learning contexts.

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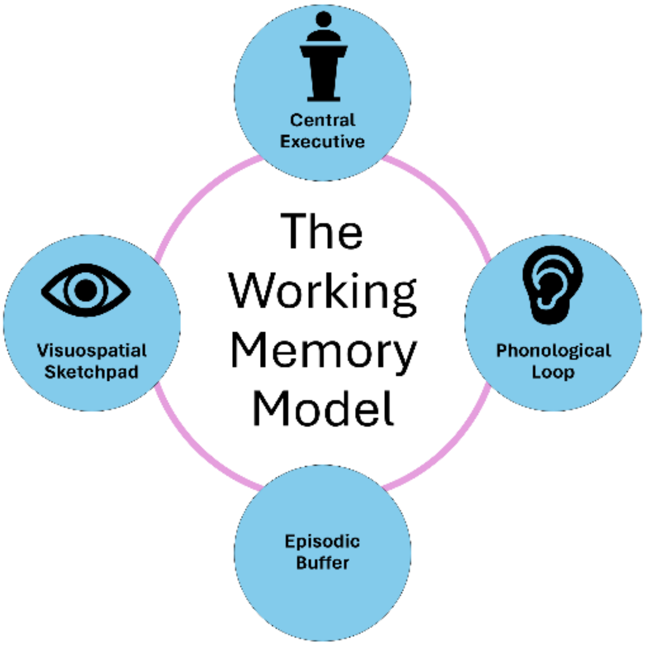

Figure 1: Conceptual Framework Based on Baddeley's Broader Working Memory Model, with the Present Study Focusing on the Central Executive, Visuospatial Sketchpad, and Phonological Loop.

Literature Review

Theoretical Foundations of Working Memory

Working memory is a limited-capacity memory system that stores and processes information required for high-level cognitive functions (Cowan, 2014). In his revised model Baddeley added four essential components: central executive, phonological loop, visuospatial sketchpad and episodic buffer. This study concerns the three main subsystems that are relevant to immediate task performance in education, the episodic buffer being beyond these three subsystems, it integrates information across domains and links to long-term memory.

In blended learning, the working memory is crucial to comprehend the working mechanisms of this system, as a successful management of cognitive load can improve learning outcomes (Müller & Wulf, 2024). This is consistent with the idea that educational interventions need to consider the cognitive load imposed on the student to maximize his or her engagement and retention of information. This align is also supported by the discussion of the use of technology, such as chatbots, on students' working memory, as presented by Rostami & Mehdi Abadi 2023). The results showed that cognitive load theory is essential when determining the use of technology as a tool that can enhance the functioning of working memory in learning experiences (Rostami & Mehdi Abadi, 2023). This indicates that to effectively learn, movement and interaction with technology should be integrated as a means of cognitive processing. Swanson et al. (2014) examined how working memory capacity affects reading comprehension in elementary school children.

International Journal of Education, Psychology and Counseling
IJEPC
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Volume 11 Issue 63 (June 2026) PP. 1370-1390
The central executive oversees attentional control, task switching, and goal-directed behaviour. The phonological loop holds and rehearses verbal information while the visuospatial sketchpad deals with visual and spatial information. These components work interact together in academic tasks like comprehending texts, understanding math concepts, and engaging in science inquiry.

Working Memory in Education

There are studies indicating that working memory capacity is strongly associated with academic achievement (Alloway & Alloway, 2010). The students who have a greater working memory capacity tend to have better performance in standardized tests, problem solving skills, and ability to multitask more effectively. In contrast, working memory impairments have been found to be associated with learning problems, especially in mathematics and reading (Gathercole & Alloway, 2008).

In technical or applied contexts, such as those from an education and training program, working memory plays a special role, requiring the learner to keep information from diagrams, instructions, and manipulative devices organized. Such learning contexts require high cognitive demands, which will necessitate that teachers understand students' working memory strategies and apply instructional techniques that will respond to them (Sweller, 1988).

Empirical Studies on Working Memory Strategy Use

There are several empirical examined about the use of different working memory components in classroom setting. For instance, Mayer and Moreno (2003) have pointed out the role of visuospatial processing in multimedia learning. Diagrams and animations are used to aid in the retention and understanding of the material being presented, making it easier for the viewer to understand. Attention and problem-solving during math instruction have been explored in other studies, Swanson & Jerman, (2007) which examined the role of the central executive in attention and problem-solving during math instruction.

While much of this research has been carried out in Western contexts, but there are cultural and contextual differences that appear in emerging studies in Asian contexts. For instance, Lee and Ng (2010) reported that Malaysian students preferred the visual and verbal strategies in learning science content. However, few studies that have explicitly compared the relative use of these strategies across disciplines and academic levels.

