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THE EFFECT OF TEACHING SCIENCE BASED ON MNEMONICS IN REDUCING THE SIXTH-GRADE FEMALE STUDENTS' COGNITIVE LOAD ACCORDING TO THEIR IMAGERY STYLE

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Abstract

This study aimed to determine the impact of using mnemonics in reducing the Cognitive Load (CL) of sixth-grade students according to the students' imagery style. The study sample consisted of 212 sixth-grade students in the Governorate of Muscat in the Sultanate of Oman. A quasi-experimental design was used to collect the data for the study. It included two experimental groups and a control group. The first experimental group (EG1) was taught using six strategies of mnemonics (method of loci, peg word, keyword, acronyms- acrostic, linking chain, and rhyme). In contrast, the second experimental group (EG2) students built their mnemonics, while the conventional teaching methods taught the control group (CG). The imagery style scale was conducted beforehand to classify the students according to the type of imagery style. The CL scale was performed before and after the intervention. The study results indicated statistically significant differences in favour of the two experimental groups in reducing the cognitive load. In addition, there were no statistically significant differences in the cognitive load between the study groups due to the imagery style or the interaction between the teaching method and the imagery style. The study recommended that teachers use mnemonics to develop schemas that reduce the cognitive load to raise learning efficiency.

Keywords: Mnemonics, cognitive load, imagery style, sixth grade.

INTRODUCTION

One of the main reasons for the emergence of the cognitive load theory is the limited working memory which often hinders learning. The Theory of Cognitive Load (CLT) emerged by Sweller in the 1980s and is based on the concepts of information processing and the development of schema (Kirschner et al., 2011). Sweller initiated this theory during his study of problem-solving because it requires exceptional demands on working memory. Based on Miller's determination of the capacity of short-term memory, which ranges between 5-9 cognitive units and limited retention time (Erber, 2013), these working memory limitations are responsible for passive learning. In contrast, long-term memory has unlimited capacity, for storing processed information. Sweller et al. (2019) explained that learning occurs effectively when keeping the cognitive load on working memory to its minimum to facilitate long-term memory changes. They clarified that the cognitive load theory depends on forming a permanent knowledge base in long-term memory and forming temporary and conscious processing in memory working.

Cognitive load theory is important for developing and activating the recovery process from long-term memory. A recall is the task of working memory, and the planning process for retrieval is influenced by the way information is organized and stored. The limited capacity of working memory can be overcome by grouping simple items together into larger units called schemas that are stored in long-term memory (Milenković et al., 2014). Learning requires the existence of much-interrelated information to form the basis for the schemas in long-term memory. In the schema, the body of knowledge is integrated and thus treated as a single element by working memory, reducing the required capacity in working memory and enabling effective information processing (Jung et al., 2016).

Mnemonics are a way of organizational actions that activate memory (Governor et al., 2013). They also devise the best ways to encrypt information for easy retrieval. They are effective because they create visual-verbal links between the stimulus and the response (Scruggs et al., 2010). Mnemonics are known as means of helping a student remember information through mental signals created to retrieve information (Richmond et al., 2011). Mnemonics include imagining through a mental representation of something or an act that may not have an actual existence (Matlin, 2009). The student stores the experience visible (e.g., image, drawing) and verbal (e.g., word, and sentence), then retrieves the experience when he/she remembers the image, drawing, or shape and describes it verbally (Woolfolk, 2019). Students' connections are the anchors that summon knowledge and form the basis of long-term memory.

The importance of the current study stems from its handling of essential variables in the educational situation. The study presents teaching strategies concerned with encoding information effectively, thus facilitating the process of its retrieval. The study is also interested in identifying the impact of these strategies on reducing the cognitive load and dealing with another variable namely the imagery style. Students differ in how their information is organized and processed. As researchers acknowledge, the mental imagery style variable is one of the variables that studies have rarely dealt with in general. Thus, the current study findings are expected to add further knowledge to the broad educational literature in the area of teaching science. It addresses the variable cognitive load, which is one of the recent trends that have gained the attention of researchers in educational and cognitive psychology. The variables addressed in the study constitute a system that can be further studied. This is what distinguishes the current research from previous studies.

THEORETICAL BACKGROUND

Knowledge structure is determining learning that creates a knowledge environment that represents the content of the learner's knowledge experiences and how they are organized and used in different situations. Mnemonics clarify a student's cognitive structure, including facts, concepts, and theories. They help organize information as it is stored. It also takes some time to organize, but it is easier to recall. Two types of organizations occur, one in working memory where its limited capacity is improved by chunking new information, and the other in long-term memory by developing knowledge structures (Solso, 2001).

