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Enhancing Information Encoding to Improve Working Memory in Students with Learning Disabilities

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Abstract

This study aimed to enhance information encoding abilities and assess their influence on the working memory capacity of students with learning disabilities. These students often employ ineffective academic strategies, leading to a sense of inadequacy and underachievement. The research sample included 20 male and female fourth-grade students, aged between 8 and 11 years. An experimental method was employed using a two-group design, with pre-test, post-test, and follow-up assessments to evaluate changes in the study variables. The research tools used were the Stanford-Binet Intelligence Scale, the Information Encoding Level Scale, the Quick Neurological Screening Test, and a specialized program designed to develop information encoding skills. Data analysis involved statistical techniques such as means, standard deviations, paired sample t-tests, and independent sample t-tests using a statistical software program.

Keywords: Working memory, Learning disabilities, Information encoding, Early childhood

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Introduction

Theoretical perspectives suggest that individuals with learning difficulties often struggle with encoding information and forming meaningful connections between knowledge units. This is largely due to their reliance on random strategies stemming from underdeveloped skills in organizing and encoding information. Encoding refers to the process of entering information into memory by transforming it into symbolic forms. Psychologists emphasize that the way information is encoded significantly influences how easily it can be recalled and the meaning it holds. Consequently, students with learning difficulties often lack the cognitive representation skills and the awareness needed to understand their own cognitive limitations.

Swanson *et al*. (2004) suggest that memory-related processes such as encoding, processing, and retrieval are foundational cognitive skills that are not directly dependent on overall intelligence or learning ability [1, 2]. Furthermore, Swanson and Ashbaker (2000) present evidence indicating that difficulties in working memory can reliably predict a person's performance on various tasks [3]. Information first enters the sensory register, and if attention is paid to it, the data is passed on to short-term memory or directly to working memory for further processing [4].

The process of information representation unfolds in three main stages. The initial stage involves encoding, where cognitive symbols are formed [5]. This is followed by storage and processing, and finally, the retrieval stage, which demonstrates the effectiveness of the earlier phases [6]. The format of stored information varies depending on the memory store, often being converted into abbreviated or symbolic forms [7].

Greeno Hicks, as cited by Suleiman Abdel Wahid (2010) and Anwar El Sharkawy (1992), classifies encoding into six primary types: visual, auditory, operative, verbal, semantic, and dynamic [6]. Additional types include gustatory, olfactory, and emotional encoding. Leahey and Harris (2003) argue that enhancing encoding processes is the most effective way to improve memory function and retrieval efficiency [8].

Research problem

Cognitive impairments linked to learning difficulties pose significant challenges, particularly due to their impact on working memory, which plays a crucial role across all academic domains. These students commonly exhibit general encoding weaknesses and limited ability to establish links between pieces of information, resulting in frequent forgetfulness. The study seeks to address the following research question: *What is the effect of training aimed at enhancing information encoding levels (phonemic encoding, semantic encoding, and combined semantic-phonemic encoding) on improving the working memory capacity of students with learning difficulties?*

Research objectives and terminology

Research objectives

This study aimed to accomplish the following:

- To assess how effectively the strategies and techniques applied during program sessions enhance the different levels of information encoding.
- To determine the impact of the program on improving working memory capacity in students with learning difficulties, as measured through pre- and post-intervention assessments.
- To identify the key skills and methods that transform students' information recall habits and positively influence their academic performance.

Terminology

- **Encoding:** Refers to the process of transforming perceived information and stimuli from their original form into specific symbols or codes. This transformation allows the information to be cognitively represented in meaningful ways, aiding in its organization, processing, storage, and eventual retrieval.
- **Working Memory:** A cognitive system responsible for the temporary storage and processing of information encountered during daily perceptual tasks. It is characterized by limited capacity and plays a vital role in learning and reasoning [9, 10].
- **The Training Program:** Designed to improve the levels of information encoding in individuals with learning difficulties, this program includes targeted activities and methods that develop three key encoding levels: phonemic, semantic, and combined phonemic-semantic. Through structured sessions, students learn to encode information based on sound and meaning, linking vocabulary with cognitive experiences, using keywords, and employing various strategies to optimize encoding, representation, storage, and long-term retention of information [11, 12].

Theoretical framework and review of literature

Encoding is the process by which information is converted into mental images or symbolic representations—codes with assigned meanings. Effective encoding ensures that information remains accessible over time and is resistant to distortion or forgetting. Re-encoding using updated or more suitable codes can further strengthen memory retention. To facilitate encoding, individuals can use cognitive strategies such as self-labeling, mental mapping, keyword association, summarization, sound patterns, organization, storytelling, and visualization.