Inclusive Instruction and Universal Design for Learning (UDL)

Acknowledge multiple cognitive profiles in inclusive instructional design. The Universal Design for Learning (UDL) principles advocates the use of multiple means of representation, engagement and expression for a range of learners (CAST, 2018). Working memory research can be valuable in supporting UDL by matching instructional approaches to the students' processing and management of information.

Instruction using a cognitive-informed approach allows teachers to minimize extraneous cognitive load, maximize germane processing and individualize instruction. Knowing the most common strategies students use in working memory allows teachers to create lesson content and activities that draw on the strengths of the students' memory processes (Miller, 2011).

International Journal of Education, Psychology and Counseling
IJEPC
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Volume 11 Issue 63 (June 2026) PP. 1370-1390

Methodology

Research Design

This study adopted quantitative approach with cross-sectional research design, which was used to study the working memory strategies of tertiary students in Malaysia. The main purpose was to detect the predominant cognitive strategies and to determine if there were differences in the use of these strategies across demographic groups. The overall phases and the steps of the study are shown in figure 2. Phase 1 involved a literature search to determine variables relevant to working memory types, and development of a Likert scale questionnaire. Data collection, statistical analysis with SPSS and interpretation of data were the second phase. This culminated in the generation of conclusions consistent with those of Baddeley's working memory model in relation to the control of attention, maintenance of task goals and efficient task organization.

Participants

The total number of students involved in the study were 212 including undergraduate and postgraduate students from various academic fields. The participants were purposively selected to include both technical and non-technical background. Gender, education level and academic discipline were demographic variables that were collected. The respondents were almost equally divided between male and female: females comprised 49% while males made up 51% of the sample shown in Table 1. Due to the purposive sampling method, this balanced gender distribution allows for comparison between male and female respondents, but generalisation should be made with caution.

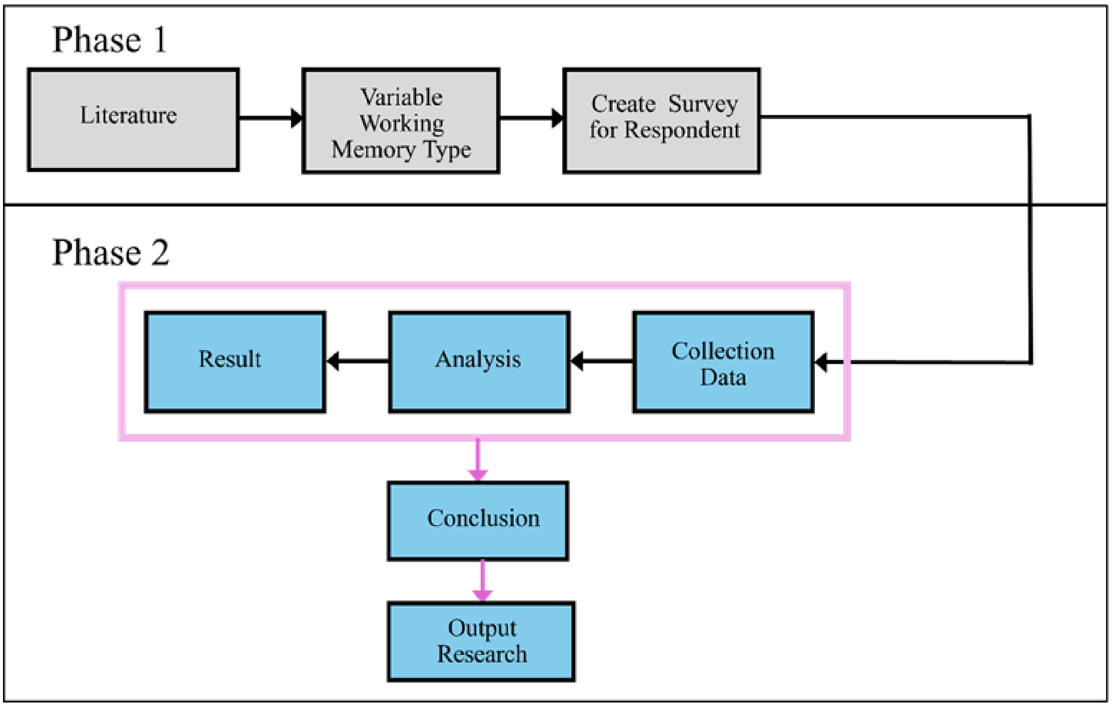

Figure 2: Phases and Procedural Steps of The Study, From Literature and Instrument Development to Data Collection, Analysis, and Research Outputs Aligned with Working Memory Functions

International Journal of Education, Psychology and Counseling
IJEPC
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Volume 11 Issue 63 (June 2026) PP. 1370-1390

Table 1: Percentage for Gender

Gender	Percentage
Male	51%
Female	49%

The distribution of the participants according to their field specializations is given in Table 2. The major proportion of the respondents (62%) are from Science and Technology (Pure Science) disciplines and 38% are from Non-Science (Social Science) disciplines. This distribution indicates that there are a higher proportion of students from science and technology backgrounds that may affect their perception of information processing and working memory because of the nature of their studies.

