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Enhancing Information Encoding and Its Effect on Working Memory in Students with Learning Disabilities

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Abstract

The focus of this study was to examine the improvement of information encoding and its subsequent impact on working memory in students with learning disabilities. These students often face challenges with ineffective learning strategies, which hinder their academic performance and foster a sense of failure in meeting expectations. The study included 20 fourth-grade students, ages 8 to 11 years, male and female. A two-group experimental design was used, which included pre-, post-, and follow-up assessments of key variables. The research instruments included the Stanford-Binet Intelligence Scale, the Information Encoding Level Scale, the Quick Neurological Screening Test, and a tailored program aimed at enhancing information encoding abilities. Statistical analyses were performed using standard means, deviations, paired t-tests, and independent t-tests with the help of statistical software.

Keywords: Working Memory, Information Encoding, Learning Disabilities, Cognitive Development

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Introduction

Theoretical frameworks suggest that individuals with learning difficulties often struggle with encoding information and establishing meaningful connections between knowledge elements. These students tend to select strategies haphazardly due to underdeveloped skills in organizing and encoding information effectively. Encoding refers to the process of converting information or stimuli into a format that can be stored in memory. Research in psychology indicates that how information is symbolized significantly influences the ability to recall it and assign meaning to it. For students with learning difficulties, the lack of cognitive representation and the inefficiency of their cognitive structures lead to challenges in understanding and retaining information.

Studies by Swanson *et al.* [1] emphasize that memory processes, such as encoding, processing, and retrieval, are essential skills that shape learning abilities. According to Swanson and Ashbaker [2], there is evidence linking working memory problems to poor task performance, suggesting that difficulties with memory processing predict an individual's overall ability to complete tasks. Information first enters the sensory register, and if it captures attention, it is then transferred to short-term or working memory for further processing [3].

The information encoding process unfolds in three stages: first, the encoding stage, where the cognitive code is established [4]; second, the storage and processing stage; and third, the retrieval stage, where the stored information is accessed [5]. Information is stored in different formats depending on the store, often converted into shorthand codes [6]. Greeno Hicks (cited in Suleiman [4]; Anwar [5]) identified six types of encoding: visual, auditory, operative, verbal, semantic, and dynamic. Additional forms of encoding, such as taste, smell, and emotional coding, also play a role. Leahey and Harris [7] argue that enhancing the encoding process is one of the most effective strategies to improve memory and facilitate better retrieval of information.

Research Problem

Cognitive deficiencies in students with learning difficulties often manifest in weak working memory performance, as their executive functions are impaired, impacting their ability to process and retain information. One of the significant challenges is encoding difficulties, which result in low overall memory capacity. These students struggle to form connections between individual knowledge units and pieces of information, leading to frequent forgetting. Therefore, the central question of this research is: What is the effect of training on improving encoding levels (phonemic encoding, semantic encoding, and semantic-phonemic encoding) in enhancing the working memory capacity of students with learning difficulties?

Research Objectives

This study aims to achieve the following objectives:
1. To assess how encoding levels can be improved through the strategies and techniques utilized in the training sessions.
2. To examine the effect of the training program on improving the working memory capacity of students with learning difficulties, using pre-, post-, and follow-up tests.
3. To identify the most effective skills and methods that alter recall habits and influence students' academic achievement.

Terminology of the Research

- Encoding: The process of transforming perceived information and stimuli from their original form into specific symbols or codes, which are cognitively represented and assigned meaning. This process facilitates organizing, preparing, processing, storing, and eventually retrieving the information.
- Working memory: A system responsible for temporarily storing and processing information received through daily perceptual activities. It has a limited capacity and is central to cognitive tasks [8, 9].
- Training program: Aimed at improving the levels of information encoding for individuals with learning difficulties. The program includes training on activities and methods that enhance three encoding levels: Phonemic code level, Semantic code level, and Semantic-phonemic code level. The program utilizes techniques like associating words with their meanings, using keywords to represent phrases and other methods to optimize encoding and storage for long-term recall [10, 11].

Theoretical Framework and Previous Studies

Encoding is the process of converting information into a set of images or symbols (codes) with specific meanings. Proper encoding is crucial for retaining information over time and protecting it from distortion. Re-encoding—transforming information with new codes—helps further solidify memory. Cognitive strategies such as self-designation, mental mapping, summarization, and the use of keywords are essential for effective encoding [12]. After sensory stimuli are recorded, they are processed and represented more complexly. Psychologists suggest that encoding significantly impacts the memory system, and improper encoding can lead to weakened or distorted memory over time [13].

Information can be encoded using various formats: acoustic, visual, haptic, and semantic codes [14]. Research by Hossam [15] highlighted the effectiveness of spatial and reclamation strategies in helping students with developmental learning difficulties. Furthermore, Adel Hussein (2001) examined how different strategies, such as organization, rehearsal, and memory aids, affected students' recall of numbers, letters, abstract words, and syllables in both immediate and delayed recall tasks.

