A Cognitive-Based Training Program for Graphic Designers to Improve Science Textbook Illustrations

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Abstract

Illustrations are an inseparable part of science textbooks. To design effective illustrations, the science textbook graphic designers need to understand about how the student's mind functions. Unfortunately, the lack of training of the graphic designers in Egypt has resulted in a generation of designers who are unable to apply effective cognitive principles of visual design in the textbooks. This study was carried out to examine the effect of a cognitive-based training program for graphic designers on the quality of science textbook illustrations. The training program was prepared to encourage graphic designers to apply effective cognitive principles when designing science textbook illustrations. Nine graphic designers were asked to design a lesson of "density" before and after the training program. A list of criteria was prepared to examine the quality of illustrations. Thirty three science teachers were asked to use this criteria to evaluate the illustrations in the designed lessons. The teachers pointed out that the pre-training illustrations were more compatible with the cognitive principles than the post-training illustrations. These results can serve as a reference for reform of the graphic preparing and training programs.

***Keywords*:** Cognitive Principles, Graphic Designers, Illustrations, Science Textbook.

Introduction

Science educators agree that textbooks play an important role in the teaching and learning processes (Clement, 2008). Information in the science textbooks should combine the text with illustrations, i.e., both descriptive and visual information

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should be provided. Texts are usually descriptive while images, photos, tables etc. are regarded as visual illustrations. Line diagrams and schemes are also regarded as visual forms of presenting data (Schnotz, 2005).

Studies have pointed out that the amount and space allotted for visual illustrations in science textbooks keep increasing, yet not all of the illustrations are beneficial for learning (Clark & Lyons, 2004). Well-designed illustrations create a mental model without struggling with the written word, thereby bridging the gaps in understanding. It may take only 2-3 seconds to recognize the content in an illustration, but 20 -30 seconds to read a verbal description of the same illustration and 60- 90 seconds to read it aloud. In addition, pictures have a strong emotional impact and most people believe that pictures tell the truth (Pettersson, 2003).

Several authors (e.g. Birisci & Metin, 2010; Kirsh, 2002; Piht, Raus, Kukk, Martin, & Riidak, 2014) state the importance of illustrative material in textbooks as the source for knowledge acquisition, which contributes to the interactive process between learner and the taught material. They describe illustrations as carrying different purposes mainly because they help the viewer to focus on the text and make it easier to understand. Illustrations also save memory because they allow the viewer to look at all the facets of the situation at once rather than sequentially. Moreover, those abstract illustrations, such as graphics or concept maps, can organize complex information into scientific formats, which can represent a large number of messages efficiently in limited space.

The didactic effectiveness of illustrations is not only related to their quality, but also to the learner's mind and his prior knowledge. So, it is a challenge to provide textbooks, which support student learning in the best possible way- taking into consideration cognitive processes, different learning styles, levels of previous knowledge and many other relevant factors (Piht et al. 2014).

Studies focusing on cognitive processing of textual and visual information (e.g. Mayer, 2010, 2014; Stull & Mayer, 2007) yielded several principles for designing textbooks to help learners receive and automatize new knowledge. Cheng, Chou, Wang and Lin (2014) found that the modified textbook with a cognitive principles-driven design enhanced the participants' learning performance in terms of conceptual knowledge, as well as transfer and retention. Kaptan and Kaptan (2005) claim that no matter how much expertise the authors have in the subject area, the textbooks can be of low quality if the instructional design principles are not followed.

The field of textbook design suffers from a colossal gap between theory and practice; i.e., the design principles derived from the grounded theory are not applied in the science textbook illustrations. Mayer (2000) claims that most of the visuals used in instructional materials do not have an instructional purpose, they rather serve as decorative items. Besides, most visuals are likely to increase the extraneous cognitive load since they are used haphazardly in most textbooks rather than in an informed way. Slough, McTigue, Kim and Jennings (2010) found that one third of all graphics in middle school science textbooks were decorative in nature, most graphics were static, and approximately one third were not connected to the text spatially or semantically.

A graphic designer creates the graphics primarily for published, printed, or electronic media. A core responsibility of the designer's job is to present information in a way that is both accessible and memorable (Helfand, 2012). Compiling textbooks with visuals is a task to be taken carefully and meaningfully. To design effective illustrations, the textbook graphic designers need to understand the cognitive principles of visual design. They need special programs, which can prepare them to achieve that complicated task. An initial questionnaire conducted by the researcher- as a pilot study- on 28 graphic designers, working for three publishing companies in Egypt, revealed that 92.9% of them have not participated in any programs on how to design illustrations; 78.6% of them have not studied design or art in colleges; and 85.7% of them have a little information about the cognitive principles of visual design. Unfortunately, the lack of training of graphic designers in Egypt has resulted in a generation of designers who are unable to apply effective cognitive principles of visual design in textbooks.