Table 2: Percentage for Discipline

Discipline	Percentage
Science & Technology (Pure Science)	62%
Non-Science (Social Science)	38%

The following information is provided in tabular format in Table 3, which shows the respondents according to the level of their study. The respondents were from various levels of academic training, ranging from foundation to diploma and degree programmes, master's and PhD programmes. The largest cohort of students were diploma students (39%), followed by degree students (34%), PhD students (11%), foundation students (9%) and master's students (7%). This distribution offers a wider perspective of the use of working memory strategies in the context of tertiary education.

Table 3: Percentage for Level of Study

Level of Study	Percentage
Foundation	9%
Diploma	39%
Degree	34%
Master	7%
Phd	11%

The demographic profile of the participants indicates that the study involved a balanced gender representation, a meaningful distribution of level of studies, and participants from both science and non-science disciplines. Although science and technology students formed most of the sample, the inclusion of diverse academic backgrounds strengthens the relevance of the findings in understanding working memory strategies among higher education students across different learning contexts.

Instrumentation

Data for this study were collected using a theory-informed self-report questionnaire developed to assess students' working memory strategies in learning. The seven working memory items were developed and adapted from constructs identified in established working memory

International Journal of Education, Psychology and Counseling
IJEPC
EISSN : 0128-164X
Volume 11 Issue 63 (June 2026) PP. 1370-1390
frameworks, particularly Miller (1956), Aben et al. (2012), and Baddeley's multicomponent model of working memory (Baddeley, 2003). Items were selected to reflect processes of cognition that are most germane to the study goals: attention control, task monitoring, goal maintenance, mental imagery, spatial recall, verbal rehearsal, and auditory recall. The questionnaire consisted of two sections. Demographic data (gender, field of study, level of study, and age group) was collected in Section A and students' self-reported working memory strategies were collected in Section B.

The Seven items (EWMQ1–EWMQ7) were rated on a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree) in the working memory section. The items were intended to reflect important working memory functions in learning such as attention control, task monitoring, goal maintenance, mental imagery, spatial organization, verbal rehearsal, and auditory recall. Items were divided into three sets, representing three main subsystems of working memory: Central Executive, Visuospatial Sketchpad, and Phonological Loop.

The Central Executive component comprised three items: EWMQ1: attention control, EWMQ2: task monitoring, planning and EWMQ3: goal maintenance. The Visuospatial Sketchpad component comprised two items (EWMQ4-EWMQ5), mental imagery and spatial recall. The Phonological Loop component consisted of two items (EWMQ6–EWMQ7), focusing on verbal rehearsal and auditory memory. Although the original working memory framework acknowledges the episodic buffer as an integrative component, the present study focused on the three core components most directly represented by the questionnaire items. The distribution of items according to working memory components, item codes, number of items, and reliability values is summarized in Table 4.

Table 4: Distribution of Working Memory Items in the Survey

Section	Construct	Component	Item Code	Number of Items	Reliability
B	Working Memory	Central Executive	EWMQ1–EWMQ3	3	0.852
		Visuospatial Sketchpad	EWMQ4–EWMQ5	2	—
		Phonological Loop	EWMQ6–EWMQ7	2	—
	Total Working Memory Scale		**EWMQ1–EWMQ7**	**7**	**0.923**

Note: Separate Cronbach's alpha values were not reported for the two-item Visuospatial Sketchpad and Phonological Loop components. Reliability interpretation therefore focuses primarily on the overall seven-item scale.

To establish content validity, the questionnaire was reviewed by subject-matter experts in cognitive psychology and instructional design to assess the relevance, clarity, and alignment of the items with the three working memory components. A pilot study involving a separate sample of 30 participants was conducted to evaluate item clarity and preliminary reliability. Internal consistency was assessed using Cronbach's alpha. The Central Executive subscale

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 11 Issue 63 (June 2026) PP. 1370-1390
recorded an alpha of .852, while the overall seven-item working memory scale recorded an alpha of .923, indicating strong internal consistency.

Data Collection Procedure

Participation was voluntary, and informed consent was obtained from all respondents. Data collection was conducted during one academic semester using an online questionnaire distributed to students enrolled in that semester. Data were collected electronically using an online, secure data collection form and kept confidential for research purposes.