Information Encoding Levels

Contemporary studies indicate that students with learning difficulties face challenges with memory, especially when using strategies that are typically effective for their peers, such as simple repetition techniques. Reddy and Bellezza [16] compared different encoding strategies in recall tasks. One group was trained to focus on the meanings of words, while another group used visual imagery to form stories. The results revealed statistically significant differences in word recall, favoring the group trained with more advanced repetition strategies. Additionally, organizational strategies, like categorizing information (e.g., remembering grocery items by categorizing them into groups), were shown to be beneficial.

Boltwood [17] proposed various encoding strategies used by university students. In his study, 38% of students employed the first-letter strategy, 31% used organizational methods, and 22% utilized storytelling techniques. Furthermore, mnemonics, such as multiplication tables, were also identified as effective strategies for encoding information. These strategies suggest that employing a variety of encoding methods can significantly enhance memory recall.

Working Memory

Working memory (WM) is a limited-capacity cognitive system that enables temporary storage and manipulation of information. It is essential for tasks such as comprehension, learning, and reasoning, consisting of three main components: the phonological loop, visual-spatial sketchpad, and central executive system. The phonological loop stores speech-based information, which decays over time. The visual-spatial sketchpad holds visual and spatial information for short durations [18].

Working memory relates incoming information to existing knowledge stored in long-term memory. Modulation techniques, such as chunking, clustering, and rehearsal, help to retain and manipulate this information. However, information may be lost from working memory due to interference, displacement, or decay. Baddeley and Hitch [19] highlighted that working memory temporarily holds and processes information during cognitive tasks. Once the information is received, it is converted into a code that holds multiple meanings, making it easier to recall.

Ramadan and Magd [20] examined various coding strategies and found statistically significant differences in recall task performance, favoring students with stronger verbal coding skills. Although the capacity of working memory is small compared to long-term memory, it plays a crucial role in daily cognitive tasks [21]. Walid [22] explored a model illustrating the relationships between cognitive task strategies and memory. Danielsson *et al.* [3] argued that working memory demands could simulate learning disabilities, particularly in recognition tasks. The working memory model (**Figure 1**) further elaborates on these processes.

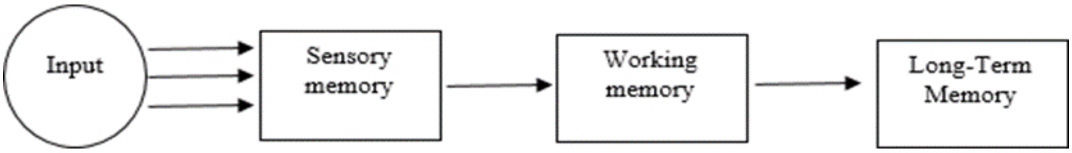

Figure 1. The working memory model [19]

Research Hypotheses

The study aims to test the following hypotheses:

There will be significant differences in the mean scores of the experimental group between pre- and post-assessments on the information encoding scale, with post-test scores being higher.

The experimental group will show statistically significant differences compared to the control group in the post-test scores of the information encoding scale.

There will be significant differences in the working memory scores of students with learning difficulties between the pre- and post-tests, with post-test scores being superior.

The experimental group will demonstrate statistically significant improvements in working memory scores from pre- to post-test compared to their initial performance.

The experimental group will show significant improvements between post- and follow-up tests on the information encoding scale.

No significant differences will be observed between the experimental group’s post- and follow-up test results on the working memory scale.

A positive correlation will exist between scores on the information encoding scale and the working memory scale after the program intervention for students with learning disabilities.

Methodology

Data Collection and Sample Selection

An experimental research design was used for this study. The sample included 40 students with learning difficulties, aged between 8 and 11 years, enrolled in the fourth grade of primary school in Northern Borders, Saudi Arabia. These students were divided into two groups:

The experimental group (20 students), underwent the specialized training program.

The control group (20 students), did not receive the program intervention.

This design aims to investigate the effects of the training program on improving the students’ information encoding abilities and working memory. Pre-, post-, and follow-up testing were conducted to evaluate the program’s effectiveness over time.

Table 1. Characteristics of the experimental and control group

Variables	Group	N	Medium	Standard deviation	Mean rank	Sum of ranks	U value	Z value	Sig.
	Test	20	8.600	1.578	16.43	350.0			

Age	Control	20	9.375	1.642	18.33	385.0	164.0	0.49	No
Intelligence	Test	20	94.55	7.315	19.65	327.5	179.5	0.77	No
	Control	20	94.40	5.571	19.45	394.5			
Learning disabilities	Test	20	51.32	1.484	21.24	377.0	133.7	0.62	No
	Control	20	54.71	1.633	21.56	376-0			
Levels of information encoding	Test	20	44.32	3.45	20.79	326.0	156.0	0.52	No
	Control	20	45.48	2.47	18.21	338.0			
Working memory	Test	20	44.36	4.24	17.30	353.0	143.0	0.70	No
	Control	20	44.45	4.26	18.24	347.0			

Table 1 indicates that there were no significant differences in the average scores between the experimental and control groups regarding age, intelligence, learning difficulties, information encoding levels, and working memory. This suggests that both groups were homogenous at the start of the study.