Many studies, which were conducted on science textbook analysis in Egypt (e.g. Elhosary, 2004; Youns, 2003), found that illustrations are often neglected aspects of science textbooks which makes pupils unable to grasp proper understandings from the learning process. Most of the illustrations are decorative while the transformational illustrations are comparatively scarce. The text and illustration of related concepts sometimes appear unconnected on separate pages and the relationships among elements in the illustration are unexplained.

Statement of the Problem

The problem of this study is specified in "the low quality of science textbook illustrations in Egypt resulting from the deficiencies in the graphic designers' skills". Accordingly, the researcher attempts to answer the following main question: What is the effectiveness of a cognitive-based training program for graphic designers on the quality of science textbook illustrations? In attempting to answer this question, the following sub-questions will be answered:

- What are the components of a cognitive based training program to improve science textbook illustrations?
- What is the effectiveness of the training program on the quality level of illustrations?

Definition of Terms

- *A Cognitive-Based Training Program*: is a specific activities designed to help the graphic designers in the acquisition of knowledge, practical skills, and competencies that improve their capability of implanting the cognitive principles in the science textbook illustrations.

- *Illustrations*: are visual means of communication that are used to explain, elucidate, enhance, and call attention to a text in science textbooks. They can be classified into two groups: qualitative illustrations (e.g. photos, diagram, cartoon, clip art, information graphic, and map) and quantitative illustrations (e.g. data tables, line graph, area graph, bar graph, scatter plot, pie chart, pictogram, and Gantt chart).
- *Graphic Designer*: is a professional who creates the graphics for printed science textbooks.

Limitations of the Study

The present study is limited to:

- A group of science textbooks graphic designers who work for the Egyptian International Publishing Company-Longman (EIPL).
- Five cognitive theories, which are information-processing theory, model of working memory, dual-coding theory, cognitive load theory, and cognitive theory of multimedia learning.
- Some of the cognitive principle of design, which are related to illustrations used in the science textbooks.
- A group of science teachers who evaluated the illustrations before and after the training program.

Hypotheses

- To solve the study problem, the researcher tries to test the following hypothesis: There is a statistically significant difference between the mean scores of the graphic designers' performance on the pre-application of the criteria of illustrations versus the post application in favor of the post application.

Significance of the Study

This study might be of importance to the following stakeholders:

- *The graphic designers*: the research can help the graphic designers to understand about how the student's mind functions and apply effective cognitive principles when they design science textbook illustrations.
- *The trainers of graphic designers*: the research provides the trainers of the graphic designers with a cognitive-based training program that can improve their performance.
- *The Curriculum Planners*: this research can grasp the attention of the curriculum planners to increase the amount and space allotted for visual illustrations in science textbooks.
- *Science teachers*: this research provides the science teachers with a list of criteria that can help them to evaluate and choose the illustrations, which they need in their teaching processes.

Theoretical Background

1. Illustrations

Scientific communications of all types and levels involve mixtures of words, numerical values, and scientific symbols and illustrations. Many publishers and educators believe that not only texts, but also illustrations, are essential for science learning (Cook, 2008; Lee, 2010). According to Mirriam Webster's dictionary (2005), an illustration is a picture or diagram that helps make something clear or attractive. Halkia & Theodoridis (2001) regarded Illustrations as means of contemporary human communication that make the transfer of knowledge more friendly and attractive to the student. Vinisha and Ramadas (2013) defined illustrations as visual means of communication that are particularly helpful in introducing abstract concepts in science.

In recent years, illustrations have become a determining issue in education, occupying more and more space in school textbooks, educational software, and material of every kind (Halkia & Theodoridis, 2001). A large number of different illustrations, such as pictures, flowcharts, diagrams, maps, charts, drawings, etc., can be used in science textbooks to describe events and processes. Figure 1 shows a variety of illustrations which can be used to express concepts of "force and motion" as an example.