Data Analysis

Prior to conducting inferential analyses, the data was screened to ensure that the assumptions for the selected statistical tests were reasonably met. Descriptive statistics were used to summarize the working memory scores for each component. Group comparisons were conducted using independent samples t-tests for two group demographic variables, namely gender and field of study, while one-way ANOVA was used to examine differences based on current enrolment level. The statistical analyses were supported by visualizations, including boxplots, violin plots, and density plots, to provide a clearer interpretation of the score distributions.

For the visual comparison of education level, the analysis focused on diploma and degree students because these two groups represented the largest academic categories in the sample and provided a more stable basis for comparison than the smaller foundation, master's, and PhD groups. The inferential analysis, however, considered current enrolment level as reported in the dataset.

Results

The results are presented according to gender, education level, and field of study. Descriptive statistics and visual summaries were used to illustrate the distribution of scores across the three working memory components. Inferential tests were then conducted to examine whether working memory scores differed significantly across selected demographic factors.

Descriptive statistics for the seven working memory items are given in Table 5. Overall, the three components had the following mean scores: Visuospatial Sketchpad: M = 3.95; Central Executive: M = 3.73; Phonological Loop: M = 3.55. The mean for EWMQ4 (recall of visual appearance) was the highest at the item level, followed by EWMQ5, recall of object location (M = 3.90). The results shown above suggest a relative superiority in the use of visual-spatial strategies, consistent with the role of the visuospatial sketch pad in visual and spatial information processing (Baddeley, 2003). Attention control and task-goal maintenance (EWMQ1 and EWMQ2) both recorded mean score of 3.80, while task organization and planning (EWMQ3) had a mean score of 3.60. The item exemplifies functions related to the central executive such as attentional control, goal maintenance, and task management (Baddeley, 2012; Dunlosky & Metcalfe, 2009). The phonological items yielded relatively low mean scores: EWMQ6 (auditory word recall) M = 3.50, and EWMQ7 (verbal repetition) M = 3.60. These results indicate that rehearsal through verbal and auditory mechanisms were employed moderately, as is expected of the phonological loop in processing and rehearsing verbal information (Baddeley, 2003). Overall, students reported using all three working

International Journal of Education, Psychology and Counseling
IJEPC
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Volume 11 Issue 63 (June 2026) PP. 1370-1390
memory components, although visual-spatial strategies were more prominent than phonological strategies.

Table 5: Mean Scores for Working Memory Strategy Items

Working Memory Assessment Items	Mean
EWMQ1 I can direct my attention when I need to	3.8
EWMQ2 I can maintain my task goal when I am working	3.8
EWMQ3 I am able to organize, plan and carry out my tasks efficiently	3.6
EWMQ4 When I want to remember anything, I try to recall what they look like	4.0
EWMQ5 When I want to remember anything, I try to recall the location of the object	3.9
EWMQ6 I can easily remember words I hear	3.5
EWMQ7 I can easily repeat words I have heard	3.6

Component-level mean scores were estimated by averaging the reported item means within each working memory component. The Visuospatial Sketchpad recorded the highest mean (M = 3.95), followed by the Central Executive (M = 3.73) and the Phonological Loop (M = 3.55).

Gender Comparisons

Figure 3 displays boxplots comparing male and female scores across the three working memory components. The median scores showed minimal differences between genders: for the Central Executive, males scored 3.83 while females scored 3.67; both genders reported a median of 4.0 for the Visuospatial Sketchpad; and for the Phonological Loop, males scored 3.5 compared to 4.0 for females. Although slight differences were observed in median scores, males scored slightly higher in the Central Executive, and females in the Phonological Loop, these differences were not statistically significant. For the Central Executive, $p = .433$ ($r = .062$); for the Visuospatial Sketchpad, $p = .408$ ($r = .064$); and for the Phonological Loop, $p = .465$ ($r = .057$). All effect sizes were below 0.1, indicating minimal practical differences. These findings support the conclusion that working memory strategy use is consistent across gender groups.