Study Tools

The study employed several tools to assess the cognitive abilities and learning difficulties of the participants:

1. Stanford-Binet Intelligence Scale, 5th Edition

The Stanford-Binet Scale is a widely recognized test for assessing cognitive abilities and intelligence in individuals from ages 2 to 85. It is commonly used to diagnose various cognitive conditions, including mental retardation, learning disabilities, and autism, and it also helps to identify individuals with exceptional cognitive talents.

2. Questionnaire for Assessing Levels of Information Encoding (Developed by the Researcher)

This questionnaire was specifically designed to measure how students with learning difficulties encode information at three distinct levels:

- Phonemic code level
- Semantic code level
- Phonemic and semantic code level
- The tool identifies the encoding strategies used by students based on either the phonemic or semantic properties of the information or a combination of both.

The validity of this encoding scale was confirmed through multiple psychometric evaluations. The content validity was established by having the scale reviewed by 10 experts in educational and psychological fields, who agreed that the items and response alternatives met the intended purpose. The validity coefficients for expert agreement ranged from 0.80 to 1.00, indicating strong validity, and these results were verified using the Lawshe method.

Additionally, global reliability was assessed through an exploratory factor analysis, using a sample of 100 students. The analysis confirmed the presence of three main factors that explained the data, with significant results in the Kaiser test. The factors were then rotated using the Varimax method, and **Tables 2-4** detail the factor loadings after the rotation.

Table 2. The first factor saturation of Phonemic encoding

No	Saturation	Sentence
1	The student prefers memorizing the vocabulary alike in the rhyme.	0.76
2	The student is fluent in crafting a musical melody for memorizing vocabulary and texts.	0.74
3	The student converts the text vocabulary into syllables.	0.73
4	The student memorizes songs, although he does not understand their meanings.	0.72
5	The student prefers to help him convert the texts into rhymed sentences.	0.67
6	The student remembers the rhymed songs and texts easily.	0.65
7	The student easily memorizes songs.	0.62
	Variance ratio	18.63%
	Eigen value	3.43

Table 3. The second factor saturation of semantic coding

No	Saturation	Sentence

8	The student is interested in looking for the meanings of the vocabulary to understand it before studying.	0.74
9	The student finds it difficult to memorize incomprehensible songs.	0.71
10	The student is interested in researching the origins and meanings of vocabulary.	0.70
11	The student memorizes the texts that have a clear meaning for him easily.	0.69
12	The student is constantly asked about the meanings of vocabulary and words.	0.64
13	The student classifies words and vocabulary according to their meanings.	0.62
14	The student searches for the relationship between vocabulary and words according to their meanings.	0.59
	Variance ratio	15.43%
	Eigen value	3.15

Table 4. The Third Factor Saturation of phonemic and semantic encoding

No	Saturation	Sentence
15	The student associates the same rhyme words and vocabulary with their meaning according to their previous cognitive experience.	0.70
16	The student uses rhymed keywords to signify the meaning of each phrase.	0.68
17	The student mimics the meanings of words and represents them with their peers in rhymed phrases.	0.67
18	The student associates the learned material with new connotations that have the same rhyme.	0.67
19	The student classifies the information in lists according to its meaning while associating it with a familiar tone.	0.61
20	The student synthesizes a meaningful story that connects the rhymed words to be learned.	0.52
	Variance ratio	11.13%
	Eigen value	2.84

Statistical Analysis of Saturation Values

In **Tables 2-4**, it can be seen that all saturation values are statistically significant, with each value surpassing the 0.30 threshold in the Guildford test. Additionally, the researcher calculated the stability coefficients of the information encoding scale dimensions using Cronbach's alpha method on a sample of 100 children. The results revealed that the stability coefficients for phonemic encoding (0.77), semantic encoding (0.75), and combined phonemic and semantic encoding (0.76), along with the overall score (0.77), showed adequate reliability. Furthermore, when the stability coefficients were recalculated using a two-week re-application method with the same sample, the findings indicated very high stability: phonemic encoding (0.94), semantic encoding (0.96), phonemic and semantic encoding (0.97), and the total score (0.95), confirming the robustness of the scale.

Arabized Quick Neurological Screening Test

This tool was used to identify children with learning difficulties using brief individual tests that lasted approximately 20 minutes. It offers a swift method for monitoring neurological observations related to learning abilities. The test comprises tasks adapted from a children's neurological exam. The test showed a high validity coefficient of 0.889, indicating strong validity, while the stability coefficient of 0.944 further supported the test's consistency.