Hamdi (2008) explains that once sensory stimuli are initially registered, they undergo a more complex processing and representation phase [13]. Psychologists agree that encoding leaves a lasting imprint on memory, which can be influenced over time—either weakened or altered—if the encoding is ineffective [14]. This transformation involves converting raw sensory input into meaningful representations, including acoustic, visual, tactile, and semantic codes [15].

Khalil's (2014) research demonstrated the benefits of spatial and recall strategies when applied to students with developmental learning difficulties [16]. Similarly, Adel Hussein (2001) explored the differences in encoding and memory recall—both immediate and delayed—between high-achieving and struggling students. His study highlighted the importance of strategies like rehearsal, organization, and memory aids in tasks involving numbers, letters, abstract words, and nonsensical syllables.

Paraphrased section

Information encoding levels

Modern research highlights that students with learning difficulties often experience memory challenges, particularly when using strategies commonly employed by their peers without learning difficulties—such as repetition. Reddy and Bellezza (1983) examined different encoding strategies and their effects on memory recall [17]. In their study, one group practiced repetition while focusing on word meanings, and another group formed visual stories. The results revealed significant differences in word recall between the groups, favoring the group that used enhanced repetition strategies. Organizational strategies, like categorizing items based on shared characteristics, also proved effective. For instance, when someone tries to remember grocery items for dinner preparation, grouping those items makes recall easier.

Boltwood (1970) studied the coding strategies used by university students, training groups in story creation, using acronyms, and organizing information [18]. Results showed that 38% of students preferred the acronym strategy, 31% opted for organizational techniques, and 22% used story-based strategies. Another effective strategy is the use of mnemonic devices, such as remembering multiplication orders through rhythmic or patterned repetition [19].

Working memory

Working memory (WM) is a limited-capacity cognitive system responsible for the short-term storage and manipulation of information. It plays a crucial role in tasks such as comprehension, learning, and reasoning. Working memory consists of three main components: the phonological loop, which temporarily holds auditory or speech-based information; the visuospatial sketchpad, which stores visual and spatial data; and the central executive, which oversees attention and integrates information across subsystems [20].

Working memory serves as a bridge, connecting newly received information with existing knowledge stored in long-term memory. Techniques like chunking, clustering, and rehearsal help retain information within working memory. However, information held in working memory is vulnerable to interference, displacement, or decay, which may lead to memory loss.

Baddeley and Hitch (2000) conceptualized working memory as a system that temporarily stores and processes information necessary for complex cognitive activities [21]. Once information is perceived, it is converted from its raw sensory form into meaningful codes. Ramadan and Magd (2001) explored various encoding strategies aimed at enhancing recall, finding that students who employed verbal encoding techniques performed significantly better in memory tasks [22].

While the capacity of working memory is limited—especially compared to long-term memory [19]—its role in learning remains foundational. Walid (2004) attempted to develop a model describing the relationship between encoding strategies and performance in memory-related cognitive tasks [23]. Furthermore, Danielsson *et al*. (2006) demonstrated that the cognitive profile of students with learning difficulties can be simulated by increasing the demands placed on working memory during specific recognition tasks [4].

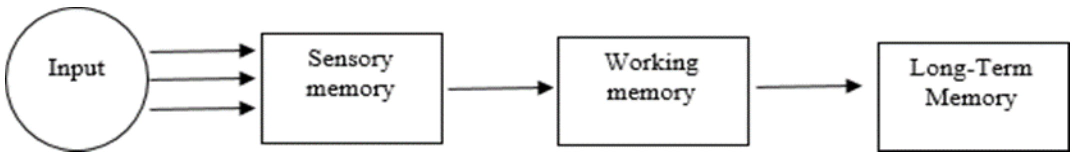

Figure 1. The Working Memory Model (Baddeley and Hitch, 1974)

Hypotheses

This study sought to examine the following hypotheses:

- There will be statistically significant improvements in the experimental group's performance on the information encoding scale between the pre-test and post-test, with higher scores expected after the intervention.
- A statistically significant difference will be observed between the post-test scores of the experimental and control groups on the information encoding scale, favoring the experimental group.
- Statistically significant differences will be found between pre- and post-test scores of students with learning disabilities on the working memory scale, with post-test results showing greater improvement following program implementation.
- Students in the experimental group are expected to show statistically significant improvement in their working memory test scores from pre- to post-intervention, in favor of the post-test results.
- Statistically significant differences will appear between the post-test and follow-up (tracing) test scores of the experimental group on the information encoding scale, indicating the program's lasting effect.
- No statistically significant differences will be found between the post-test and follow-up scores on the working memory scale for students with learning disabilities, suggesting stability in the outcome over time.
- A statistically significant positive correlation is expected between the students' scores on the information encoding scale and their scores on the working memory scale after completing the training program.