Mnemonics are based on verbal expressions and mental images to link the knowledge with the information and experiences already presented in the student's schemas. Several types of mnemonics have been reported in the literature (Bakken & Simpson, 2011; Eggen & Kauchak, 2009; Ormord, 2020; Woolfolk, 2019) including:

1. Method of loci: This strategy links the material to be remembered with places known to the students. After the students select a familiar place, they create visual images of the information they want to remember and link it with the components of the place they chose. Recalling places provides the student with mental cues for information. This strategy is practical and easy to use, memorizing vocabulary, poetry, problem-solving steps, and action steps. It is also effective for remembering new words, names, facts, and concepts. For example, to learn how the

digestion process occurs, you can imagine a factory where the digestion process takes place.

2. Peg word strategy: This strategy requires forming a mental association between the information to be remembered and vocabulary familiar to the students. This strategy identifies pickup words or pegs for which the words or sentences to be remembered are related. The student creates a mental image that links what he wants to remember and his peg word. An application of the peg word strategy that helps retain the causes of deforestation, representing in mining, gathering wood to burn as fuel, collecting wood to make furniture, vacating land for farming, vacating land for industry, and vacating land for habitation, is One: a genie carrying metal weights (mining), two (field): Soldiers getting warm from the cold (heating wood), three: A fridge stocked with furniture (furniture making), four: A big upturned hat with plants grown in it (for farming), five: A big factory and the chimney is lettuce (clearing land for the industry), six: A goose wears glasses and sips tea on the sofa (for the residence). They are frequently used for arranged and numbered information. For example, numbers can be represented by the words corresponding to them as follows: one: bun, two: shoes, etc. This is in English, but in Arabic, the situation is different. Where one is a genie, two is a field, three is a refrigerator, four is a hat, and five is lettuce, and so on.

3. Linking chain strategy: The linking chain strategy is based on visual sensory links between the cognitive components to be remembered. It provided that these links are formed according to a specific sequence so that an earlier idea facilitates the recall of a subsequent idea so that mental images create a link sequence of ideas that link the idea and the next idea and so on. For example, let students remember the factors affecting microorganisms' growth: the availability of a warm, humid environment and the abundance of oxygen. Thus, the Linking chain is as follows: On a hot day (warmth), Khaled went to the valley and enjoyed seeing the water (humidity) and inhaling pure oxygen (the abundance of oxygen).

4. Acronyms-acrostic strategy: This type of mnemonics involves finding the word (Acronyms) or a sentence (Acrostic) from the first letters of each word in the list of vocabulary to be remembered. This strategy is used in the pronunciation of scientific names and terms. For example, the law of work required to move the total charge (q) across the average potential (v), which is expressed by the formula: $w= 1/2qv$ can be remembered by the word Nescafe (the term for half in Arabic is pronounced “nes”).

5. Keyword strategy: This strategy is usually used to memorize the meanings of the vocabulary of foreign languages. These words are linked to similar words pronunciations from the original language. This strategy goes through two stages: the first is to find a word from the original language that is identical in accent to the word from the foreign language. The second stage links the two words through a sentence or a mental image. In science, the keyword can be used for a suspension solution (a misty [unclear] mixture of particles of a solid that is insoluble in a liquid). The word suspension is similar to the word skier (in Arabic). It is possible to imagine a skier using snow skis on misty clouds.

6. Rhyme strategy: The items to be remembered are associated with a rhyming or melody word. Students tend to repeat rhymes to memorize them.

Coding is the most critical stage as it is easy to remember the encoded information in an orderly manner, reducing the cognitive load (Kalyuga & Singh, 2016). If the information is well encoded in memory, it will be accessible to process and store. Pass & Ayres (2014) explained that a student's working memory boundaries disappear when an individual can integrate new information with previous knowledge in a schema, which helps facilitate the process of information processing and reduce the load on working memory. Mnemonics require a link between new learning and student experiences, so mnemonics overcome working memory capacity limitations by obtaining information from long-term memory directly through the connections in the storage process (Seay & McAlum, 2010).

There are three types of cognitive load as it is cited in the literature (Windell & Wiebe, 2007):

1. Intrinsic Cognitive Load: This type of load arises from the nature of the learning task and its interaction with the student's abilities and experiences.

2. Extraneous Cognitive Load: This type of load results from educational designs and activities and is inappropriate for the educational material.

3. Germane Cognitive Load: This type of load is formed by the student's use of working memory processes that lead to schemas and automatic operation development.

Based on the types of cognitive load, it is clear that both the intrinsic and extrinsic cognitive loads are undesirable and should be minimized during the learning process. In contrast, the germane cognitive load is relevant to learning. In general, regardless of its source, all types of cognitive load should be controlled as an excess effort on working memory (Ayres, 2020).