Working Memory Tasks Scale (Storage and Processing)

The scale designed by Al-Zoghbi [23] is aimed at evaluating the storage and processing capacity of working memory components, such as the articulatory loop and visual-spatial stimuli. It also assesses the participant's ability to handle dual tasks and allocate cognitive resources between verbal and visual-spatial components. The psychometric properties of the scale were validated through correlation with the Stanford-Binet intelligence test in a sample of 80 students, yielding the following high validity coefficients: articulatory loop (0.96), visual-spatial sketchpad (0.97), central executive (0.95), and the overall score (0.96). Additionally, internal consistency was verified with significant correlation coefficients: articulatory loop (0.89), visual-spatial sketchpad (0.91), central executive (0.93), and the overall score (0.90). Stability coefficients were calculated using Cronbach's alpha on the same sample, with results indicating strong reliability: articulatory loop (0.81), visual-spatial sketchpad (0.78), central executive (0.76), and the overall score (0.79). Re-assessment of stability after a two-week interval further confirmed the scale's reliability with coefficients of articulatory loop (0.93), visual-spatial sketchpad (0.95), central executive (0.94), and the overall score (0.93), reinforcing the scale's stability.

Program Description

The program developed for this research consists of 30 sessions, scheduled three times a week over two months, to enhance students' information encoding abilities at three levels: phonemic encoding, semantic encoding, and combined phonemic and semantic encoding.

• Program approach: The researcher incorporated a variety of methods to cater to the unique needs of students with learning difficulties, ensuring that each session maintained students' attention through engaging and exciting elements. The program used diverse techniques, avoiding reliance on any single method. Materials, worksheets, and exercises were designed to progressively build the students' encoding skills. Each session was evaluated to ensure its effectiveness, and the final program was reviewed by experts in the field.

Table 5 presents the distribution of the teaching plan for the program.

Table 5. Breakdown of the teaching plan for the program

Lesson	Topic	Number of sessions
Phonemic encoding		
First	- Memorizing vocabulary with similar rhymes. - Creating paragraphs from texts using familiar melodies. - Breaking down vocabulary into syllables.	4
Second	- Memorizing songs and rhymed texts. - Repeating rhyming words until memorized. - Analyzing words into syllables.	4
Third	- Identifying words with similar syllables. - Singing songs using a familiar melody.	2
Semantic encoding		
Fourth	- Searching for multiple meanings of a word before memorizing. - Converting words into synonyms. - Categorizing words based on their meanings. - Investigating relationships between vocabulary in the lesson.	3
Fifth	- Creating a vocabulary grid for key terms. - Drawing meaningful images to aid memorization of written texts. - Summarizing lessons into meaningful phrases. - Extracting main ideas from each paragraph.	3
Sixth	- Understanding new vocabulary meanings within the lesson. - Writing a fictional lesson after reading multiple times. - Identifying the main idea of a song. - Explaining a song after comprehension.	3
Seventh	- Connecting words with synonyms to form useful sentences. - Determining the correct meanings of spoken words. - Engaging in peer dialogues about the meanings and synonyms of lesson content. - Creating meaningful phrases from selected words. - Designing a word map for synonyms in the lesson.	3
Phonemic and semantic encoding		
Eighth	- Searching for meanings of similar rhyming vocabulary. - Using keywords that rhyme and are meaningful. - Actively representing word meanings with peers through rhymed phrases. - Connecting learned vocabulary meanings with similar rhyming words.	4
Ninth	- Categorizing vocabulary into lists based on meaning and linking them to a familiar tone. - Telling a story with meaningful musical expression.	2
Tenth	- Identifying opposites and meanings for each word.	2
Total		30

Program Strategies Applied

The program utilized a range of teaching strategies designed to enhance learning outcomes. Group work, or cooperative learning, was a central strategy, where students collaborated, exchanged ideas, and developed teamwork skills. Immediate correction of errors was also an important element; the teacher promptly addressed mistakes made by students, providing the correct responses to guide their learning. To encourage positive behavior and reinforce learning, the program incorporated various forms of reinforcement, such as physical, verbal, symbolic, and active rewards, offered immediately after correct responses. Additionally, homework was assigned to help students practice and apply what they learned in class, encouraging continued learning outside the school environment.

Study Application Procedures
The researcher followed several steps to finalize the research tools and ensure proper implementation. First, the tools were developed and tested to ensure their relevance and suitability for the research sample. Primary schools were chosen as the locations for program implementation, and the Quick Neurological Screening Test, as well as the Stanford Binet scale, were used to assess the students' cognitive abilities. The researcher ensured that both the experimental and control groups were comparable in terms of age and intelligence before the program began. Schools from Rafha Governorate were selected for the study, and students were divided into two groups: an experimental group that participated in the program and a control group that did not. Pre-tests were administered to both groups before the program's implementation. Following the program, a post-test was conducted to assess students' information encoding and working memory. A follow-up test was also administered one month after the program to track any lasting effects. Finally, statistical analyses were carried out to examine the study's hypotheses.

Study Design
The research design was semi-experimental, with two key variables: an independent variable (the program) and dependent variables (information encoding and working memory). The study involved a pre-test, post-test, and follow-up test, with both control and experimental groups being assessed at various stages. The results were analyzed using an equivalent group method to determine the impact of the independent variable on the dependent variables. The study employed various statistical techniques, such as calculating correlations, means, medians, and standard deviations, as well as conducting t-tests and Wilcoxon's tests to identify significant differences between the experimental and control groups.

