Iranian Educational Psychology Association

Iranian Journal of Learning and Memory

Print ISSN: 2645 - 5455
Online ISSN: 2645 - 5457

Homepage: https://journal.iepa.ir

Effectiveness of Metacognitive Learning Strategies in Working Memory among University Students

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Article Info

Article type:
Research Article

Article history:
Received October 05, 2023
Received in revised form November 22, 2023
Accepted November 24, 2023
Published onlin November 29, 2023

Keywords:
Learning strategies, Metacognitive, Working memory, Students

ABSTRACT

The present study aimed to investigate the effectiveness of metacognitive learning strategies in working memory among university students. This quasi-experimental research adopted a pretest-posttest control group design with follow-up. The statistical population included 268 students at Applied Sciences and Technology University in Tehran in 2022. The convenience sampling method was employed to select 30 students randomly assigned to two groups with 15 participants, i.e., the metacognitive training (experimental) and the control groups. The experimental group received 10 sessions of metacognitive strategy training based on the protocol of Wells (2011). Daneman and Carpenter's (1980) working memory test was conducted to collect data which were then analyzed using the repeated measures analysis of variance in SPSS. According to the findings, the pretest mean scores of the experimental group for storage and processing differed significantly from those of the posttest and follow-up stages ($p<0.01$). Furthermore, in terms of information storage and processing, there was a statistically significant difference between the mean scores of the experimental group and those of the control group ($p<0.05$). Thus, it can be stated that metacognitive learning strategies had a positive effect on improving the working memory of university students. University instructors can enhance students' learning by creating conducive conditions for acquiring metacognitive strategies and fostering an engaging and appropriate educational environment.

Cite this article: Farazandeh, F., Younesi, S. J., & Tarverdizadeh, H. (2023). Effectiveness of Metacognitive Learning Strategies in Working Memory among University Students. *Iranian Journal of Learning and Memory*, *6*(23), 52-59. https://doi.org/10.22034/iepa.2023.170857

Publisher: Iranian Educational Research Association.
DOI: https://doi.org/10.22034/iepa.2023.170857/

Introduction

An essential aspect of the qualitative development of educational centers involves the exploration of strategies to enhance the quality of learning among students. In contemporary education, objectives extend beyond the mere transmission of information, emphasizing the cultivation of individuals who possess the ability to critically assess scientific knowledge rather than rely solely on rote memorization (Darling-Hammond et al., 2020). Many students lack knowledge regarding the memory and learning strategies, as well as the methods of enhancing their effectiveness (Rea et al., 2022). Research evidence supports the notion that human learning is not a static phenomenon. In addition to intelligence and aptitude, other factors (such as memory and learning strategies) play key roles in shaping the learning process (Shahrakipour, 2021; Tyng et al., 2017). Meanwhile, teachers also have pivotal roles in fostering knowledge acquisition and enhancing students' working memory.

Working memory is a cognitive system responsible for the temporary storage and simultaneous processing of information (Chai et al., 2018). Memory is essential to various cognitive processes and tasks, such as comprehension, thinking, calculation, reasoning, and knowledge acquisition (Cherukunnath & Singh, 2022). The working memory capacity is limited and can only accommodate a finite amount of information. Working memory plays a key role as it both stores and manipulates information, thereby facilitating the development of complex skills and knowledge (Rahaei et al.,2022). Working memory has a dual function of storing and processing information despite its limited capacity (Forsberg et al., 2021). According to research findings, working memory is linked to learning strategies and academic achievement (Bergman Nutley & Söderqvist, 2017). Insufficient working memory capacity has been found to be detrimental to learning outcomes (Friso-van den Bos & van de Weijer-Bergsma, 2020; Jones et al., 2020). Numerous educational programs have been developed to strengthen memory, one of which is a series of training metacognitive strategies.

According to Malinovitch et al., (2021), improved working memory performance by practice is closely linked to learning strategies and can bring memory performance to the desired level. Other studies have also demonstrated the significant impact of working memory on students' learning processes which continues throughout adulthood (Abbasi & Tabatabaee, 2022). Additionally, previous studies also suggest that there is a correlation between learning strategies and working memory and that training metacognitive strategies can enhance the working memory capacity (Dirette & Anderson, 2016; Fogel, 2022).