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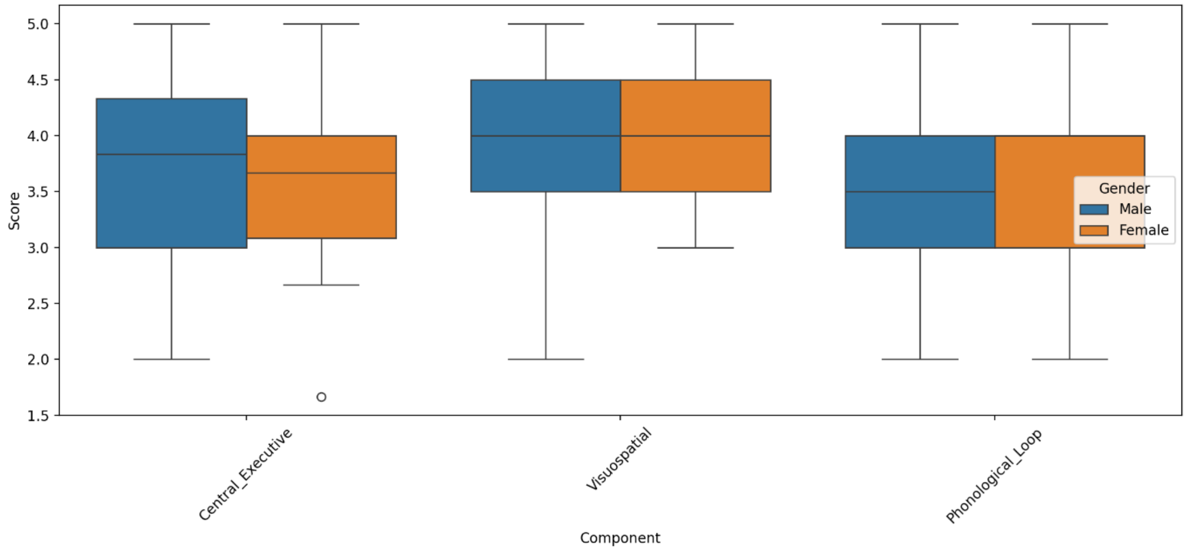

Figure 3: Distribution of Working Memory Component Scores by Gender. Median Scores Appear Comparable, Though Wider Spread is Observed Among Males for the Central Executive Component.

Visual Summary of Distributions

Boxplots, violin plots, and density curves for the distributions of the overall components are provided for these comparisons in Figure 4. The visuals emphasize that there are no significant differences between the components and highlight the range and the central tendencies within the entire sample.

The violin plots a indicate that most scores fall within the range of 3.0 to 4.5, with lower and higher scores having fewer participants. This indicates that the respondents on average had medium to high levels of self-reported working memory strategy scores for all three components. The Visuospatial Sketchpad has a slightly higher number of scores around 4.0-4.5 than the other components, suggesting that participants might have felt that they used visual and spatial strategies to a slightly greater extent when completing tasks associated with visual and spatial processing.

The box plots further support this observation where median score for the Visuospatial Sketchpad is slightly higher than those of the Central Executive and Phonological Loop. The Central Executive is more variable, with a wider range of scores, indicating the variation of attention control, information coordination, and cognitive regulation among participants. The median and the distribution of scores for verbal and auditory self-reported working memory strategies seems to be slightly lower, suggesting Phonological Loop, but the distributions are more concentrated.

There is also significant overlap among the density curves of the three components implying that there are no significant differences in patterns of scores across the domains. The curve of the Visuospatial Sketchpad is slightly shifted to the higher scores. However, the curve of the Phonological Loop has a greater density of scores in the middle range scores. This pattern suggests that while all three components are closely related, participants may have shown a

International Journal of
Education, Psychology and Counseling
IJEPC
EISSN : 0128-164X
Volume 11 Issue 63 (June 2026) PP. 1370-1390

small advantage in visuospatial working memory compared with phonological working memory.

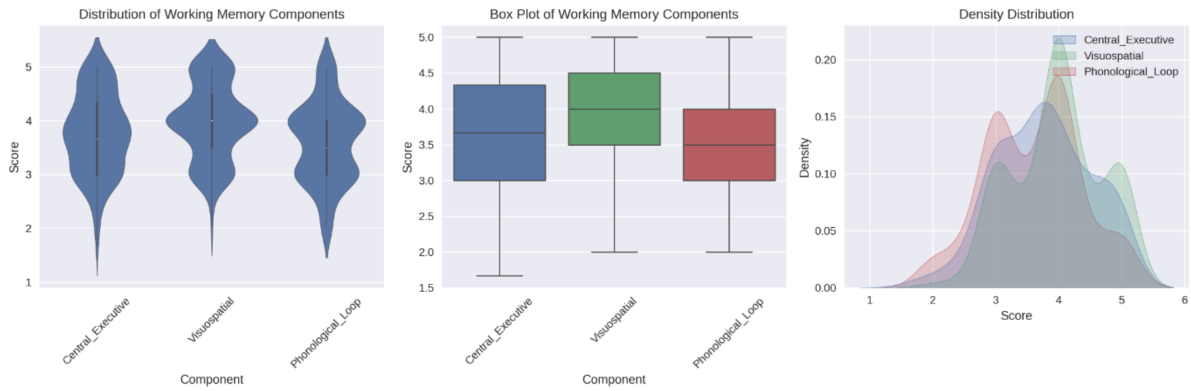

Figure 4: Visual Summary of The Score Distributions for The Three Working Memory Components

Education Level and Field of Study Comparisons

Figures 5 and 6 focus on diploma and degree students, as these two groups formed the largest education-level categories in the sample and represented the main undergraduate learning pathways examined in this study. Figure 5 illustrates the distribution of self-reported working memory component scores across diploma and degree students. The median scores were identical for both groups across all three components: 3.67 for the Central Executive, 4.00 for the Visuospatial Sketchpad, and 3.50 for the Phonological Loop. Effect sizes (η^2) were very small, indicating negligible practical differences between these two groups. As shown in Figure 6, the score distributions largely overlapped, with greater within-group variability than between-group variation. These findings suggest that, within the diploma and degree subsample, self-reported working memory strategy scores were broadly comparable. However, interpretation should be limited to these two education levels and should not be generalized to all academic levels represented in the wider sample.