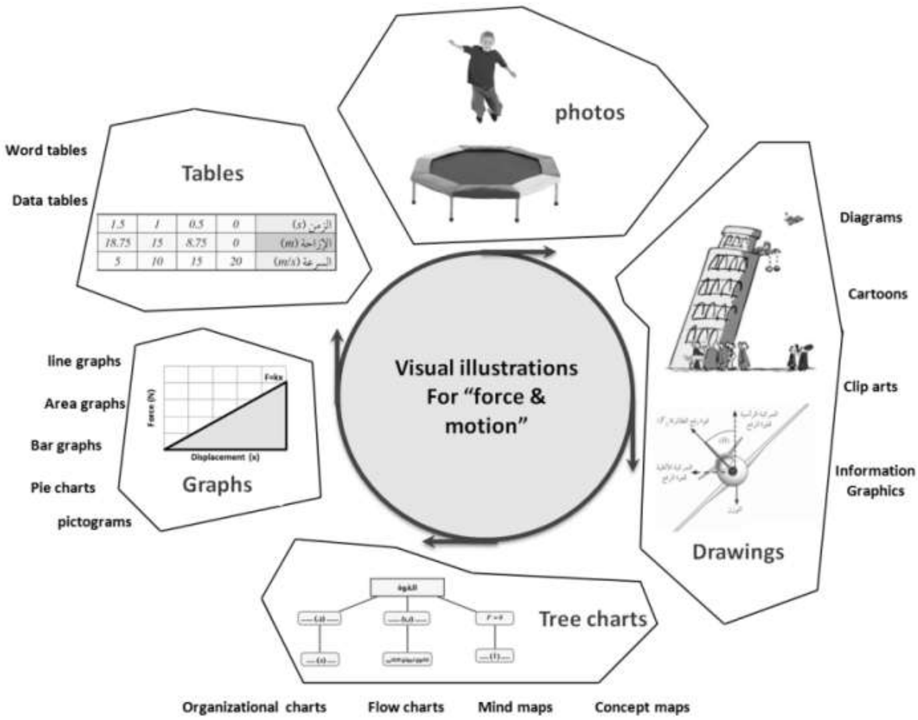

Figure 1. Types of Illustrations Which Can Be Used to Express Concepts of "Force and Motion"

Illustrations are powerful aids to understanding scientific information. They take the viewer to the often unobservable - from molecules and viruses to the universe, from depiction of the internal anatomy of arthropods and plants to geologic cross sections and reconstruction of extinct life forms, ranging from realistic to abstract portrayal (Hodges, 2003). Illustrations can help students grasp principles, which, on the basis of discursive accounts alone, may be hard to comprehend. They offer the chance to emphasize certain elements of the real object, which are hard to see, either because of 3D perspective, or because the natural object cannot, in real life, be cut away to best effect, or because its parts cannot be separated as cleanly as they can be in illustrations, where clutter can be removed (Kirsh, 2002).

Researchers have increasingly demonstrated the role of illustrations in improving the understandability of textbook passages. Using illustrations along with textual information enhanced learners' performance to a considerable extent. Aro and Woodard (2005) noted that visuals help in conceptualizing solutions to problems. Accordingly, it is best to combine imagistic and linguistic literacies as interdependent and cross-complementing frameworks in the meaning process in order to enable students acquire visual literacy. Birisci and Metin (2010) have succeeded in using illustrations to teach six graders science and technology in Turkey. Lee (2010) examined the extent to which representations in textbooks published in the US have changed over the past six decades. It was found that high-fidelity images, such as photographs are more often used than the schematic and explanatory images to promote the familiarization to students.

2. Cognitive Theories

Theories of learning contribute to our understanding of how science textbooks should be presented for effective learning and performance, particularly those theories that are based in the cognitive sciences and the study of how knowledge is acquired. Five related cognitive theories important to graphic designers are summarized: information-processing theory, model of working memory, dual-coding theory, cognitive load theory, and cognitive theory of multimedia learning.

2.1 Information-processing theory. Information processing theory is also known as the "dual-store model of memory." In 1968, Atkinson and Shiffrin proposed a model of memory based on two types of memory, short-term memory and long-term memory. In this model, short-term memory is very limited in duration (only seconds) and capacity (only seven units of information). Short-term memory includes sensory and working memory. Working memory is a system that performs an executive capacity by managing and manipulating information that constitutes a learner's current attention. Long-term memory has a seemingly infinite duration and capacity. The interaction of short-term and long-term components is the focus of learning. Although virtually anyone can attend to a particular stimulus, learning is dependent on the transfer of relevant information to long-term memory and its retrieval when performance is required (Chen, 2004; Lohr & Gal, 2008).