It goes without saying that the classroom conditions and environment (i.e., learning environment) affect the learners' learning and competence (Closs et al., 2022; Villarreal Arroyo et al., 2023). One factor that impacts the classroom environment is the social-psychological atmosphere shaped by cognitive and metacognitive strategies (Rivas et al., 2022). According to psychological theorists, the mastery and proper use of learning strategies are considered fundamental requirements for the learning process. This is influenced by the cognitive and emotional prerequisites associated with each learning task (Stanton et al., 2021). Metacognitive strategies encompass the planning, revising, and modifying of cognitive activities, while cognitive strategies pertain to the methods that learners employ to learn, memorize, recall, and comprehend (Al-Azzemy & Al-Jamal, 2019). The self-directed students who employ metacognitive strategies demonstrate high levels of academic performance and possess a strong belief in their ability to overcome obstacles and challenges (Akamatsu et al., 2019). In fact, metacognition predicts self-efficacy, as Mahbod and Yousefi (2017) demonstrated in their study. Numerous studies have reported that instructing students in metacognitive learning strategies can enhance their academic performance and elevate their academic achievement (Abdelrahman, 2020; Hayat et al., 2020).

Working memory has been a subject of considerable empirical and theoretical interest over the past two decades. Research on working memory has established the significance of identifying and uncovering memory mechanisms and metacognitive strategies perse (Chai et al., 2018; Spencer, 2020). Extensive research supports the crucial and influential role of working memory in various cognitive tasks including learning (Forsberg et al., 2021; Oberauer, 2019; Spencer, 2020). Individuals with greater capacity and efficiency in their working memory tend to exhibit superior academic achievements compared with those with lower working memory capacity and efficiency (Miller & Unsworth, 2018).

The significance of memory in human life and mental functioning becomes evident when the relevant literature is reviewed. This pursuit holds intrinsic values and contributes to the progress of scientific knowledge and appreciation of different mental functions. It is also essential to teach learning strategies since modern psychologists have developed effective self-regulated learning solutions. Despite ongoing research in this field, numerous fundamental inquiries about memory remain unresolved. Focusing on the learner's working memory quality and efficiency can positively affect education, especially in designing and presenting educational materials to promote learning and decision-making. Therefore, this study aimed to analyze whether the deployment of metacognitive strategies can contribute to working memory capacity. Accordingly, the present study investigated the effects of metacognitive learning strategies on working memory among university students. As a result, the current research tried to answer the following questions by emphasizing the problems in the field of active memory and the effect of metacognitive learning strategies:

- Do metacognitive learning strategies affect university students' data storage?
- Do metacognitive learning strategies affect data processing in university students?
- Do metacognitive learning strategies improve working memory in university students?

Method

Design

This quasi-experimental research adopted a pretest-posttest control group design with follow-up.

Participants

The statistical population included 268 students at Applied Sciences and Technology University in Tehran in 2022. The convenience sampling technique was employed to select 30 students who were then assigned to two groups, each consisting of fifteen participants. The groups were assigned as follows: one group received metacognitive training (experimental) whereas the other served as the control group. Their assignment was based on simple randomization. The inclusion criteria encompassed informed consent, age between 19 and 24 years, and non-participation in any other treatments during the research period. The exclusion criteria included chronic physical illnesses, withdrawal from participation, and absence in more than two sessions. The participants' working memory was assessed at baseline (pretest). The experimental group underwent group training in metacognitive learning strategies for ten 90-minute sessions. The control group was not provided with the aforementioned training. The posttest was administered to both groups after the intervention. Similarly, a follow-up was conducted for the two groups after a month.

Instruments

The Working Memory Capacity Test was employed to assess the working memory of the participants (Daneman & Carpenter, 1980). The test consists of 27 statements and can be administered either individually or in a group. The key feature of this test is the concurrent evaluation of the two components of working memory, i.e., processing and storage. The test administration procedure involved instructing participants to attentively listen to a series of different and slightly difficult sentences presented orally. Subsequently, the participants were required to perform two tasks: 1) determining the semantic correctness of each sentence; and 2) recalling the last word of each sentence. The first task assesses the processing aspect whereas the second task evaluates the degree of storage. The test statements are categorized as sections consisting of two to seven sentences. In this test, all sentences hold equal value, with each accurate response being assigned one point, whereas incorrect responses or no responses receive no points. The test is graded by calculating the ratio of correct answers to the total number of questions (i.e., 27), which is then multiplied by 10. Each participant's working memory capacity score was derived by calculating the average sum of their processing and storage scores.

Procedure

The experimental group received a metacognitive strategies training package, which consisted of ten 90-minute sessions delivered by the researcher. A summary of the training sessions is presented in Table 1 (Wells, 2011).

Table 1.
A Summary of Metacognitive Learning Strategies Sessions

Session	Description
1	Becoming acquainted with the group members, establishing relationships between members, explaining the benefits of using metacognitive strategies; and planning skills; activating students' awareness, identifying tools, formulating the problem statement for idea generation and categorization for planning; determining study objectives, and estimating the amount of time required to study.
2	Learning, determining the study rate, and analyzing how to approach learning as a subject; estimating the time required to study and read; remembering to set the reading rate.