Cognitive load theory (CLT) is based on principles where much of the learned information is lost unless appropriate mental operations are performed due to the limited working memory capacity. Learning becomes ineffective when working memory capacity is exceeded. Learning requires active working memory that processes, encodes, and stores information in long-term memory (Kirschner et al., 2011). It is possible to increase the cognitive reserve in long-term memory by using specific strategies, thereby contributing to the processing of information in working memory—a high level of cognitive load results from the content or presentation of educational materials. Therefore, learning methods should be sought to reduce the cognitive load. These methods take into account the arrangement of the educational material to minimize the need for attention and to link the diverse sources of information by re-designing the educational material. Using text or images to represent knowledge reduces the cognitive load (Park et al., 2020). Problem solving also strains working memory, so using the example solution strategy when solving problems reduces the cognitive load (Sweller et al., 2019).

Several research studies have dealt with cognitive loads, such as the study of Al Atiyat (2018), which examined the effect of multimedia instructional design based on Sweller's theory on reducing the cognitive load of deaf students in the primary stage in Saudi Arabia. The results showed the superiority of the experimental group that studied according to the theory of cognitive load principles with statistically significant differences in reducing the cognitive load. The study of Minkley et al. (2018) aimed to explore students' performance and cognitive load for two types of representations in molecular biology: symbolic representation and symbolic-text representation. The study recommended that teachers use symbolic representations when teaching complex scientific content. Di Santo et al. (2020) investigated the effectiveness of mnemonics in improving working memory among students at the University of Trieste in Italy. The results indicated that the experimental group performed the best in memory tasks.

Mnemonics depend on linking new learning to the student's previous experiences and knowledge. Imagery style is an effective tool for creating this connection. The imagery style is the pattern of one's thinking about different situations, which varies between the pictorial pattern that focuses on colours and details. The schematic pattern focuses on the spatial relationships between the elements of the situation in question (Halpern & Collaer, 2005). Interest in imagery style to solve problems in mathematics began in the 1970s. Kozhevnikov et al. (2002) pointed out that research studies on imagery style followed but failed to describe imagery style's clarity and accuracy. They did not link visual perceptions with spatial abilities until Hegarty and Kozhevnikov (1999) classified students mainly into Schematic students and Pictorial students. Students with a schematic style used abstract spatial relationships when dealing with verbal problems and were better able to solve issues using their imaginary schemes. While pictorial, students used pictures full of details, which negatively correlated their use of pictures and their ability to solve problems.

Images are produced in 'The visual buffer' for both pictorial and schematics. This buffer has a limited capacity. Therefore, the retention of image detail in low-spatial optics during image processing increases the load on the buffer. As a result of the increased load on this buffer, the pictorial students fail the spatial tests. Conversely, schematics that do not use a lot of image detail to make spatial changes limit unnecessarily great demands on the visual buffer (Kozhevnikov et al., 2002).

Koć-Januchta et al. (2019) examined the impact of visual and verbal cognitive styles on learning from different Learning materials. The study results indicated that students with high visual style learned better when displaying static pictures with written text. There was no difference in students' learning with high and low visual style with presentation as static pictures or animation when using the spoken explanation in the sense of visual pattern.

Several studies mentioned above indicated the effectiveness of using strategies and programmes to reduce the load on working memory. Since mnemonics integrate students into active processing and help retrieve information, the researchers have felt that it is crucial to apply mnemonics in science teaching to recognize their effectiveness in reducing students' cognitive load based on their imagery style. Mainly since no study has been found that combines mnemonics and cognitive load.

The current study aimed to investigate the effectiveness of science teaching based on mnemonics in reducing the cognitive load of sixth-grade students according to the imagery style (pictorial and schematic). The study sought to answer the following research question (RQ), including testing three research hypotheses (H):

RQ: What is the effect of teaching science based on mnemonics in reducing the cognitive load of sixth-grade students according to the teaching method (offering mnemonics, building mnemonics, and prevalent ones), the imagery style (pictorial and schematic), and their interaction after adjusting for pre-differences in the performance of students on the CL scale?

There are no statistically significant differences between the mean scores of the cognitive load of the sixth-grade students after the pre-differences in students' performance have been adjusted on the CL scale according to teaching method (Ha), the imagery style (Hb), and the interaction between the teaching method and patterns of imagery style (Hc).

METHOD

Participants and Settings

The study was conducted for an entire semester in 2019. The study followed the quasi-experimental approach (with a pre/post-design with intervention in between for two experimental groups and a control group) to study the impact of mnemonics on reducing the cognitive load of sixth-grade students. The first experimental group (EG1) was taught by providing mnemonics to students using a teacher's guide. At the same time, the second experimental group (EG2) was taught by constructing mnemonics for students (students were introduced to the types of mnemonics and examples of them, and they were trained on them and then assigned the students to build their mnemonics). The control group (CG) was taught using conventional teaching methods.