Results

Hypothesis 1
The first hypothesis posited that there are statistically significant differences between the average ranks of students with learning difficulties in the pre- and post-tests of the information encoding scale for students with learning difficulties, in favor of the post-test. To test this hypothesis, the researcher used the Wilcoxon test to compare the differences in the average rank scores between the pre- and post-test results on the information encoding scale.

Table 6. Differences between the average ranks of students' scores in the pre- and post-tests of the program on the scale of information encoding for students with learning difficulties

Variables	Measurement	Pre-Post	No	Mean rank	Sum of rank	Z	Significance level	Significance direction
Phonemic encoding	Negative ranks	1			209	3.893	Sig. at 0.01	In the direction of Post
	Positive ranks	19						
	Ties	1						
Semantic encoding	Negative ranks	-			210	3.930	Sig. at 0.01	In the direction of Post
	Positive ranks	20						
	Ties	-						
Phonemic and semantic encoding	Negative ranks	-			210	3.926	Sig. at 0.01	In the direction of Post
	Positive ranks	20						
	Ties	-						
Total score	Negative ranks	-			210	3.924	Sig. at 0.01	In the direction of Post
	Positive ranks	20						
	Ties	-						

Z = 2.58 at the level of 0.01
Z = 1.96 at the level of 0.01

Interpretation
Table 6 demonstrates that there are statistically significant differences in the average scores of students with learning difficulties in the pre- and post-tests for the program on the information encoding scale. The differences favor the post-test, indicating that the program had a positive impact on the students' information encoding abilities across all levels: phonemic encoding, semantic encoding, phonemic and semantic encoding, and the overall total score.

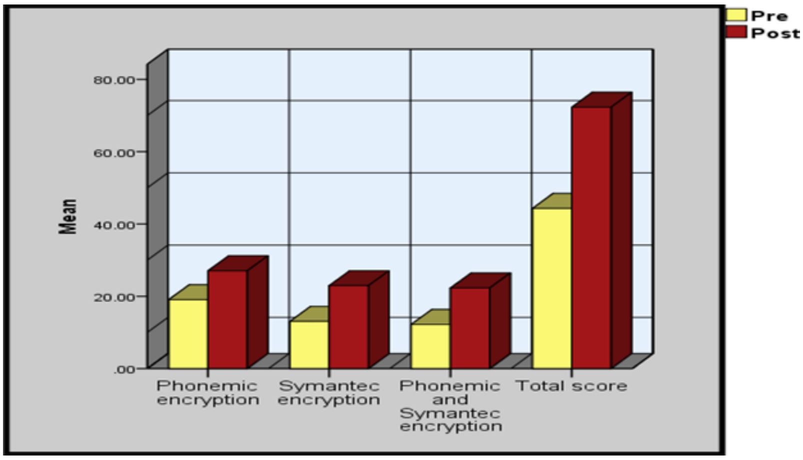

Figure 2. Differences between the average ranks of students' degrees with learning difficulties in the pre- and post-tests for the program on the scale of information encoding for students with learning difficulties

Improvement Rate

The study also examined the improvement rate between the pre- and post-test scores for students with learning difficulties in the program. **Table 7** displays the improvement percentages across various levels of information encoding.

Table 7. The percentage of improvement between the average grade levels of students with learning difficulties in the pre- and post-tests for the program on the scale of information encoding

Variables	Pre-test average	Post-test average	Improvement percentage
Phonemic encoding	19.05	27.05	29.57%
Semantic encoding	13.05	22.95	43.13%
Phonemic and semantic Encoding	12.2	22.3	45.29%
Total score	44.3	72.3	38.72%

Hypothesis 2

The second hypothesis proposed that there are statistically significant differences between the mean scores of the experimental and control groups in the post-test of the encoding information scale, in favor of the experimental group. To test this hypothesis, the researcher used the t-test to compare the mean scores between the experimental and control groups in the post-test of the encoding information scale for students with learning difficulties.

Table 8. Differences between the mean scores of students of the experimental and control groups in the post-test of the encoding information scale for students with learning difficulties

Variables	Experimental group (N1 = 20)	Control group (N2 = 20)	T	Significance level	Significance direction
Phonemic encoding	M1 = 27.05, S.D1 = 3.59	M2 = 18.15, S.D2 = 2.62	8.953	Sig. at 0.01	In the direction of the experimental group
Semantic encoding	M1 = 22.95, S.D1 = 2.25	M2 = 12.95, S.D2 = 2.37	13.652	Sig. at 0.01	In the direction of the experimental group
Phonemic and semantic encoding	M1 = 22.3, S.D1 = 2.45	M2 = 12.2, S.D2 = 1.79	14.86	Sig. at 0.01	In the direction of the experimental group
Total score	M1 = 72.3, S.D1 = 4.94	M2 = 43.3, S.D2 = 4.2	19.982	Sig. at 0.01	In the direction of the experimental group

Interpretation

Table 8 demonstrates that there are statistically significant differences at the 0.01 significance level between the mean scores of the experimental and control groups in the post-test on the information encoding scale. The differences favor the experimental group, suggesting that the program had a significant positive effect on the encoding abilities of the students with learning difficulties (**Figure 3**).