2.2 Model of working memory. In 1974, Alan Baddeley and Graham Hitch proposed a model of working memory in an attempt to describe a more accurate model of short-term memory. In Baddeley's model, working memory is composed of a central executive function. This function is involved in focusing attention, switching attention, and dividing attention. The executive function monitors two slave systems: a visual sketchpad (visual and spatial memory) and a phonological loop (auditory memory). In 2001, Baddeley added a third slave system to his model; the episodic buffer. This episodic buffer is the area that interfaces with the visual sketchpad and the phonological loop and it binds or integrates this information (Baddeley, 2003; Lohr & Gal, 2008).

2.3 Dual-coding theory. Dual-coding theory, a theory of cognition, was first advanced by Allan Paivio in 1990. According to Paivio, cognition is served by two interdependent systems; one of which is specialized for dealing with verbal information (i.e., text and speech), while the other one processes non-verbal information (i.e., graphics and animation). These separate memory systems are both capable of activating each other, as well as converting information from one form to another. Words can be coded in a verbal format, but are also capable of being converted to an image format, if prior knowledge allows. The same can be said for images whose form can be converted to a verbal description. From Paivio's point of view, the connection between the visual and verbal codes strengthens memory (Chen, 2004; Lohr & Gal, 2008; Sorden, 2005).

2.4 Cognitive load theory. Cognitive load theory, or CLT, states that working memory is limited in its capacity to selectively attend to and process incoming sensory data. From the perspective of cognitive load theory, instructional materials should be created for a theoretical optimal cognitive load. In other words, cognitive over-load impairs learning; cognitive under-load does not generate interest. The research on cognitive load describes three categories of load: intrinsic load, extraneous load, and germane load. The first type, intrinsic cognitive load, occurs during the interaction between the nature of the material being learned and the expertise of the learner. The second type, extraneous cognitive load, is caused by factors that are not central to the material to be learned, such as presentation methods or activities that split attention between multiple sources of information, and these should be minimized as much as possible. The third type of cognitive load, germane load, can be thought of as those things that can be done to facilitate optimal load, such as chunking content, sequencing it and providing analogies that can help people understand new information more quickly. Reducing extraneous, increasing germane, and managing intrinsic cognitive load can lead to effective learning (DeLeeuw & Mayer, 2008; Lohr & Gal, 2008; Sorden, 2005; Stull & Mayer, 2007; Sweller, 2005).

2.5 Cognitive theory of multimedia learning. Mayer (2009) explained the human information processing based on three basic assumptions: the dual channel assumption, limited capacity assumption, and active processing assumption. As the names suggest, the dual-channels assumption is based on the dual coding theory of Paivio. The limited-capacity assumption is based on the cognitive load theory of Chandler and Sweller. The final assumption, active processing, states that meaningful learning involves the cognitive process of actively building connections between verbal and pictorial representations.

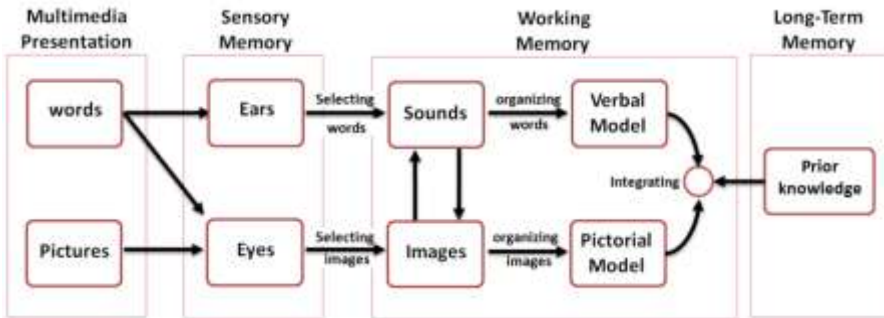

Figure 2. Mayer's Cognitive Theory of Multimedia Learning (Mayer, 2010)

As shown in Figure 2, Mayer (2010) divided human memory into three frames, which are sensory memory, working memory and long-term memory. Multimedia presentation, which includes pictures and words, enters sensory memory through the eyes and ears. Then, the sensory memory allows it to be held as exact visual images and auditory images for a very brief period in the visual and auditory sensory memory. The essential work of multimedia learning occurs in the working memory where it selects images and sound, organizes them, and integrates them. Long-term memory allows the students to store a large amount of knowledge over a long period of time. The learners represent active agents in the learning process via multimedia through these three processes: selecting, organizing, and integrating.