The Omani school system consists of two main stages: Basic Education (Grades 1-10) and Post-Basic Education (Grades 11 & 12). The Basic Education stage is composed of two sub-stages: Cycle I, which is for Grades 1-4, and Cycle II, which is for Grades 5-10. Cycle I schools adopt a co-education system where male and female students study in the same classrooms and are taught by female teachers only. On the other hand, schools in Cycle II and Post-Basic Education are single-gender and are taught by teachers of the same gender as the students. The current study applied in two girl's schools due to the logistic facilitation the researchers received from the administration of the two schools. The study sample included N= 212 female students selected randomly from two schools in the Governorate of Muscat. The sample was divided into three groups: EG1 included (n=67) female students from the first school. In comparison, EG2 consisted of (n= 75) female students from the second school. CG consisted of 70 female students from the two schools, with one class from each school. The intervention was performed after obtaining official approval from the Ministry of Education in the country. It was ensured that the teachers of the intervention were equal through their educational supervisors and had equivalent years of experience.

The independent variable in this study was the teaching method which consisted of three levels: 1) teaching based on providing mnemonics, 2) teaching based on building mnemonics, and 3) the conventional teaching method. The study considered two imagery styles (pictorial style and schematic style). The dependent variable was the cognitive load. The cognitive load scale was applied after performing a task, so the task in the current study was the achievement test. Therefore, the cognitive load of students was measured after completing this task. A pre-assessment was conducted to ensure that the three groups were equal in the cognitive load and classify the students into the two types of imagery style. The results of two-way ANOVA show there were no statistically significant differences in students’ responses to the pre-CL scale concerning teaching method, imagery style, and the interaction between teaching method and imagery style, suggesting the equivalence of the participating groups in the pre-cognitive load.

Treatment

Treatment in EGs

The two teachers in the EGs were trained on mnemonics used in the two groups. Table 1 shows how mnemonics were implemented in the two experimental groups (EG1 & EG2).

Table 1 The mnemonics applied in the two experimental groups

Scientific material	EG1	EG2
Reasons for deforestation: mining, gathering wood to burn as fuel, gathering wood to make furniture, evacuating land for farming, evacuating land for industry, and vacating habitation	The teacher teaches the students the scientific material and then introduces the mnemonics represented by the peg word (see figure 1): One: A genie carrying metal weight lifts (mining) Two (the field): Soldiers warming from the cold (heating wood). Three: Fridge Chunky Furniture (furniture manufacturing). Four: a large, upside-down hat with plants growing inside it (for cultivation). Five: a large factory and chimney-shaped lettuce (evacuating land for the industry).	The teacher teaches the students the scientific subject and then asks the students to build mnemonics for the scientific subject. One of the students made a mnemonic with the peg word: One: a genie is grown in the desert (agriculture) Two (field): Soldiers transporting iron to mining (mining). Three: a factory in the form of a refrigerator (industry). Four: A hat-shaped house where the mouse lives (for housing). Another student built the mnemonic using the linking chain: Salem made a chair, then burned it on the agricultural land, and then went to his residence.

Figure 1 Peg word for deforestation reasons

Treatment in CG

The difference between EGs and CG was limited only to the teaching method. Teaching was done in the CG according to the conventional way. Teachers committed themselves to the same period needed to teach each subject with the two experimental groups, using the same materials and tools for teaching and carrying out the activities and explorations planned in the curriculum.

INSTRUMENTS

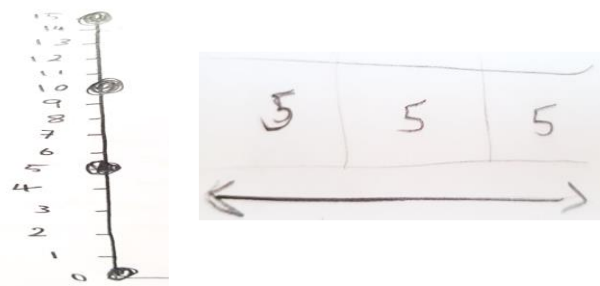
Teacher Guide

A teacher's guide for whole first semester topics of the 6th-grade science curriculum is developed by authors to fit into mnemonics. This curriculum was chosen because it has various topics, including the human body, living organisms in the environment, and matter changes. The teacher’s guide was developed after reviewing the relevant literature on mnemonics (Carney & Levin, 2011 & Lubin & Polloway, 2016) to be used in teaching during the implementation of the study to the two experimental groups. We have diversified mnemonics used to avoid overlap between information when using the same mnemonics for different information and to keep students away from boredom when repeating the same mnemonics. Therefore, six mnemonics were applied: method of loci, peg word, linking chain, acronyms- acrostic, keyword, and rhyme. The teacher’s guide was presented to ten academic and educational experts from curricula and science teaching methods in the country, two science curricula specialists at the university, as well as six educational supervisors conducting supervision at the Ministry of Education, in addition to two science teachers in the schools. The experts gave their scientific and educational notes on the guide's content. Amendments were made by adding a reference.