Research methodology

To conduct this study, an experimental approach was employed. The sample consisted of 40 male and female students diagnosed with learning difficulties, all enrolled in the fourth grade of primary school in the Northern Borders region of Saudi Arabia. The participants ranged in age from 8 to 11 years. They were randomly assigned to two equal groups: an **experimental group** (20 students) who received the training intervention designed to improve information encoding, and a **control group** (20 students) who did not participate in the program.

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
Age	Experimental	20	8.600	1.578	16.43	350.0	164.0	0.49	No
	Control	20	9.375	1.642	18.33	385.0			
Intelligence	Experimental	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	Experimental	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	Experimental	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	Experimental	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 demonstrates that there were no statistically significant differences in the mean scores between the experimental and control groups concerning age, intelligence, learning difficulties, levels of information encoding, and working memory. This indicates that both groups were homogeneous and comparable before the intervention.

The tools used in the study included the Stanford-Binet Intelligence Scale (Fifth Edition) and a researcher-developed questionnaire to assess the levels of information encoding in students with learning difficulties. The Stanford-Binet Scale is designed to measure cognitive abilities and intelligence in individuals aged 2 to 85. It is commonly used to diagnose intellectual delays, learning disabilities, autism spectrum disorders, and giftedness.

The information encoding questionnaire aimed to identify the encoding strategies employed by students across three levels: phonemic encoding, semantic encoding, and combined phonemic and semantic encoding. This tool evaluates how students process and encode cognitive content based on auditory or semantic features or a combination of both.

To ensure the validity of the questionnaire, the researcher submitted it to ten experts in the educational and psychological fields. The experts confirmed the appropriateness of the items and their alignment with the questionnaire's purpose. Validity coefficients ranged from 0.80 to 1.00 according to Lawshe's formula, indicating a high degree of content validity. Additionally, exploratory factor analysis was conducted using the principal component method on a sample of 100 children. The results revealed three significant underlying factors with eigenvalues exceeding 1. These findings were further validated through Varimax rotation, and the factor loadings after rotation are detailed in **Tables 2–4**.

Table 2. First Factor: Phonemic Encoding Saturation

No	Saturation	Sentence
1	0.76	The student enjoys memorizing vocabulary by linking it to rhyming patterns.
2	0.74	The student adeptly creates musical tunes to aid in memorizing vocabulary and texts.
3	0.73	The student breaks down text vocabulary into syllabic components.
4	0.72	The student memorizes songs even without grasping their meanings.
5	0.67	The student benefits from transforming texts into rhymed phrases to aid learning.
6	0.65	The student finds it easy to recall rhymed songs and texts.
7	0.62	The student quickly learns songs by heart.
Variance Ratio: 18.63%		
Eigen Value: 3.43		

Table 3. Second Factor: Semantic Coding Saturation

No	Saturation	Sentence
8	0.74	The student is keen on exploring the meanings of vocabulary before studying it.
9	0.71	The student struggles to memorize songs that lack clear meaning.
10	0.70	The student is curious about investigating the origins and meanings of words.
11	0.69	The student easily recalls texts with clear and understandable meanings.
12	0.64	The student frequently inquires about the meanings of words and vocabulary.
13	0.62	The student organizes words and vocabulary based on their meanings.

14	0.59	The student explores connections between words and vocabulary based on their meanings.
Variance Ratio: 15.43%		
Eigen Value: 3.15		

Table 4. Third Factor: Combined Phonemic and Semantic Encoding Saturation

No	Saturation	Sentence
15	0.70	The student links rhyming words and vocabulary to their meanings based on prior knowledge.
16	0.68	The student employs rhymed keywords to represent the meaning of phrases.
17	0.67	The student imitates word meanings and expresses them with peers through rhymed phrases.
18	0.67	The student connects learned material to new rhyming connotations.
19	0.61	The student organizes information into lists by meaning while linking it to a familiar melody.
20	0.52	The student creates a coherent story that ties rhymed words to their meanings for learning.
Variance Ratio: 11.13%		
Eigen Value: 2.84		

Tables 2–4 indicate that all factor loadings are statistically significant, with each value exceeding 0.30 according to Guildford's test. To assess the reliability of the information encoding scale, the researcher calculated the internal consistency coefficients using Cronbach's alpha on a sample of 100 children. The coefficients were 0.77 for phonemic coding, 0.75 for semantic coding, 0.76 for combined phonemic and semantic coding, and 0.77 for the overall score. Additionally, stability was tested by reapplying the scale after a two-week interval on another sample of 100 children, yielding even higher coefficients: 0.94 for phonemic coding, 0.96 for semantic coding, 0.97 for phonemic and semantic coding combined, and 0.95 for the total score. These results demonstrate a high degree of reliability and stability for the scale.