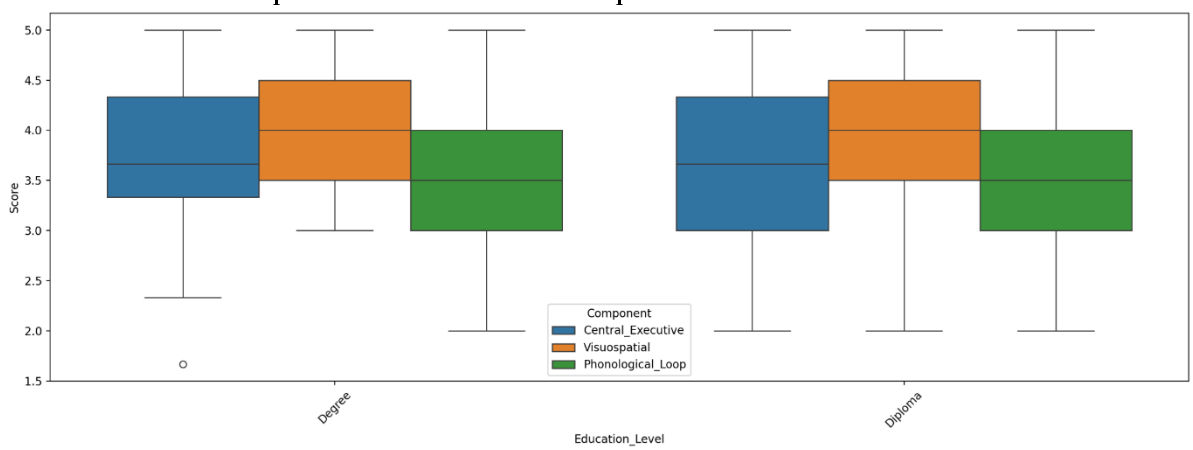

Figure 5: Distribution of Working Memory Component Scores Among Diploma and Degree Students.

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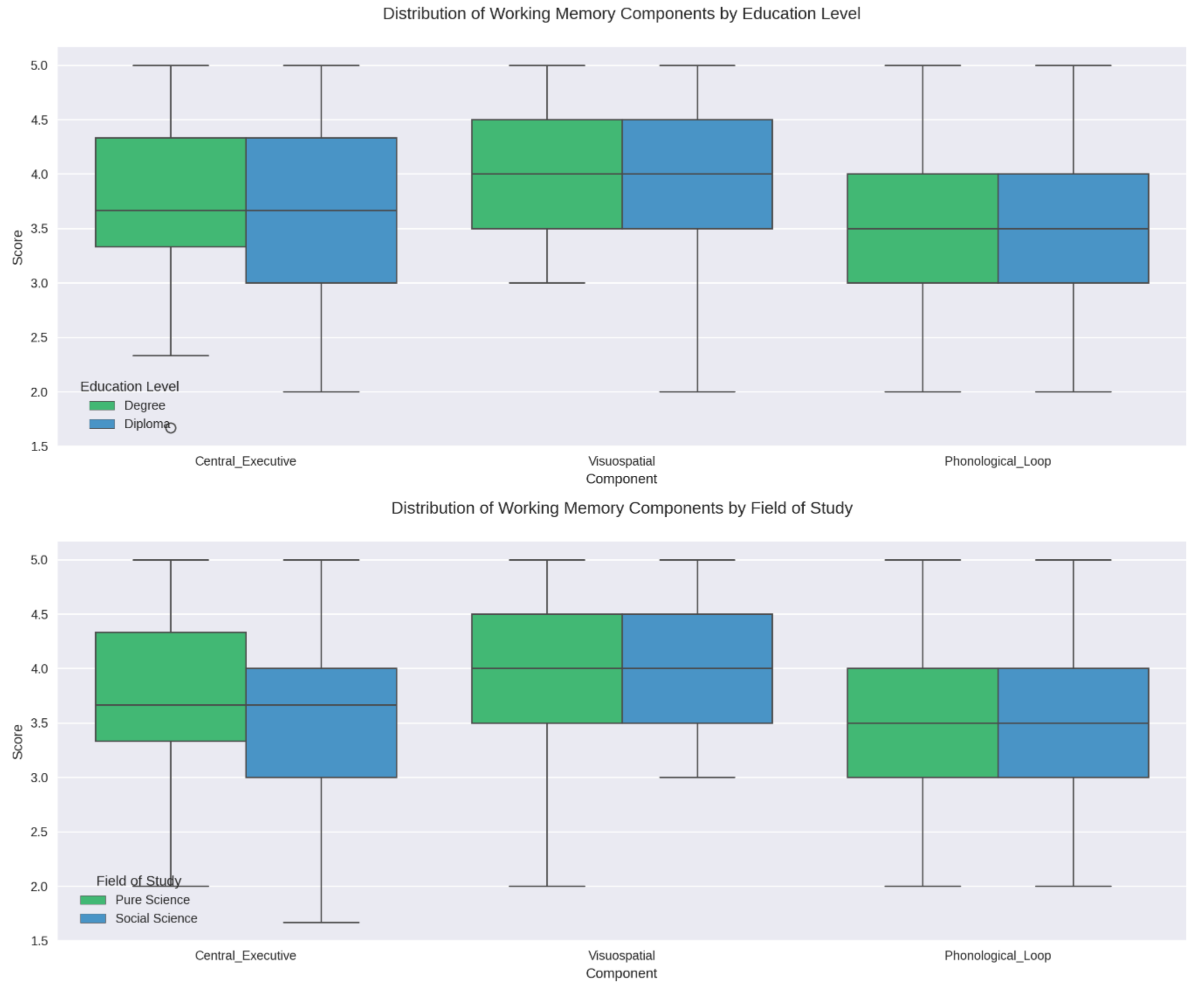