Imagery Style Scale

To determine the style of a learner's imagery a standardized instrument focusing on mental perception patterns was used (Al-Balushi & Coll, 2013). This measure was done to classify students according to their imagery style. This scale focuses on two types of visualization style, the pictorial style, and the schematic style. This type of scale usually gives the student a set of positions. The scale included five educational situations. The style of the students' imagery was determined based on the analysis of the drawings. Depending on whether it is detailed or not to reach the answer to each question. Regardless of whether the answer is right or wrong. For example, the following question was given: At each of the two ends of a straight path, a man planted a tree, and then every 5 m along the path he planted another tree. The length of the path is 15 m. How many trees were planted?

Figure 2 illustrates the students' responses classifying the imagery style. Figure (2a) was classified as a schematic style due to the expression of trees by points. Figure (2b) presented a pattern that was classified as pictorial because there are tree details such as identifying trees like palm trees and apples and the presence of apple fruits on trees.



A- Schematic style

B- Pictorial style

Figure 2 How to classify the students according to the mental image pattern

To ensure the validity of the scale, it was presented to six experts with several experience and competence in educational psychology and assessment to judge the appropriateness of the situations for the sixth-grade students and their linguistic accuracy. Minor modifications were made regarding the formulation to reach the final version of the instrument. The test-retest method was used to calculate the reliability coefficient on a pilot sample consisting of (n= 57) female students with a 4-week interval between the first and second application of the same pilot sample. The value of the Pearson coefficient correlation was (r=.86), indicating that the test scores were reliable (Akoglu, 2018). The performance of (n=20) female students of the pilot sample was evaluated on the imagery style scale by one researcher and another ratter. This ratter has been trained on how to correct the scale. The Kappa coefficient was calculated to estimate the interrater agreement and reached (K=.79). This value indicates a high and substantial agreement between the ratters (McHugh, 2012).

CL Scale: NASA-TLX Scale of Cognitive Load

The cognitive load self-assessment scale prepared by the NASA Ames Research Center was used (Human Performance Research, 1986). This scale provides us with an accurate practical indication of the cognitive load. The effectiveness of the scale allowed researchers to use it to include measuring the psychological load of individuals who perform different activities (Nikulin et al., 2019) to determine the mental ease or difficulty of the educational task given to the learner and whether it constitutes a high or low mental load. The scale consists of six dimensions: Mental demand, physical demand, temporal demand, performance, effort, and frustration level. Table 2 shows the description of these dimensions (Hart, 2006).

Table 2 Dimensions of CL scale (NASA-TLX)

Dimension	Description
Mental demand	The amount of mental activity the student is asked to do such as thinking, remembering, arithmetic, and whether the current task is complex or straightforward, easy or difficult.
Physical demand	The amount of physical activity the task requires such as turning and whether the task is slow or brisk, restful or laborious.
Temporal demand	The amount of time pressure the student feels for the rate required by the current task.
Performance	The amount of success the student believes he or she has achieved in finishing the objectives of the current assignment.
effort	The amount of difficulty the student had to work within to achieve the required level of performance.
Frustration level	The student feels anxious, irritable, and insecure while performing the current task.

Independent translators translated the scale from English to Arabic back and forth. Three experienced English teachers reviewed the translation. One of these teachers had a master's degree in English to teach non-native speakers, and another had a master's degree in measurement and evaluation. The scale has been adapted to suit the level of the sixth-grade students. This adaptation involves replacing the percentile scale in the original scale with a five-point scale. It was coded very high = 5, high = 4, medium = 3, low = 2, and very low = 1. When analysing the scale results, the grading was reversed in the load of the achieved performance. When a student reached a high level of success in answering the test questions, she was considered to have a low cognitive load. The scale's content validity has been verified by presenting it to six experts with experience and competence in educational psychology and evaluation. They were asked to judge the appropriateness of the items for defining the cognitive load on the one hand and for sixth-grade students, on the other hand, the linguistic accuracy of the formulation and the organizational notes such as deletion, addition, or comment. In light of their opinions and suggestions, some linguistic formulations related to the dimensions of the scale were modified. In addition, the reliability of the CL scale was confirmed by applying the scale to a pilot sample of (59) students from the sixth grade. Where the internal consistency of the scale was calculated using Cronbach's alpha coefficient, and its value was (.71). This value indicates an appropriate degree of reliability for actual application to the study sample (Taber, 2018).

Data Analysis

Using SPSS software, version 22, Two-Way ANCOVA was used to examine the significance of the differences between the means of the participating groups in the cognitive load after adjusting for the previous differences in the students' performance on the CL scale. The effect size was calculated for the levels in which statistically significant differences appeared. Cohen's classification has been relied upon, where the effect size is small if its eta square ($\eta2 \leq 0.06$), medium if its eta square ($0.06 < \eta2 \leq 0.14$), and large if its eta square ($\eta2 \geq 0.14$) (Cohen, 1988).