The Quick Neurological Screening Test, which was adapted into Arabic, was used to quickly identify individuals with learning difficulties through brief, objective neurological observations related to learning. This test takes about 20 minutes and consists of tasks derived from neurological examinations for children. The test demonstrated a high validity coefficient of 0.889 and a stability coefficient of 0.944, indicating its reliability and validity.

A working memory scale developed by Amal Abdel Mohsen Al-Zoghbi (2017) was also employed to measure storage and processing capacities in the articulatory loop and visual-spatial sketchpad, as well as the ability to manage dual tasks across verbal and visual-spatial components of working memory [24]. To verify the psychometric properties of this scale, validity coefficients were calculated by correlating the working memory scale scores with Stanford-Binet intelligence test scores on a sample of 80 students. The validity coefficients were high across components: 0.96 for the articulatory loop, 0.97 for the visual-spatial sketchpad, 0.95 for the central executive, and 0.96 overall, confirming the scale's validity. Internal consistency was also strong, with significant correlations between each dimension and the overall score: 0.89 for the articulatory loop, 0.91 for the visual-spatial sketchpad, 0.93 for the central executive, and 0.90 for the total score, all significant at the 0.01 level, demonstrating consistent measurement.

Stability coefficients using Cronbach's alpha on a sample of 80 students showed similarly high reliability values: 0.81 for the articulatory loop, 0.78 for the visual-spatial sketchpad, 0.76 for the central executive, and 0.79 for the overall score. Stability was further confirmed by retesting after two weeks, yielding coefficients of 0.93, 0.95, 0.94, and 0.93 respectively, supporting the scale's stability over time.

The current program is designed to achieve the main objective of improving the three levels of information encoding: phonemic encoding, semantic encoding, and combined semantic and phonemic encoding. It consists of 30 sessions, conducted at a rate of three sessions per week over a period of two months.

The content of the program is tailored to suit the characteristics of students with learning difficulties. The researcher incorporated elements of suspense and excitement to enhance students' focus and attention during the exercises. The program emphasizes diversity and flexibility by avoiding reliance on a single method. Worksheets and tools were carefully prepared for each session, with tasks designed in a graduated manner to match the students' developmental levels. Each session included an evaluation form to monitor progress. The program was reviewed and finalized with input from a panel of specialized experts in the field. **Table 5** presents the detailed distribution of the teaching plan for the program.

Table 5. Distribution of the teaching plan for the program

Lesson	Topic	No. of Sessions
	Phonemic encoding	
First	-Memorize similar rhymed vocabulary. -Composing paragraphs of texts with a familiar musical composition. -Convert vocabulary to audio syllables.	4
Second	-memorizing songs and rhymed texts. -Repeating words with a single rhyme till memorize them.	4

	-Analyze words into syllables.	
Third	-Extract words that are similar in their syllables. -Singing the songs with a familiar melody	2
	semantic encoding	
Fourth	-Search for more than one meaning for a term before memorizing it. -Convert words into synonyms and meanings. -Classify words and vocabularies according to their meanings. -Search for the relationship between the vocabularies of the lesson.	3
Fifth	-Find the vocabulary grid for some words in the lesson. -Draw meaningful pictures to memorize the written text. -The lesson is summarized in meaningful phrases. -extracts the general idea for each paragraph.	3
Sixth	-Determining the meanings of the new vocabulary with the lesson. -Writing a lesson from fiction after reading several times. -Determine the main idea of the song. -Explaining the song after understanding it.	3
Seventh	-Connect words with their synonyms, then form useful sentences for them. -Finding the correct meaning of audible words. -Peer participation in a dialogue on the meanings and synonyms of the subject of the lesson. -Create useful phrases from given words. -Design a word map for some synonyms of the lesson.	3
	phonemic and semantic encoding	
Eighth	-Searching for the meaning of similar vocabulary in rhyme. -Using keywords that have acceptable meaning and rhyme. -Actively representing the meanings of words with their peers in rhymed terms. -Linking the meanings of the learned vocabulary with similar words in rhyme.	4
Ninth	-Classify vocabulary in lists according to their meaning, and link them to a familiar tone. -Tell a story with meaningful musical performance.	2
Tenth	-Extracting opposites and meanings for each word.	2
Total		30

Program strategies applied

The implementation of the program relied on several key educational strategies tailored to the needs of students with learning difficulties:

- Cooperative learning: Students worked in groups, allowing them to exchange ideas, engage in dialogue, and build a spirit of collaboration and mutual support.
- Immediate correction of errors: Teachers provided real-time feedback by noting student errors and offering the correct answers, ensuring prompt rectification and understanding.
- Reinforcement: Various types of reinforcement (physical, verbal, symbolic, nutritional, and active) were used to immediately reward correct responses, thereby encouraging positive behavior and motivation.
- Homework assignments: Students were given exercises and examples to complete at home, reinforcing what they learned in class and supporting skill retention.