3. Cognitive Process Principles

The previous cognitive theories can help the graphic designers to create effective illustrations. Several researchers (e.g. Cheng et al., 2014; Mayer, 2008, 2010; Stull & Mayer, 2007) have conducted experiments based on these cognitive theories to generate suggestions for the design of the textbook. The researcher studied these researches to identify some of the most important cognitive principles for illustrations design. These principles can guide the science textbook graphic designers to present illustrations corresponding to the student mental processing of knowledge. Hence, these principles can reduce cognitive load, promote meaningful learning and link the new knowledge with the prior knowledge. They are presented as follows:

Principle 1. Illustration and text are better than illustration alone or text alone. The verbal elements play different roles when they are included in the illustrations. Students learn better from illustration and text than from illustration alone or text alone. In some illustrations, the words are the labeling of illustrations with captions, which are spatially integrated into the illustrations. Florax and Ploetzner (2010) showed that labeling of pictures can improve learning by guiding the learners' attention and signaling the relations among different pieces of information.

When words and pictures are both presented, learners have the chance to construct verbal and visual cognitive representations and integrate them into the long term memory; hence these representations will not be lost (Mayer, 2008; Sorden, 2005). In 2005, Sweller's research showed that the use of both words and pictures allows the brain to process more information in the working memory. Mayer (2008) found that In 11 out of 11 experiments, involving paper-based lessons on brakes, pumps, generators, and lightning; and computer-based lessons on brakes, pumps, lightning, and arithmetic; learners who received corresponding graphics with words performed better on transfer tests than learners who received words alone. For example, figure 3 shows an illustration of how a tire pump works. In a words-only presentation, learners receive a printed text explaining how a tire pump works; in a words-and-pictures presentation, learners receive the same printed text along with an illustration depicting the pump when the handle is pushed down and pulled up (Mayer, 2008).

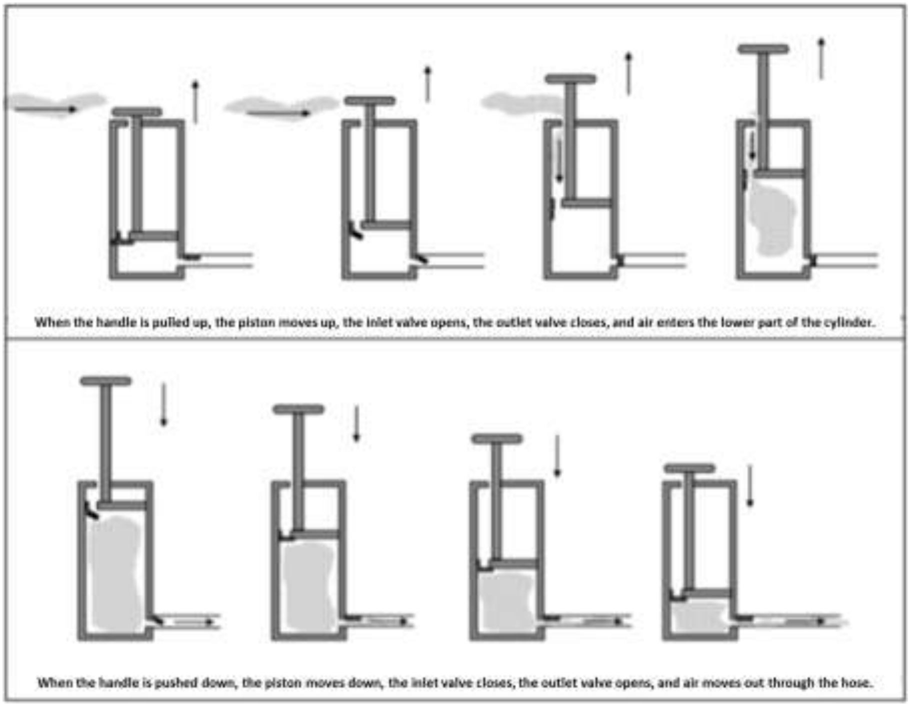

Figure 3. An illustration of How a Tire Pump Works (Mayer, 2014)

Principle 2. Illustration is more effective when learner's attention is focused. Students learn better when corresponding illustration and text are presented near rather than far from each other on the page (Mayer, 2008). When illustration and text are not presented together, learner's attention is split and the brain has more work to do to integrate the disparate sources of information (SEG research, 2008). Placing text under an image (i.e., a caption) is sufficient, but placing the text within the image is more effective (Doolittle, 2002). Mayer (2008) found that In five out of five tests, involving paper-based lessons on brakes and lightning and computer- based lessons on lightning, learners who received integrated presentations performed better on transfer tests than did those who received separated presentations. For example, students performed better on a transfer test after viewing an illustration about lightning in which printed words were placed next to the part of the lightning system they described than when printed words were placed at the bottom of the illustration as a caption (Mayer, 2014).