Figure 6: Distribution of Working Memory Component Scores by Education Level and Field of Study Among Diploma and Degree Students.

To further examine whether working memory strategy scores differed across selected demographic factors, Table 6 summarizes the test type, test statistic, and p-value for each demographic factor analyzed. The t-test comparing Working Memory scores between males and females yielded a t-statistic of -0.634 and a p-value of 0.527. Since all p-values exceeded the conventional significance threshold of 0.05, the findings suggest that gender, field of study, and current enrolment level did not have a statistically significant influence on students' self-reported working memory strategy scores.

Table 6: Statistical Analysis of Working Memory Scores Across Demographic Factors

Demographic Factor	Test Type	Test Statistic	P-Value
Gender	T-test	-0.634	0.527
Field of Study	T-test	-0.205	0.838
Current Enrolments	ANOVA	0.462	0.764

Similarly, the t-test comparing Working Memory scores between students in Science & Technology (Pure Science) and Non-Science (Social Science) field yielded a t statistic of -0.205 and a p value of 0.838. This result shows that there is no significant difference between

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the field of study and scores on the Working Memory, which means that the field of study has no influence on the scores of Working Memory. For educators and policy makers, it has implications that students' self-reported working memory strategy scores were rather similar across academic disciplines.

Thus, by comparing the ANOVA test result to the F value, the Working Memory vs Current enrolments levels (Foundation, Diploma, Degree, Master, PhD) showed an F-statistic of 0.462 and a p value of 0.764. The result shows that there is no significant difference among the scores of Working Memory for all the levels of academic enrolment. The present result indicates that the level of academic development is not a significant factor on Working Memory, which is the stability of this cognitive function throughout the academic levels.

The result of this study adds to the educational application of the Baddeley's multicomponent working memory model, which demonstrates how tertiary students report using the central executive, visuospatial sketchpad and phonological loop as learning strategies in familiar educational situations. This learner-reported perspective adds to past research which has largely focused on either working memory capacity or performance in cognitively controlled tasks. The results are generally in line with Forsberg et al. (2021) who propose that the use of working memory can aid the formation of long-term memory. Students who rely more on visual-spatial processing, executive control, and verbal rehearsal processes might have a better ability to organize and retain information for future retrieval. The constant use of the visuospatial sketch pad and central executive functions also corroborates the literature that highlighted the importance of these functions in the applied learning context that requires visual processing and goal maintenance (Mayer & Moreno, 2003; Sweller, 1988).

Importantly, statistically significant differences across gender, education level and field of study show that there is not much variation across students in the pattern of their cognitive engagement. This finding indicates a consistent trend regarding the use of the working memory strategies by the sampled students. Although previous research has shown gender and disciplinary differences in learning style preferences (e.g., Felder & Brent, 2005), this research suggests that these differences are not meaningful in terms of the basic use of the working memory components. The results of this study have implications for inclusive instructional design that are directly relevant. The use of visual and executive strategies shows the importance of the use of visual-aid materials, conceptual mapping and structured task planning in the delivery of curriculum. Although there was verbal rehearsal, it was moderately used, indicating that verbal rehearsal alone may not be enough for learners' cognitive tendencies.