Results

Table 3 shows differences between the means of the post-application of the CL scale according to the method variables and imagery style among the participating groups (RQ).

Table 3 The adjusted means and standard deviations of the results of students' performance in the post- CL scale according to the method and imagery style

Group	Schematic style			Pictorial style		
	N	*M*	*SD*	*N*	*M*	*SD*
EG 1	31	2.70	0.12	36	2.77	0.11
EG2	34	2.90	0.12	41	2.80	0.11
CG	31	3.40	0.12	39	3.35	0.11

The two-Way ANCOVA was used (Table 4) after isolating the effect of the pre-application of the CL scale.

Table 4 Two-Way ANCOVA for the post- CL scale after adjusting for the pre-differences in students' performance on the CL scale.

Source	Sum of squares	*df*	M^2	*F*	ρ	Partial η^2
Pre-performance	0.59	1	0.59	1.31	0.25	
Method	16.25	2	8.13	18.06	<0.01	0.15
Imagery style	0.04	1	0.04	0.09	0.77	
Participating Groups* imagery style	0.24	2	0.12	0.22	0.76	
Error	92.08	205	0.45			

As shown in Table 4, results indicated statistically significant differences at the level of ($\alpha \leq 0.05$) between the participating groups due to the method after adjusting for the pre-differences in students' performance on the CL scale. The results also showed no statistically significant differences at the significance level ($\alpha \leq 0.05$) between the participating groups due to the imagery style and the interaction between the method and the imagery style. The effect size indicates that the teaching method explains 15% of the variation among students in the adjusted cognitive load of pre-differences in students' performance on the CL scale, which is large according to Cohen's classification (Cohen, 1988).

Post-hoc comparisons were made to the students' performance on the CL scale with the Bonferroni correction to determine the direction of the differences between the participating groups and isolate the pre-differences in the students' performance on the previous CL scale (Table 5).

Table 5 The results of the post- hoc comparisons of the performance of the participating groups in the CL scale

Group A	Group B	M Difference (A-B)	ρ
EG 1	EG2	-0.12	0.93
	CG	-0.64	< 0.001
EG 2	CG	-0.53	< 0.001

Table 5 shows the nature of the differences in cognitive load. There were statistically significant differences at the significance level ($\alpha \leq 0.05$) between the EG1 and the CG in favour of the EG1. There are also statistically significant differences between the EG2 and the CG in favour of the EG2. Accordingly, the Ha is rejected, and the Hb and Hc can be confirmed.

Discussion

This study's initiative focused on the impact of Mnemonics-based science education in reducing the cognitive load according to the imagery of sixth-grade students. The main RQ of the study was focused on the effect of teaching science based on mnemonics in reducing the cognitive load of sixth-grade students according to the teaching method (offering mnemonics, building mnemonics, and prevalent ones), the imagery style (pictorial and schematic), and their interaction after adjusting for pre-differences in the performance of students on the CL scale.

The results indicate that using and constructing mnemonics can overcome some students' cognitive problems, particularly problems associated with poor concentration while the teacher is lecturing. The mnemonics also stimulated the students' attention, which reduced the cognitive pressures caused by the memorization method, unlike in the control group, in which the information was continuously pumped. It was impossible to process the information in the working memory for ease of storage. On the other hand, the students of the two experimental groups succeeded in processing the information. They have an explicit schema that enables them to recall the information with the least pressure and effort during the achievement test. Mnemonics provide students with cues for storage and recall. It has also increased the vitality of students' in addressing the information they were exposed to. Di Santo et al. (2020) explained that the application of mnemonics has positive effects on working memory tasks. Viennot (2020) stated that memory aids are easy to memorize. When using mnemonics, the information is active in working memory, enabling students to use it and build structured, coherent, and meaningful knowledge. It results in their working memory being more efficient at processing the large amount of information that the educational situation requires.

The cognitive load is addressed through the theory of information processing. The working memory is the one that pays attention to the information and processes it and relates to the limitation of its capacity (Kalyuga & Singh, 2016). Therefore, the cognitive load theory is concerned with the amount of information in working memory and how to reduce the student's cognitive load to achieve effective learning. One way to accomplish this is to help students develop schemas and deal with knowledge through strategies that expand their working memory boundaries. Hadie et al. (2018) argue that actual learning is the learning that can acquire and retain knowledge for students by improving students' working memory capacity and enhancing the germane cognitive load. The current study results illustrated the impact of using mnemonics in reducing the cognitive load. A degree of interdependence was achieved between the elements of one topic that were placed in working memory during the study of the topic.