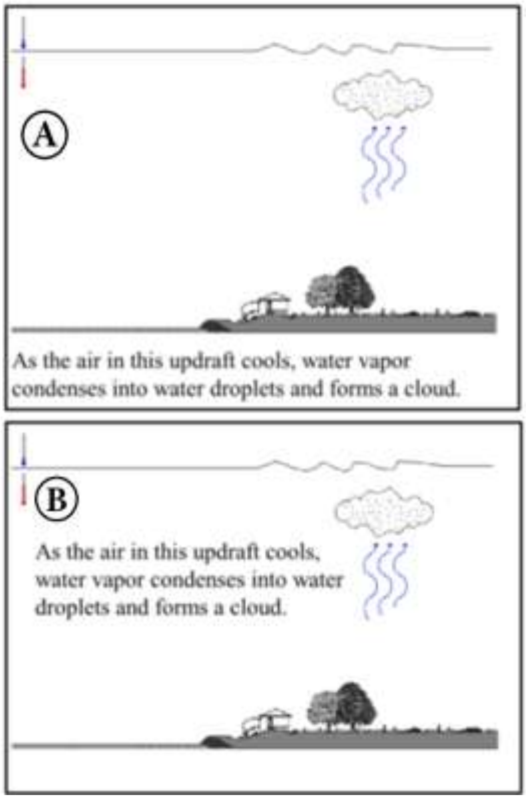

Figure 4. (A) Separated and (B) Integrated Presentation of Lightning (Mayer, 2009).

Principle 3. Illustrations should exclude extraneous and redundant information. In order to prevent redundancy, extraneous descriptions should be minimized in the text along with extraneous visual features such as unnecessary colors and details (Mayer, 2000). Mayer (2008) pointed out that students learn better when extraneous pictures and words are excluded rather than included. Inserting extraneous material may cause learners to engage in extraneous processing-by using their processing capacity to attend to and process material that is not essential. Learners given an expanded lesson may have less cognitive capacity for processing the essential material and therefore may be less likely to build a learning outcome that can be used to generate useful answers on a transfer test.

Principle 4. Essential information in the illustration should be highlighted. Most important information in illustrations must gain the attention of the learner, be held in the working memory, and ideally be in a form that is readily incorporated into the long-term memory (Lohr & Gal, 2008). People learn better from a lesson when the key ideas are highlighted both in the illustrations and in the text through using underlining styles, appropriate font sizes, font colors and styles, highlights, and arrows (Mayer, 2000). According to the cognitive theory of multimedia learning, signaling can help guide the learner's attention toward the essential material, thereby minimizing the learner's processing of extraneous material. Mayer (2008) found that In six out of six experiments, involving both paper-based lessons on lightning and biology and computer-based lessons on airplanes, learners who received signaled lessons performed better on transfer tests than those who received nonsignaled lessons.

Principle 5. Illustrations should be meaningful to the learner. The illustrations should be familiar to learners so that they could apply relevant past experiences to understand the material (Mayer, 2000). Long-term memory organizes information into meaningful chunks called schema. Presenting information in a way that makes use of existing organizing structures (schema) or that helps students organize the information can greatly assist the students in incorporating information into long term memory (SEG research, 2008). Mayer (2010) stated that meaningful learning occurs when students engage in active processing within the channels. It occurs through selecting suitable words and pictures, organizing them into coherent pictorial and verbal models, and integrating them with each other based on appropriate prior knowledge. These active learning processes occur when corresponding verbal and pictorial representations are in the working memory simultaneously.

Principle 6. Illustrations should be simple, with little elements. The fewer different objects are present in an illustration, the simpler it is. Several authors (e.g. Carney & Levin, 2002; Chrosniak, 2009; Schnotz, 2005) advise to keep illustrations simple, with little elements. Mikk (2000) recommends that a good illustration should not include more than seven objects or elements. Illustrations that are too colored and full of different information make understanding more complicated, because a student does not know where to put his focus. It can also complicate the learning process, because there is too much new information. The simplicity of an illustration means using fewer elements, clearer and understandable details; and also involves clarity in the background that is linked to the illustration (Piht et al. 2014).

Complex phenomena with highly interactive elements should be represented by using serial illustrations. For example, an explanation of how lightning storms develop consists of several steps and dozens of elements. This amount of detail is needed for even a simplified explanation of how lightning works, but the learner's cognitive system is likely to be overloaded by all this essential material. One cannot delete the material because it is needed for the learner to build a coherent mental representation (Mayer, 2008). Using serial illustrations to represent complex phenomena helps in minimizing extraneous load. The experiment should be presented in serial illustrations which indicate the experiment's steps. These steps should be arranged in a top-down order to correspond with the written procedures. (Cheng et al., 2014).