The amount of consistency in the use of working memory strategy is also the evidence platform for the creation of a cognitive-informed instructional model. A model such as this should include multimodal visual-verbal representations, explicit goal setting, and metacognitive scaffolding to support executive functioning skills (e.g., reflection checklists or task breakdowns). These strategies are also in line with the Universal Design for Learning (UDL) approach to teaching which recommends flexibility and response of the teaching approaches to meet the needs of a diverse range of learners. Additionally, the absence of significant group differences supports the applicability of cognitive-informed instructional strategies to the student populations selected for this study, though the effectiveness of these strategies needs to be confirmed through continued research with interventions. The universality also makes cognitive-based tools and frameworks more scalable.

While the findings are encouraging, but not without their limitations. The use of self-reported data may result in response bias, and the cross-sectional design does not allow the analyses to make causal inferences. Longitudinal designs and experimental interventions to reinforce components of working memory using targeted pedagogy may be useful for future research. Overall, the findings of this study confirm the significance of designing teaching methods that are cognitively and instructionally appropriate, as well as create an educational setting that is inclusive and cognitively responsive.

Limitations and Directions for Future Research

This study gave valuable insights, although there are some limitations that should be noted. The study was purposive sampling, which made it difficult to generalize the result of the study to other respondents. Second, the data were self-reported; it is possible that there may be response bias or that students are aware of their cognitive strategies. Third, the cross-sectional design precludes conclusions regarding changes in working memory strategy use over time. Additional research studies could consist of performance-based working memory tasks, larger and more varied samples, as well as longitudinal and experimental designs to explore the impact of the cognitive-informed instructional strategies on learning outcomes.

Conclusion and Recommendations

This study aimed to examine the working memory strategies that were used by tertiary students in various academic levels and academic subjects in Malaysia, supported with the theory of the multicomponent model of working memory by Baddeley. The results showed a common use of the visuospatial sketchpad and central executive functions in all the demographic groups. No statistically significant differences were observed based on gender, education level, or field of study, indicating a largely uniform cognitive engagement profile among tertiary learners.

The results imply that the working memory strategy patterns of students in this sample were generally similar across the sampled demographic groups. This uniformity in cognition highlights the need to develop instruction which taps into the dominant memory processes, specifically, visual encoding and executive functioning. In response, this paper offers preliminary evidence for the relevance of cognitive-informed instructional strategies with the selected student groups. These principles align to the Universal Design for Learning (UDL) framework and can be applied to developing inclusive and scalable learning strategies in all subject areas.

Educators should incorporate diagrams, visual mapping, spatial organization, structured task planning, and goal-setting prompts to enhance students' dominant processing styles of visuospatial and executive. Use of verbal strategies like summarization and mnemonics can complement but not supplant. The following methods should be used universally, across subjects and without assuming any differences between genders or subjects. Future studies are encouraged that will involve longitudinal studies, examine the effect of cognitive-aligned instructional interventions, and explore changes in strategy use as students move from secondary to tertiary education. These directions will make a further contribution to personalizing, cognitively informed and scalable educational practices.

In conclusion, it is important to understand the use of working memory in real academic contexts to develop an inclusive, evidence-based pedagogy. Overall, the findings from this study can help advance the research literature in the field of cognitive-informed education and provide a model for memory-informed instruction. In general, the results demonstrate the potential of visual-spatial and executive oriented teaching strategies for supporting inclusive, mindful learning in higher education.

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Ethics Statement:	This study involved minimal risk and was conducted using an anonymous online self-report questionnaire. The respondents were asked to participate voluntarily, and informed consent was obtained from all of them. There was no personal data collected that would be considered sensitive, and that responses were kept confidential and for research purposes.
Author Contribution Statement:	All authors contributed significantly to the development of this manuscript. Zatul Iffah Abd Latiff contributed to the conceptualization, literature review, instrument preparation, data collection, data analysis, and initial drafting of the manuscript. Aznilinda Zainuddin supervised the study, refined the research design and methodology, reviewed the intellectual content, and coordinated the final manuscript preparation as the corresponding author. Maisarah Noorezam contributed to language refinement, literature review, and critical revision of the manuscript. Sangeeth Ramalingam contributed to the educational and pedagogical framing of the study. Mayamin Yuhaniz contributed to the interpretation of findings and practical implications in applied learning contexts. Didi Susianto contributed to methodological input, literature review, and interdisciplinary interpretation of the findings. Suhazlan Suhaimi contributed to the technology-enhanced learning perspective, cognitive-informed instructional implications, and final manuscript revision. All authors read,

	reviewed, and approved the final version of the manuscript prior to submission.

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