Study application procedures

The researcher implemented the following steps to ensure the research tools and procedures were effective and appropriate for the sample:

- Preparation and validation of the tools used in the research to confirm their suitability for the study sample.
- Selection of primary schools in Rafha Governorate where the program would be applied.
- Administration of the Quick Neurological Screening Test and the Stanford-Binet Intelligence Scale to assess neurological and cognitive baselines.
- Verification of equivalence between the experimental and control groups in terms of age and IQ prior to program implementation.
- Division of students into two groups: an experimental group (exposed to the training program) and a control group (not exposed).
- Administration of pre-tests to both groups to establish baseline levels for information encoding and working memory.
- Implementation of the training program for the experimental group over the defined period.
- Administration of post-tests to both groups to assess the development in information encoding and working memory.

- A follow-up test was conducted one month after the end of the program to assess retention of effects.
- Appropriate statistical analyses were carried out to test the study's hypotheses.

The study design

- Design: The study followed a quasi-experimental design with pre-, post-, and follow-up tests for both control and experimental groups.
- Study variables:
  - Independent variable: the training program.
  - Dependent variables: information encoding and working memory.

Data analysis methods included correlation, medians, means, standard deviations, t-tests, and Wilcoxon tests to identify significant differences between the groups and assess the impact of the program.

Results and Discussion

Hypothesis 1

There are statistically significant differences between the average ranks of students with learning difficulties in the pre- and post-tests of the program of the information encoding scale for students with learning difficulties, in favor of the post-test.
To test this hypothesis, the Wilcoxon signed-rank test was employed to examine the differences between the average ranks of the degrees of students with learning difficulties on the information encoding scale in both the pre-test and the post-test.
Below is a paraphrased version of the provided table, maintaining the structure, data, and meaning while rephrasing for clarity and variety.

Table 6. Statistical Analysis of Variables

Variables	Measurement	No	Mean Rank	Sum of Ranks	Z	Significance Level	Significance Direction
Phonemic Encoding	Negative Ranks Positive Ranks Ties Total	1 19 0 20	1 11	1 209	3.893	Significant at 0.01	Favoring Post
Semantic Encoding	Negative Ranks Positive Ranks Ties Total	0 20 0 20	- 10.5	- 210	3.930	Significant at 0.01	Favoring Post
Phonemic and Semantic Encoding	Negative Ranks Positive Ranks Ties Total	0 20 0 20	- 10.5	- 210	3.926	Significant at 0.01	Favoring Post
Total Score	Negative Ranks Positive Ranks Ties Total	0 20 0 20	- 10.5	- 210	3.924	Significant at 0.01	Favoring Post

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

Table 6 shows that there are statistically significant differences between the average scores of students with learning difficulties in the pre- and post-tests on the scale of information encoding. This confirms the effectiveness of the program in enhancing their encoding abilities.
Figure 2 illustrates the differences in average ranks of students' scores in the pre- and post-tests, further supporting the visual evidence of improvement following the application of the program.

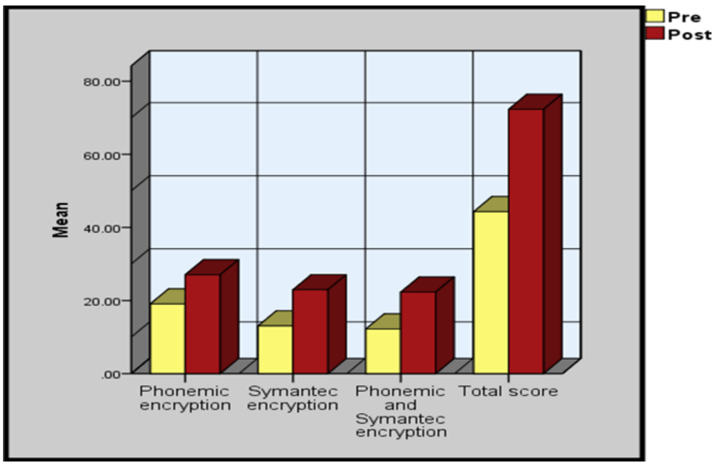

Figure 2.

To quantify this development, the researcher calculated the rate of improvement between the pre- and post-test average scores.

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

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

Hypothesis 2 (paraphrased)

There is a significant difference between the average scores of the experimental and control groups in the post-test of the information encoding scale among students with learning difficulties, favoring the experimental group. To test this hypothesis, the researcher applied the t-test to compare the post-test mean scores of both groups on the information encoding scale.