Principle 7. Illustrations should be effective for student learning. Carney and Levin (2002) categorized textbook illustrations as decorational, representational, organizational, interpretational, or transformational. Decorational illustrations just embellish the page; they bear little or no relationship to the print-based textual content. Representational illustrations mirror part or all of the text content and are the most commonly used type. Organizational illustrations provide a useful structural framework for the print-based textual content. Interpretational illustrations help clarify difficult text. Transformational illustrations include systematic, mnemonic components designed to improve a reader's recall of textual information. Illustrations under different categories have varying levels of influence on students' learning performance. Purely decorational illustrations exhibit virtually no beneficial text-learning effects, whereas the other types of illustrations' degrees of effect range from moderate (for representational illustrations) to quite substantial benefits (for transformational illustrations). Eliminating irrelevant illustrations helps in minimizing extraneous load.

Principle 8. Color should be used to connect illustrations with the text and distinguish different concepts. Colors in a visual can also play an important role. Apart from aesthetically enhancing the visual display, they could be used effectively to convey information, order, direction and categorization; to draw attention; to emphasize; and so on (Vinisha & Ramadas, 2013). Same color to represent relevant materials should be used in order to minimize learners' search time and to help them integrate information from visual channels. Different colors should be used to represent various concepts and structures. This helps in minimizing extraneous load. For example, red is used to represent combustion, green for the production and examination of oxygen, blue for the production and examination of carbon dioxide, yellow for the applications of oxygen and carbon dioxide in daily life, and gray for ways to extinguish fires (Cheng et al., 2014). According to Cook (2008), using color codes to relate graphical and textual elements can avoid the split-attention effect and promote learners' understanding of visual text.

Methodology

Eight cognitive principles were determined after studying the five cognitive theories. In the light of these principles, the training program for the science textbook designers was prepared by specifying its aims, content, training methods, activities, learning sources and evaluation techniques. As shown in table 1, the training program consisted of five main sections. This training program was examined by seven experts in the field of science education in Egypt. They confirmed that the training program could be useful after the modifications they suggested were done.

Table 1

The main sections of the training program

Sections	Contents	Time
1. The importance of illustrations	Introduction: the role of illustrations in the science textbook and the importance of illustrations for students and teachers	2 hours
2. Different types of scientific illustrations	Qualitative illustrations: photos, drawings (e.g. diagram, cartoon, clip art, information graphic, and map), tree charts (e.g. concept map, flow chart, organizational chart, mind map), and word tables (comparison of terms)	6 hours
	Quantitative illustrations: data tables (comparison of numbers) and graphs (e.g. line graph, area graph, bar graph, histogram, deviation bar graph, scatter plot, pie chart, pictogram, and Gantt chart)	
3. The cognitive Theories	The importance of studying the cognitive theories for science textbook designers, information-processing theory, model of working memory, dual-coding theory, cognitive load theory, and cognitive theory of multimedia learning	10 hours
4. The cognitive principles of illustrations design	1. Illustration and text are better than illustration alone or text alone	16 hours
	2. Illustration is more effective when learner's attention is focused	
	3. Illustrations should exclude extraneous information	
	4. Essential information should be highlighted	
	5. Illustrations should be meaningful	
	6. Illustrations should be simple	
	7. Illustrations should be effective for student learning	
	8. Color should be used to connect illustrations with the text and distinguish different concepts	
5. Applications	Using the cognitive principles to evaluate science textbooks from different countries (e.g. Egypt, Syria, Kuwait, Singapore, and the United States of America)	8 hours

The participants in the training program were nine science textbooks graphic designers who work for the Egyptian International Publishing Company-Longman (EIPL). EIPL was established in Cairo in 1982 as an Egyptian joint venture company. Over the years, EIPL has developed into a major publisher of science textbooks for schools in Egypt. It has produced about 33.3% of the science textbooks in Egypt. The participants have experience of 5-10 years in designing textbooks. However, their college studies were different, as shown in the following table:

Table 2

The college studies of the nine graphic designers

Academic Qualification	**Number of designers**	**Percentage**
Bachelor of Management	2	22.2%
Bachelor of Arts Education	2	22.2%
Bachelor of Language	2	22.2%
Bachelor of Law	1	11.1%
Bachelor of Arts	1	11.1%
Bachelor of Arabic and Islamic Sciences	1	11.1%

The content of "density" lesson, which contains the descriptions of 13 illustrations, was prepared by the researcher. The graphic designers were asked to design this lesson and the illustrations which are involved in it according to the descriptions, before the beginning of the training program, in light of their previous experiences. The training program was launched on January 16, 2014. It took 42 hours, as shown in table 1. These hours were distributed among 11 days. After completing the training program, the graphic designers were asked to design the “density” lesson and its illustrations, for the second time, in light of the cognitive principles of illustrations design, which they had learned in the training program.