Session	Description
3	Attention and concentration training; description of distracting visual, auditory, or other stimuli; explanation that attention is essential for learning, comprehension, and solving the study time problem (when to read).
4	Analysis of how to address the learning problem; conscious control of the individual through self-learning and inner dialogue; emphasis on students' capacity to engage in active learning; and the search for new learning techniques.
5	Semantic expansion strategies; use of mental images and mediators; summarization; semantic expansion strategies for simpler materials, including the use of mediators (mental imagery); establishing a connection between contents (method of loci); mentally visualizing the location of objects (keywords and acronyms); teaching tactics related to more complex material, including note-taking, summarizing, marking, annotating, making analogies, summarizing material in one's own language, and retelling material to others.
6	Ordering or organizing; modifying or changing cognitive strategies; disciplinary strategies with monitoring and evaluation techniques; categorizing and organizing your work while studying to avoid forgetting material.
7	Teaching problem-solving skills; fostering creativity; fostering mental maturity; instilling a sense of self-responsibility; bolstering a student's sense of self-confidence; learning new learning techniques; overcoming obstacles.
8	Planning for editing and revision; reconstructing and locating key points and elaborating on them; supervising students in the finalization of ideas and the improvement of problem-solving techniques; fostering imaginative thinking.
9	Correcting the methods and words used or written; planning, observing order, and problem-solving rules; respecting the thoughts and ideas of peers during discussions; organization of solutions, problem-solving, and practice (brainstorming).
10	Summarizing the sessions, reviewing strategies, and providing additional explanations in order to consolidate the content, analyzing the problems and deficiencies; summarizing; posttest administration

Data Analysis

Data analysis was done in SPSS. The descriptive statistics (means and standard deviations) and repeated measures analysis of variance (ANOVA) were used for data analyze data.

Findings

This study included thirty students with an average age of 20 years. Table 2 displays the means and standard deviations of working memory scores at three measurement stages (i.e., pretest, posttest, and follow-up) for control and metacognitive learning strategy groups.

Table 2.
Mean and Standard Deviation (SD) of Research Variables in Control and Metacognitive Learning Strategy Groups

Dependent variable	Phases	Metacognitive group	Control group
		Mean ± SD	Mean ± SD
Storage	**Pretest**	53.80 ± 7.39	52.40 ± 6.17
	Posttest	61.40 ± 8.06	53.60 ± 4.84
	Follow-up	59.80 ± 6.96	52.60 ± 6.40
Processing	**Pretest**	58.80 ± 5.98	55.60 ± 4.97
	Posttest	66.40 ± 5.32	56.90 ± 5.17
	Follow-up	64.46 ± 5.91	56.50 ± 3.17
Working memory	**Pretest**	56.30 ± 6.36	54.00 ± 4.14
	Posttest	63.90 ± 6.51	55.25 ± 3.37
	Follow-up	62.13 ± 6.27	54.55 ± 3.06

According to Table 2, in the control group, the mean pretest scores did not differ significantly from the posttest and follow-up stages while in the experimental group, working memory scores increased over time from the pretest to the posttest and follow-up stages.

According to the results, the significance level for the box's M test was 0.302, a value that confirms the assumption of homogeneity of the covariance matrix. Levin's test verified the assumption of homogeneity of storage variance and processing in the pretest, posttest, and follow-up phases. Furthermore, the statistical analysis revealed that Mauchly's test of sphericity did not yield a significant result for the variables of storage and processing. This outcome supports the assumption of sphericity.

Table 3.
Repeated Measurement Results for the Effects of Metacognitive Learning Strategies on Working Memory Components

Variable	SS	df	MS	F	p	η^2
Storage	378.02	2	189.01	42.61	0.001	0.61
Processing	346.14	2	173.07	54.56	0.001	0.67

Table 3 reports the results of the single-variable within-subject effects test, which aimed to compare the control and the experimental groups in terms of working memory. The F-values relating to the interaction effects between groups and time (i.e., the differences between groups across measurement steps) were significant for both working memory components (p<0.01). The interaction effects demonstrated a difference in the alterations of working memory scores between the control and the experimental groups throughout the measurement stages.

Table 4.
Bonferroni Post-hoc test for Paired Comparison of the Storage and Processing across Time Series

Scales	Phase A	Phase B	Mean difference (A-B)	SE	p
Storage	Pretest	Posttest	-7.60	0.97	0.001
		Follow-up	-6.00	1.03	0.001
	Posttest	Follow-up	1.60	0.82	0.782
Processing	Pretest	Posttest	-7.60	0.68	0.001
		Follow-up	-5.66	0.85	0.001
	Posttest	Follow-up	1.94	0.85	0.092

Table 4 draws pairwise comparisons to assess the difference in working memory scores between the control and the experimental groups across the treatment stages. The experimental group exhibited a significant difference in mean scores between the pretest, the posttest, and the follow-up stages (p<0.01). The mean scores for storage and processing revealed significant increases in the posttest and follow-up stages compared to the pretest stage (p<0.01). There were no significant differences between the scores of the posttest and follow-up phases indicating the stability of treatment effects over time.