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

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

t = 2.42 at the level of 0.01
t = 1.68 at the level of 0.01

The results in **Table 8** reveal a significant difference at the 0.01 level between the post-test scores of the experimental and control groups on the information encoding scale. These findings suggest that the experimental group, which received the intervention, outperformed the control group.

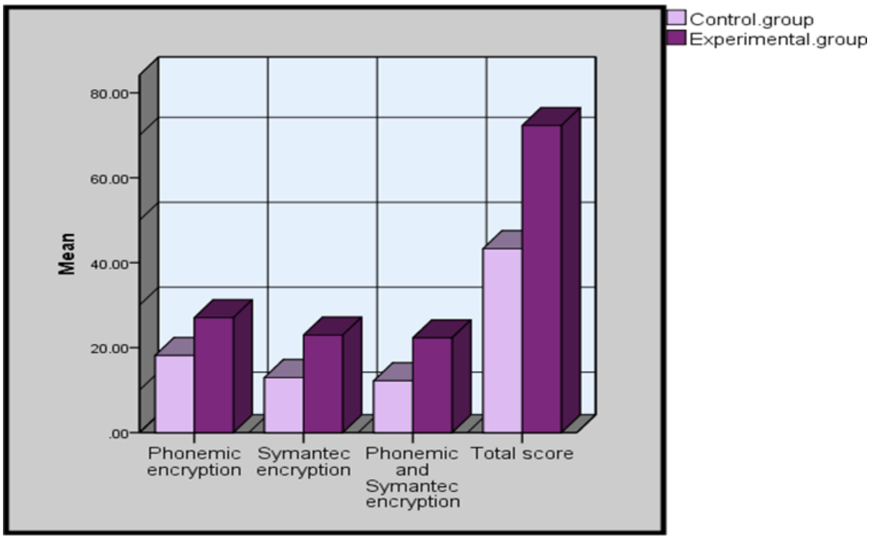

Figure 3.

Figure 3 illustrates the variation in post-test mean scores between the experimental and control groups on the information encoding scale for students with learning difficulties, highlighting the superior performance of the experimental group following the intervention.

Hypothesis 3:

The study anticipates significant changes in the working memory scores of students with learning difficulties, comparing their performance before and after the intervention, with improvements expected in the post-test.

To assess this, the researcher employed the Wilcoxon signed-rank test to evaluate whether the differences in average working memory scores between the pre-test and post-test for the students were statistically meaningful.

Table 9. Statistical Analysis of Variables

Variables	Measurement	No	Mean Rank	Sum of Ranks	Z	Significance Level	Significance Direction
Articulatory Loop	Negative Ranks Positive Ranks Ties Total	0 20 0 20	- 10.5	- 210	3.942	Significant at 0.01	Favoring Post
Visual-Spatial Sketchpad	Negative Ranks Positive Ranks Ties Total	0 20 0 20	- 10.5	- 210	3.946	Significant at 0.01	Favoring Post
Central Executive	Negative Ranks Positive Ranks Ties Total	0 20 0 20	- 10.5	- 210	3.948	Significant at 0.01	Favoring Post
Total Score	Negative Ranks Positive Ranks Ties Total	0 20 0 20	- 10.5	- 210	3.930	Significant at 0.01	Favoring Post

Note: Z = 2.58 at the 0.01 significance level; Z = 1.96 at the 0.05 significance level.

Table 9 reveals a statistically significant difference ($p < 0.01$) between the mean scores of students with learning difficulties on the working memory scale before and after the intervention program.

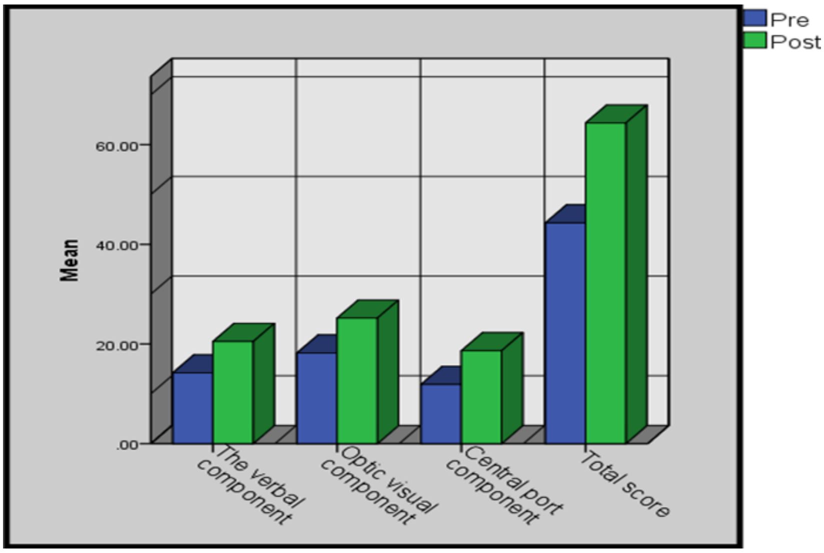

Figure 4.