According to the Atkinson and Sheffern model (see Figure 3, mentioned in Hill, 2001), clustering works to overcome short-term memory limitations (Reisberg, 2019). Units can be grouped functionally and meaningfully like a link chain to the student. To answer the question “what materials can be recycled?” the student recalls the link in the recycling lesson supported by the image in Figure 4., the student remembers ‘The father sitting on the metal bench in the garden reading an article entitled ‘Recycling’ in his usual newspaper and on the table his favourite glass and plastic dish with the leftovers of the fruits he ate.’ The image comes to the student's mind, representing a holistic picture of the subject and depicting its details. From them, she can enumerate all of these materials and retrieve information without overloading the working memory as a result of recalling this information. Caplan and Stern (2008) stated that mnemonics affect working memory by reducing the cognitive load, increasing the efficiency of memory acquisition and coding of information by assembling information into verbal or visual cues that can be entered into working memory.

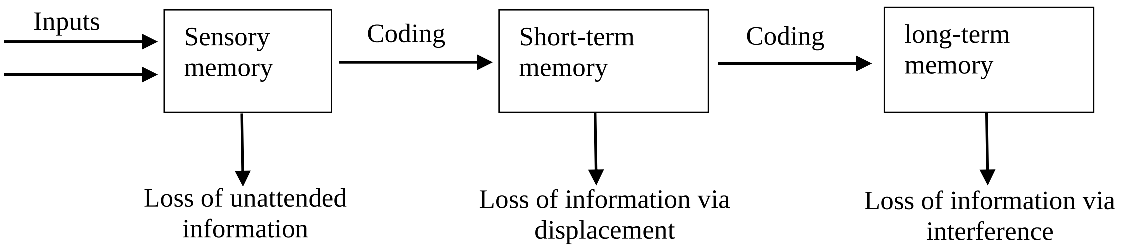


Figure 3 Atkinson and Sheffern model (Hill, 2001, amended by authors)

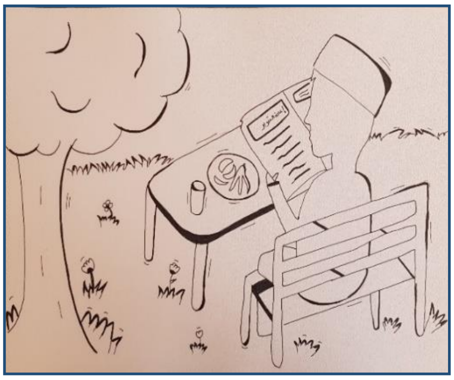


Figure 4 Mnemonic for recycled materials

The study was concerned with reducing the cognitive load by linking the content elements to encode information and exclude redundant information. In addition, students work on imagining links, building mnemonics, and using verbal and visual aids. Costley and Lang (2017) found a positive correlation between diversity in audio-visual media and the germane cognitive load. This diversity may help students establish connections between media and content. Mayer and Moreno (2003) added that the integration of verbal and visual media leads to activating the verbal and visual channels and increases students' comprehension of the content. In addition, visual presentations, whether static (such as images and illustrations) or dynamic (such as videos and animations), are attractive and enjoyable for students and have significant positive effects on their attention and recall of information (Castro-Alonso et al., 2019). Kordjazi (2014) mentioned that using images in mnemonics stimulates students' memory to retrieve learning. Therefore, the current study took care to apply the principles of Sweller's theory of cognitive load (Bates, 2019), which includes a single representation of knowledge by text or image, so the mnemonics were either text or an image to which the teacher comments.

In addition, the mnemonics allow organizing information in a manner that is easy to integrate into students' schemas. That results in the completion of the learning process for the students of the two EGs with less mental effort than the mental effort of the students of the CG and working on expanding and stimulating the students' working memory to build and develop schemas. The low cognitive load among the students of the two experimental study groups can be attributed to the students' enjoyment when using and creating mnemonics. The students were more positive during the educational process through aids in all lessons. That is due to the diversity of strategies and students' imaginations, which added fun and stimulated the students' enthusiasm for more interaction. Pedler et al. (2020) indicated that students' participation and involvement in the learning process increases their enjoyment of learning and makes them responsible for their education, which entails achieving the desired goals.

The lower cognitive load of students in the two experimental study groups compared to those in the control group can be attributed to the fact that the mnemonics worked to highlight the essential concepts and ideas in the lesson and focus on them during learning and studying. The mnemonics also provided the students with more efficient memory systems than the prevailing method of memorizing and recalling. This result is consistent with Amadieu et al.'s (2011) findings which revealed that focusing students' attention on relevant information and ignoring irrelevant information makes way for working memory for more effective processing of complex information.