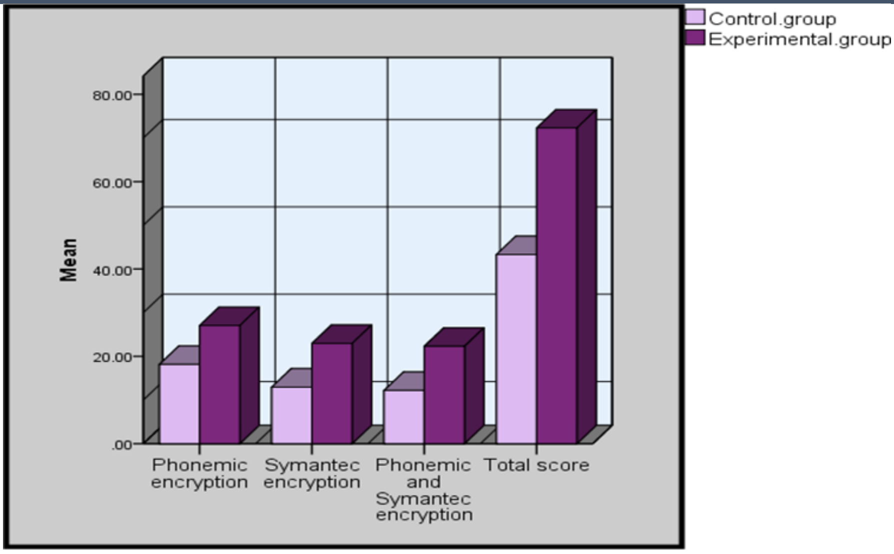

Figure 3. Differences between the mean scores of students in the experimental and control groups in the post-test of the encoding information scale in students with learning difficulties.

Hypothesis 3

The third hypothesis proposed that there are statistically significant differences between the average scores of students with learning difficulties in the pre- and post-test of the program on the working memory scale for students with learning difficulties, specifically in the post-test.

To test this hypothesis, the researcher used the Wilcoxon test to compare the differences between the average scores of students with learning difficulties in the pre- and post-tests of the program on the working memory scale.

Table 9. Differences between the average grade levels of students with learning difficulties in the pre- and post-test of the program on the working memory scale for students with learning difficulties

Variables	Measurement	Pre-Post	No	Mean rank	Sum of rank	Z	Significance level	Significance direction
Articulatory loop	Negative ranks	20	-10.5	-210	3.942	Sig. at 0.01	In the direction of Post	
	Positive ranks	20						
Visual-spatial sketchpad	Negative ranks	20	-10.5	-210	3.946	Sig. at 0.01	In the direction of Post	
	Positive ranks	20						
Central Executive	Negative Ranks	20	-10.5	-210	3.948	Sig. at 0.01	In the direction of Post	
	Positive Ranks	20						
Total score	Negative Ranks	20	-10.5	-210	3.930	Sig. at 0.01	In the direction of Post	

Interpretation

Table 9 shows that there are statistically significant differences at the 0.01 significance level between the average grades of students with learning difficulties in the pre- and post-tests for the program on the working memory scale. These differences are all in favor of the post-test scores, indicating that the program had a significant positive impact on the working memory abilities of students with learning difficulties (Figure 4).

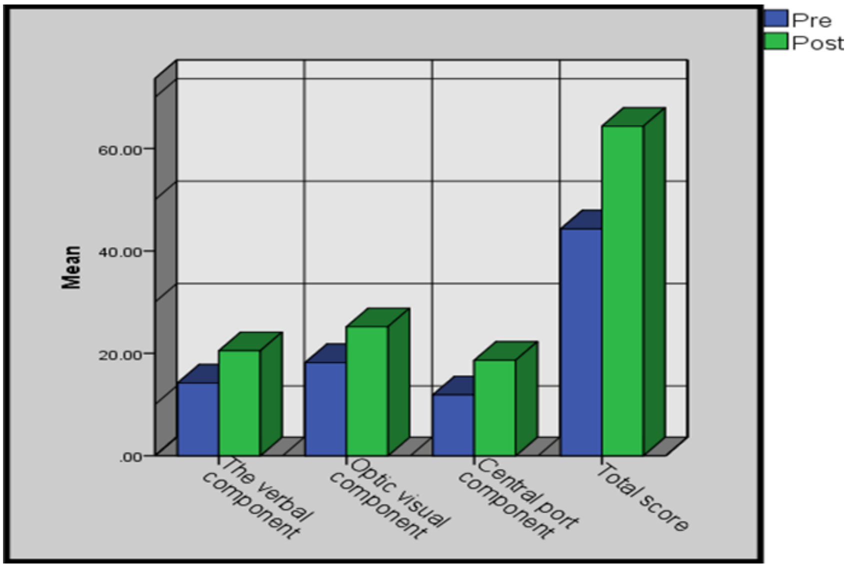

Figure 4. Differences between the average ranks of students' degrees with learning difficulties in the pre- and post-test of the program on the working memory scale for students with learning difficulties

Improvement Rate in Working Memory

The improvement rate was calculated between the average scores of students with learning difficulties in the pre- and post-tests for the program on the working memory scale. The results are shown in Table 10, which outlines the improvement percentage for each variable.