Figure 4 depicts the variation in average rankings of students' scores with learning difficulties between the pre-program and post-program assessments on the working memory scale.
The results show a noticeable improvement in the mean scores of students with learning difficulties on the working memory scale from the pre-test to the post-test following the program.

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%

Hypothesis 4

There are significant differences between the average post-test scores of the experimental group and the control group on the working memory scale for students with learning difficulties in the experimental group.

To test this hypothesis, the researcher applied a t-test to compare the mean post-test scores of students in the experimental and control groups on the working memory scale for students with learning difficulties.

Table 11. Comparison of Mean Scores Between Experimental and Control Groups in the Post-Test of the Working Memory Scale for Students with Learning Difficulties

Variables	Experimental Group (N1 = 20)	Control Group (N2 = 20)	T	Significance Level	Significance Direction
	Mean (M1)	S.D1	Mean (M2)	S.D2	
Articulatory Loop	1.39	20.5	14.45	2.06	10.859
Visual-Spatial Sketchpad	1.36	25.2	18.75	1.97	12.046
Central Executive	1.66	18.65	12.8	1.82	10.6
Total Score	2.75	64.35	46	4.06	16.7

Note: t = 1.68 at the 0.05 significance level; t = 2.42 at the 0.01 significance level.

Table 11 indicates that there are statistically significant differences at the 0.01 level between the mean scores of the experimental and control groups in the post-test on the working memory scale for students with learning difficulties, favoring the experimental group.

Hypothesis 5

There are significant differences between the mean scores of students with learning difficulties on the information encoding scale in both the post-test and follow-up test.

To test this hypothesis, the researcher employed the Wilcoxon test to examine the differences in average scores of students with learning difficulties between the post-test and follow-up test.

Below is a paraphrased version of **Table 12. Differences in Average Ranks of Students with Learning Difficulties in Post-Test and Follow-Up Tests of the Program on Information Encoding**, preserving the structure, data, and meaning while rephrasing for clarity and variety.

Table 12. Comparison of Mean Ranks for Students with Learning Difficulties in Post-Test vs. Follow-Up Tests on the Information Encoding Scale

Variables	Measurement	No	Mean Rank	Sum of Ranks	Z	Significance Level	Significance Direction
Phonemic Encoding	Negative Ranks Positive Ranks Ties Total	3 6 11 20	4.5 5.25	13.5 31.5	1.15	Not Significant	—
Semantic Encoding	Negative Ranks Positive Ranks Ties Total	0 5 15 20	- 3	- 15	2.236	Significant at 0.05	Favoring Follow-Up
Phonemic and Semantic Encoding	Negative Ranks Positive Ranks Ties Total	0 3 17 20	- 2	- 6	1.633	Not Significant	Favoring Follow-Up
Total Score	Negative Ranks Positive Ranks Ties Total	2 12 6 20	6 7.75	12 93	2.696	Significant at 0.01	Favoring Follow-Up

Note: Z = 2.58 at the 0.01 significance level; Z = 1.96 at the 0.05 significance level.

Table 12 reveals statistically significant differences at the 0.01 level between the average scores of students with learning difficulties on the total information encoding scale in the post-test and follow-up test, particularly for the sequence test. Additionally, significant differences at the 0.05 level were found between the average ranks of students' scores on the semantic encoding subscale of the information encoding scale for the same tests. However, no statistically significant differences were observed between the average scores of students with learning difficulties in the post-test and sequence test of the program.

Hypothesis 6

There are statistically significant differences between the mean scores of students with learning difficulties on the working memory scale in the post-test and follow-up test of the program.

To test this hypothesis, the researcher used the Wilcoxon test to compare the average scores of students with learning difficulties between the post-test and follow-up test.

Table 13. Comparison of Mean Ranks for Students with Learning Difficulties in Post-Test vs. Follow-Up Tests on the Information Encoding Scale

Variables	Measurement	No	Mean Rank	Sum of Ranks	Z	Significance Level	Significance Direction
Articulatory Loop	Negative Ranks Positive Ranks Ties Total	5 2 13 20	3.9 4.25	19.5 8.5	0.654	Not Significant	—
Visual-Spatial Sketchpad	Negative Ranks Positive Ranks Ties Total	4 3 13 20	4 4	16 12	0.378	Not Significant	—
Central Executive	Negative Ranks Positive Ranks Ties Total	5 5 10 20	6 5	30 25	0.277	Not Significant	—
Total Score	Negative Ranks Positive Ranks Ties Total	8 6 6 20	7.69 7.25	61.5 43.5	0.578	Not Significant	—

Note: Z = 2.58 at the 0.01 significance level; Z = 1.96 at the 0.05 significance level.