The mnemonics also contributed to enhancing the students' confidence in possessing the information correctly and to overcoming the anxiety and hesitation factors that might cause them to feel like they failed to perform the educational tasks. Students in the Stalder and Olson Study (2011) consider that mnemonics help them learn, enjoy, stimulate, and reduce anxiety. Building mnemonics in the current study led the students to depend on themselves. This self-dependence would enhance confidence in themselves, their potential, abilities, and educational readiness and reduce their level of anxiety.

Education must be linked to the student's knowledge stock to achieve effective learning (Brandstetter et al., 2017). The decrease in the cognitive load among the students of the two EGs compared to the CG may result from students of the two experimental groups organizing the learned material, rebuilding it, and linking it to previous knowledge, thus helping to make the schemas more stable. The time available for students to build mnemonics, whether during class or at home, may have helped the students feel comfortable and psychologically relaxed in dealing with information. It may have contributed to reducing the time pressure imposed by the duration of the lesson, which imposes on the student the speed of processing information in working memory before losing it at the end of the lesson. This conclusion is consistent with Liao et al.'s (2019) findings that when students take the time to review the cognitive processes necessary for their learning, they can manage their cognitive resources more effectively, which increases their motivation to learn.

Conclusion, limitation, and implications

Overall, the current study showed that mnemonics reduced students' cognitive load. Thus, the work of mnemonics can be explained by the theory of cognitive load. As the working memory becomes able to encode, store and retrieve information, thus increasing the efficiency of education. The current study results align with previous studies that have indicated the effectiveness of some strategies and programmes in reducing the cognitive load. Mnemonics share with these strategies and programmes in providing the opportunity for students to process information through its organization and correlation with previous knowledge and the development of schemas. These studies are Turan et al. (2018) examined the effect of augmented reality, and Al Atiyat’s study (2018), which provided a multimedia educational design according to the "Sweller" theory, and Kilic's study (2014), which employed digital stories.

The results revealed no statistically significant differences in the cognitive load between the two types of imagery styles of students. Students deal with information according to their imagery style with ease. This study produced a similar cognitive load for students without statistically significant differences.

This way seems to make it easier for them to process the information. Sweller et al. (2019) asserted that limited working memory in terms of capacity and information retention leads to a cognitive load, resulting in an inability to process information.

The effectiveness of the teaching method in reducing the cognitive load was shown, regardless of the students' imagery style. The results show no statistically significant difference between the study groups due to the teaching method and the imagery style. This result indicates that the teaching method affects the cognitive load separately from the imagery style. They do not need to interact to impact the cognitive load. The main effect of the teaching method in reducing the cognitive load does not depend on the imagery style, and each variable works independently of the other.

It should be noted that this study has some limitations. The study was limited to the scientific content of the first semester in the science curriculum for the sixth grade. The study also followed the quasi-experimental approach. According to the educational system in the country, the intervention was limited to sixth-grade students. There is a separation of males and females in the second basic education cycle. The study was limited to two female schools affiliated with the Ministry of Education in the Governorate of Muscat. The participating schools were deliberately chosen because the teachers agreed to participate in applying the intervention and promised to facilitate the difficulties that might face the application. In addition, there were more than two classes for the sixth grade in each school, and the presence of projectors in each classroom to display mnemonics. These reasons may limit the generalizability of the results to the country or other countries.

The theoretical added value of this study is to provide a content model that was formulated according to the strategies of mnemonics as stated in the teacher's guide. Teachers can benefit from the theory of cognitive load principles when choosing strategies and means that reduce the cognitive load and the occurrence of active learning. It also draws teachers' attention to the different methods of processing the information provided to them (pictorial/schematic), which helps them diversify the methods of presentation of information in line with different styles of imagery of the students. Curriculum planners and designers can benefit from the theoretical framework and the teacher guide to include similar examples of mnemonics when planning science curricula for different educational stages. The principles of cognitive load theory can also be applied when designing science curricula to reduce the cognitive load that a scientific presentation may cause. In addition to taking into account the imagery style variable, it is one of the determinants of student performance in science because it represents how the student acquires knowledge and how he/she treats it. It provides a theoretical framework related to mnemonics, cognitive load, and imagery style, which researchers can reference. The study came out with a set of recommendations and suggestions based on its findings, such as 1) holding training workshops for science teachers and supervisors to use mnemonics in science classes, 2) directing educators and teachers to adopt teaching methods and strategies for students' abilities and appropriate methods for developing schemas that reduce the cognitive load to raise learning efficiency, 3) other subordinate variables such as critical thinking, problem-solving, learning efficiency, self-learning orientation, visual intelligence, modifying misconceptions and student learning patterns, have been addressed in future research, 4) comparison between the effectiveness of mnemonics that use static images and those that use animation in reducing cognitive load, and 5) conducting comparative studies of mnemonics' effectiveness with other strategies to define their preference for reducing the cognitive load.

Disclosure statement

The authors reported no potential conflict of interest.

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