Table 10. The percentage of improvement between the average grade levels of students with learning difficulties in the pre- and post-tests of the program on the working memory scale for students with learning difficulties

Variables	Pre-test average	Post-test average	Improvement percentage
Articulatory loop	14.20	20.50	30.73%
Visual-spatial sketchpad	18.20	25.20	27.7%
Central Executive	11.90	18.65	36.19%
Total score	44.30	64.35	31.15%

These figures indicate an overall improvement across all working memory variables, with the highest improvement observed in the Central Executive component (36.19%).

Hypothesis 4

Hypothesis 4 postulated that there are statistically significant differences between the mean scores of students in the experimental and control groups in the post-test of the working memory scale, favoring the experimental group.

To test this hypothesis, the researcher used the t-test to compare the mean scores of students in both groups in the post-test of the working memory scale.

Table 11. Differences between the mean scores of students in the experimental and control groups in the post-test of the working memory scale for students with learning difficulties

Variables	Experimental group	Control group	T	Significance level	Significance direction
Articulatory loop	M1= 20.5, S.D1= 1.39	M2 = 14.45, S.D2 = 2.06	10.859	Sig. at 0.01	In the direction of the experimental group
Visual-spatial sketchpad	M1= 25.2, S.D1= 1.36	M2 = 18.75, S.D2 = 1.97	12.046	Sig. at 0.01	In the direction of the experimental group
Central Executive	M1= 18.65, S.D1= 1.66	M2 = 12.8, S.D2 = 1.82	10.6	Sig. at 0.01	In the direction of the experimental group
Total score	M1= 64.35, S.D1= 2.75	M2 = 46, S.D2 = 4.06	16.7	Sig. at 0.01	In the direction of the experimental group

Interpretation

Table 11 shows statistically significant differences at the 0.01 significance level between the mean scores of students in the experimental and control groups in favor of the experimental group. The experimental group performed better in all areas of the working memory scale.

Hypothesis 5

Hypothesis 5 proposed that there are statistically significant differences between the mean scores of students with learning difficulties in the post-test and follow-up tests of the program on the information encoding scale for students with learning difficulties, specifically in the direction of the follow-up test.

To test this hypothesis, the researcher used the Wilcoxon test to analyze differences between the average grade levels of students in the post-test and follow-up tests of the program.

Table 12. Differences between the average ranks of students' scores in the post- and follow-up tests of the program on the information encoding scale for students with learning difficulties

Variables	Measurement	Pr-Post	No	Mean rank	Sum of rank	Z	Significance level	Significance direction
Phonemic encoding	Negative ranks	3	4.5	13.5	1.15	Sig. No		
	Positive ranks	6	5.25	31.5				
Semantic encoding	Negative ranks	5	-3	-15	2.236	Sig. at 0.05	In the direction of Follow	
	Positive ranks	15						
Phonemic and semantic encoding	Negative ranks	3	-2	-6	1.633	Sig. No	In the direction of Follow	
Total score	Negative ranks	2	6	7.75	12.93	2.696	Sig. at 0.01	In the direction of Follow

Interpretation

Table 12 indicates that there are statistically significant differences at the 0.01 significance level between the average grades of students in the post- and follow-up tests for the total score on the information encoding scale in favor of the follow-up test. Additionally, there are significant differences at the 0.05 level for semantic encoding. However, there are no statistically significant differences in phonemic encoding and phonemic and semantic encoding between the post-test and follow-up tests.

Hypothesis 6

Hypothesis 6 proposed that there are statistically significant differences between the mean scores of students with learning difficulties in the two post- and follow-up tests of the program on the working memory scale, specifically for the follow-up test.

To test this hypothesis, the researcher used the Wilcoxon test to analyze the differences between the average grade scores of students with learning difficulties in the two post and follow-up tests.

Table 13. Differences between the average ranks of students' degrees with learning difficulties in the two post- and follow-up tests of the program on the working memory scale for students with learning difficulties

Variables	Measurement	Pre-Post	No	Mean rank	Sum of rank	Z	Significance level	Significance direction
Articulatory loop	Negative ranks	5	3.9	19.5	0.654	No Sig.		
	Positive ranks	2	4.25	8.5				
Visual-spatial sketchpad	Negative ranks	4	4	16	0.378	No Sig.		
	Positive ranks	3	4	12				
Central Executive	Negative ranks	5	6	30	0.277	No Sig.		
	Positive ranks	5	5	25				
Total score	Negative ranks	8	7.69	61.5	0.578	No Sig.		
	Positive ranks	6	7.25	43.5				

Interpretation

Table 13 indicates that there are no statistically significant differences between the mean scores of students in the post- and follow-up tests for the working memory scale. This suggests that the improvements observed in the post-test may not have been sustained in the follow-up measurement.