Table 13 indicates statistically significant differences between the average scores of students with learning difficulties in the post-test and follow-up test on the working memory scale.

Hypothesis 7

There is a statistically significant positive correlation between the scores of students with learning difficulties on the information encoding scale and their scores on the working memory scale after the program.

To test this hypothesis, the researcher applied Spearman's correlation coefficient to examine the relationship between students' scores on the information encoding scale and their working memory scores following the program.

Table 14. Percentage of improvement between the average grade levels of students with learning difficulties in the pre- and post-tests on the information encoding scale

Encoding Type	Verbal	Verbal-Spatial	Central Executive	Total Score
Phenomic Encoding	0.97**	0.89**	0.96**	0.96**
Semantic Encoding	0.89**	0.97**	0.94**	0.94**
Phenomic and Semantic Encoding	0.96**	0.90**	0.96**	0.96**
Total Score	0.95**	0.89**	0.94**	0.96**

Table 14 demonstrates a statistically significant positive correlation at the 0.01 level between information encoding scores and working memory scores.

The findings of this study demonstrate that the program significantly contributed to enhancing the encoding abilities of students with learning difficulties. These students improved their use of specialized techniques that aid in effective information encoding, which in turn positively impacted their capacity to store, retain, and retrieve information, as shown in **Table 7**.

The second hypothesis confirmed the effectiveness of the program's sessions and activities, indicating that the foundations on which the program was built were well-suited for the experimental group. Students showed marked improvements in both phonemic and semantic encoding compared to their peers without learning difficulties, as detailed in **Table 8**. This aligns with Hayes' (1987) research, which emphasized the importance of effective encoding by highlighting the correlation between learned material and cognitive memory structures [25]. According to Hayes, stronger correlations lead to deeper encoding and consequently reduce the effort required during information retrieval.

Regarding the third hypothesis, the results support the program's goals: students enhanced their ability to memorize vocabulary by converting text into phonemic syllables and improved skills in analyzing, composing, and enriching words, as demonstrated in **Table 9**. This resonates with Baddeley's (1972) findings on semantic encoding in short-term memory and its influence on the encoding phase of information processing [26]. His study emphasized that encoding strategies facilitate the retrieval of information through phonemic or semantic pathways, thereby strengthening memory performance.

The fourth hypothesis showed that program techniques—such as using images to convey word meanings—helped students cognitively differentiate between words, boosting their ability to retrieve and remember vocabulary. Visual imagery promoted deeper encoding, which accelerated recall.

The fifth hypothesis' results aligned with the program's emphasis on presenting verbal, auditory, and visual information to support accurate encoding, as indicated in **Table 12**. The sixth hypothesis highlighted that training in memorization and encoding strategies improved working memory performance, suggesting that linking learned material through diverse encoding methods fosters greater student engagement and positive involvement, as shown in **Table 13**. This supports Levy and Hinchley's (1990) assertion on the critical role of enhanced working memory capacity in accelerating information processing [27].

Finally, the seventh hypothesis, illustrated in **Table 14**, reflects students' improved ability to encode information and establish meaningful links between encoded symbols through cognitive strategies. This enhancement positively influenced their working memory effectiveness and demonstrated how students with learning difficulties benefited actively from the program's sessions, methods, and techniques.

Conclusion

This study examined the effectiveness of a specialized program designed to enhance information encoding skills in students with learning disabilities. The program's sessions included various exercises and activities that utilized verbal, auditory, and visual materials to promote accurate encoding of information. The techniques taught to students for preserving information contributed to improved working memory performance. Additionally, memory can be strengthened and activated by linking new material to prior knowledge through diverse encoding strategies, fostering greater student engagement and positivity.

General recommendations

- Provide training for students with learning difficulties in specific techniques, such as audiovisual aids, to facilitate easier and more durable encoding and memorization at deeper cognitive levels.
- Emphasize teaching students how to connect learning material to their existing cognitive frameworks using effective knowledge strategies, thereby enhancing and activating working memory function.
- Encourage more studies and research focused on early therapeutic interventions aimed at improving information encoding skills in children with learning difficulties.

Suggestions for further research

The researcher recommends future studies on topics such as:

- Encoding of Information into Long-Term Memory in Children with Developmental Language Disorders.

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