Discussion

The present study investigated the effects of metacognitive learning strategies on the working memory among university students. The findings indicated a significant difference in the mean scores between the pretest, the posttest, and follow-up stages in the group that received metacognitive learning strategies training. The storage and processing mean scores of the experimental group improved with the intervention. Teaching metacognitive strategies had a positive impact on students' working memory. This result is consistent with the findings of previous studies (de Boer et al., 2018; Karami et al., 2016; Zeitlhofer et al., 2023). Consistent with the findings of the present study, Karami et al. (2016) reported that metacognitive strategies for developing reading comprehension and working memory are effective for students with dyslexia. Moreover, Zeitlhofer et al. (2023) reported that cognitive and metacognitive prompting had positive effects on learning outcomes.

The cultivation of positive ideas in students can significantly affect their academic performance, serving as a catalyst for achieving the desired levels of excellence in learning processes and outcomes. The application of metacognitive learning strategies can lead to an increase in positive beliefs as well as students' passion and interest in course materials (de Boer et al., 2018). This, in turn, enhances their participation in educational activities and facilitates the acquisition of meaningful learning experiences. This phenomenon contributes to students' academic achievement and fosters a sense of empowerment in educational endeavors. On the other hand, students' academic achievements and successful learning outcomes improved by adopting metacognitive learning strategies. This is attributed to the facilitation of successful experiences and the provision of essential opportunities for practice (Karami et al., 2016). Therefore, this has a beneficial effect on an individual's self-belief regarding their academic abilities. The aforementioned outcomes enhance working memory and correspondingly contribute to students' academic achievement.

Working memory is a cognitive function that reflects an individual's capacity to attend to stimuli while concurrently engaging in other mental processes. It requires a person to effectively chain pieces of information and perform mental shifting. Working memory is defined as a type of memory that incorporates an executive component responsible for monitoring and evaluating information (Miller & Unsworth, 2018). Instructing on metacognitive strategies, e.g., planning, monitoring, evaluation, and regulation, can enhance students' understanding of when and where to apply specific strategies (Akamatsu et al., 2019). Familiarity with the strategies employed during different information storage and retrieval stages (e.g. organization, mental review, and concentration) can contribute to effective acquisition and recall.

The students who lack metacognitive approaches can be considered learners who lack clear direction or purpose in their learning process. Therefore, it is imperative to provide learners with the necessary skills to plan their learning activities effectively. This includes teaching them how to estimate time requirements, organize materials, and follow the necessary procedures for completing an activity successfully. Metacognitive knowledge is beneficial for students as it enables them to gain a perception of their cognitive abilities, the various stages and types of memory, as well as the capacity of memory (Karami et al., 2016). Additionally, it allows students to acquire information pertaining to the nature of a given task, its type, and its quality (Rivas et al., 2022).

Memory inefficiency results primarily from insufficient attention at the outset of a task. If the initial content selection is not done carefully, it can also disrupt its recall. To ensure accurate information processing, students should possess self-awareness of their abilities in their respective fields. Metacognitive strategies are executive skills that play a key role in predicting the success of learning activities. These strategies aid in connecting new information with existing knowledge, facilitate the selection of intellectual strategies, and enable learners to engage in designing, reviewing, and evaluating their thinking (Shahrakipour, 2021). Ultimately, metacognitive strategies empower learners to plan, control, and assess their learning effectively. Implementing and utilizing learning strategies can enhance students' academic performance by mitigating inefficiency, apathy, and fatigue.

Conclusions

Metacognitive learning strategies had a positive effect on improving the working memory of university students. The research findings highlight the importance of incorporating metacognitive strategies into educational practices to enhance student's self-awareness of their learning needs. Metacognitive learning strategies and the development of inner self can help students cultivate a more positive attitude and increase interest in their educational pursuits. University professors and trainers in the education system can enhance students' learning by creating conducive conditions for acquiring metacognitive strategies and fostering an engaging and appropriate educational environment.

The research findings can potentially assist education stakeholders in improving the learning experience for learners. One practical implication of this research is the importance of training professors and instructors on the impact of metacognitive strategies and learners' working memory on the educational, social, and emotional outcomes of the education process in universities and schools. This research faced certain limitations. For instance, the participants were only associate and bachelor students at the University of Applied Sciences and Technology. It is important to exercise caution while generalizing the findings to students of other degrees and institutions.

Conflicts of Interest

No conflicts of interest declared.

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