Hypothesis 7

Hypothesis 7 posited that there is a statistically significant positive correlation between the degrees of students with learning difficulties on the encoding information scale and their degrees on the working memory scale after the program.

To test this hypothesis, the researcher used the Spearman equation to measure the relationship between the student's scores on the encoding information scale and their scores on the working memory scale after the program.

Table 14. The relationship between the degrees of students with learning difficulties on the encoding information scale and their grades on the working memory scale after the program

Working memory	Verbal encoding	Verbal spatial encoding	Central executive encoding	Total score
Phonemic encoding	0.97**	0.89**	0.96**	0.96**
Semantic encoding	0.89**	0.97**	0.94**	0.94**
Phonemic and semantic Encoding	0.96**	0.90**	0.96**	0.96**
Total score	0.95**	0.89**	0.94**	0.96**

Interpretation

Table 14 shows that there is a statistically significant positive correlation at the 0.01 significance level between the degrees of students with learning difficulties on the encoding information scale and their grades on the working memory scale. This indicates that as students' performance improved in encoding information, their working memory scores also increased, reflecting the interdependence of these two cognitive abilities.

Summary of Findings

- **Hypothesis 6** (differences between post- and follow-up tests for working memory) was not supported, as no statistically significant differences were found.
- **Hypothesis 7** (positive correlation between encoding information and working memory scores) was supported, with significant positive correlations found between the two scales at the 0.01 level. This suggests that improvements in encoding information were associated with improvements in working memory for students with learning difficulties.

Discussion

The results of the study underscore the effectiveness of the program in enhancing the information-encoding abilities of students with learning difficulties. By using specific techniques that facilitate encoding, such as phonemic and semantic coding, students were able to improve their capacity to store, preserve, and retrieve information. This improvement, as shown in **Table 7**, aligns with the second hypothesis, which demonstrated that the experimental group exhibited a significantly better encoding ability compared to their peers in the control group, particularly in the areas of phonemic and semantic encoding (**Table 8**). These findings are consistent with Hayes [24], who emphasized the importance of efficient encoding in fostering strong correlations between learned material and cognitive structures stored in memory. The deeper the encoding, the more effortlessly the information can be retrieved.

The third hypothesis, which focused on the improvement of working memory, is aligned with the objectives of the program. The results (**Table 9**) show that students in the experimental group demonstrated enhanced abilities to memorize textual vocabulary and transform it into phonemic syllables, as well as analyze, compose, and enrich words. This finding supports Baddeley's [25] study, which explored semantic encoding and its effect on short-term memory, particularly how encoding strategies can facilitate the retrieval of information, whether phonemically or semantically.

The fourth hypothesis illustrated that the use of images to convey the meaning of words significantly aided the students in understanding the meaning of those words. Visual aids enhanced cognitive distinctions and improved memory retrieval, as students were able to encode information more deeply through visual representation. This method also aligns with the idea that the use of multisensory strategies aids deeper processing and faster retrieval.

The fifth hypothesis confirmed that the integration of verbal, auditory, and visual information during the program sessions effectively supported the encoding process. The multisensory approach helped students encode information in a more structured and accessible manner, thus enhancing their overall learning experience (**Table 12**).

The sixth hypothesis highlighted that training students in encoding techniques had a positive effect on their working memory performance. By linking new material to previously learned content and encoding it through diverse methods, students were more engaged in the encoding process. This corresponds with the findings of Levy and Hinchley [26], who noted that strengthening working memory improves the speed and accuracy of information identification and retrieval.

Finally, the seventh hypothesis (**Table 14**) showed a significant positive correlation between students' ability to encode information and their improvement in working memory. This highlights the effectiveness of the cognitive strategies used during the program, particularly in helping students form meaningful connections between symbols, which ultimately led to enhanced cognitive abilities.

Conclusion

This study effectively demonstrated that a targeted program aimed at improving encoding techniques can significantly enhance the performance of students with learning disabilities. By incorporating verbal, auditory, and visual information, and utilizing multisensory encoding strategies, students were able to enhance their working memory and retrieve information more effectively. The use of cognitive strategies such as phonemic and semantic encoding, along with imagery, played a crucial role in improving their overall performance.

General Recommendations

1. Training in encoding techniques: Students with learning difficulties should be trained to use specific techniques, such as audiovisual aids, to facilitate the encoding and memorization of information at deeper levels of cognitive processing.
2. Linking learning material to cognitive structures: It is crucial to train students to link new material to their existing cognitive structures using more effective strategies, which will improve and activate working memory performance.
3. Research focus on early intervention: More research and studies should be directed at early therapeutic interventions for children with learning difficulties, particularly those focusing on training in encoding strategies.

Suggestions for Further Research

For future research, it is suggested to explore the following topic:

- Encoding of information into long-term memory in children with developmental language disorders.

This would provide insights into how encoding strategies can be applied to help children with developmental language disorders retain and retrieve information more effectively in the long term.

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