A list of criteria was prepared to examine the quality of illustrations. Each criterion represented one of the eight cognitive principles. All illustrations in the lesson were coded. Scores for the illustrations were estimated in terms of the criteria on the left-side of this instrument, on the basis that: two points = the illustration completely met the criterion; one point = the illustration met the criterion, but still had some problems; zero points = the illustration did not meet the criterion. In this respect, a perfect illustration meeting 8 criteria got a total score of sixteen. The instrument allotted a column for every single illustration used in the lesson. At the bottom this list of criteria, extra lines were provided so that the user could add additional comments about the problematic illustrations. This was deliberately done so that qualitative data could be blended with the quantitative information to get more efficient evaluation results. The users were asked to add extra comments whenever they gave zero points to a specific illustration.

Twelve experts in the field of science education examined the instrument, and were asked for modifications to the ambiguous aspects of the users' manual. They confirmed that the instrument could be useful after the modifications they suggested were done. The internal consistency reliability of the instrument was sustained. A randomly selected unit from a science textbook for seventh grade was evaluated by 15 teachers who work in the Maadi Educational Administration in Cairo. Scores were submitted into SPSS to investigate the internal consistency reliability of the instrument (i.e., Cronbach's Alpha). The alpha (α = 0.9187) was higher than the suggested ideal alpha (i.e., 0.70) which means that the instrument can be objectively and efficiently implemented by different users.

Thirty three science teachers, working in five middle schools in Basateen and Dar-Elsalam Educational Administration in Cairo, were asked to use this instrument to evaluate the illustrations of the lesson of "density", which were designed before and after the training program. About 117 illustrations (13 illustrations × 9 designers), designed before the training program, and the same number of illustrations, designed after the training program, were evaluated by each teacher. The maximum scores for any criterion were 234 points. If the graphic designers mean scores in a particular criterion were higher than 164 points (70%), this means that they were skilled in designing the illustrations in the light of this cognitive principle. If their mean scores for the eight criteria were higher than 1310 points (70%), this means that they were able to implant the cognitive principles in the illustrations.

Results

The data were submitted into SPSS. Paired-Samples T-test was employed to test the significant difference between 'pre-training and post-training designing of illustrations. The results of the analysis are represented in table 3 that shows the mean values, standard deviation value and t-value to denote the differences between the mean scores before and after the training program, as well as for each dimension (cognitive principle) of the list of criteria:

Table 3

Comparison of pre and post-training mean scores

The cognitive principles	Total scores	Before the training program			After the training program			t-value	sig	Remarks
		M	%	SD	M	%	SD			
Principle1	234	160.4	68.6	22	222.7	95.2	12.7	15.6	0.000	Sig.
Principle2	234	151.5	64.7	20.1	213.3	91.1	13.1	18.2	0.000	Sig.
Principle3	234	143.1	61.1	21	210.9	90.1	17.5	16.7	0.000	Sig.
Principle4	234	121.5	51.9	19.3	199.6	85.3	21.2	17.3	0.000	Sig.
Principle5	234	135.9	58.1	20.4	203	86.7	19.4	14.4	0.000	Sig.
Principle6	234	116.2	49.6	19.9	217.2	92.8	12.7	27.7	0.000	Sig.
Principle7	234	130.1	55.6	19.9	206.6	88.3	18	18.4	0.000	Sig.
Principle8	234	109.8	46.9	16.1	194.7	83.2	25.1	15.8	0.000	Sig.
Total	1872	1068.5	57.1	141.4	1668	89.1	119.4	21	0.000	Sig.

$df = 32$, $P < 0.01$

For the total of the eight principles, Table 3 indicates that the t-value (21) is significant at 0.01 level. Furthermore, it is obvious that the total mean value of the post-training illustrations (1668) is greater than the total mean value of the pre-training illustrations (1068.5). This shows that there is a significant difference between the quality of the pre-training illustrations and post-training illustrations. It is therefore concluded that the cognitive-based training program for graphic designers had significant impact on the quality of the designed illustrations. In other words, the training program was effective in terms of enhancing the skills of science textbook designers in implementing the cognitive principles in the illustrations design.

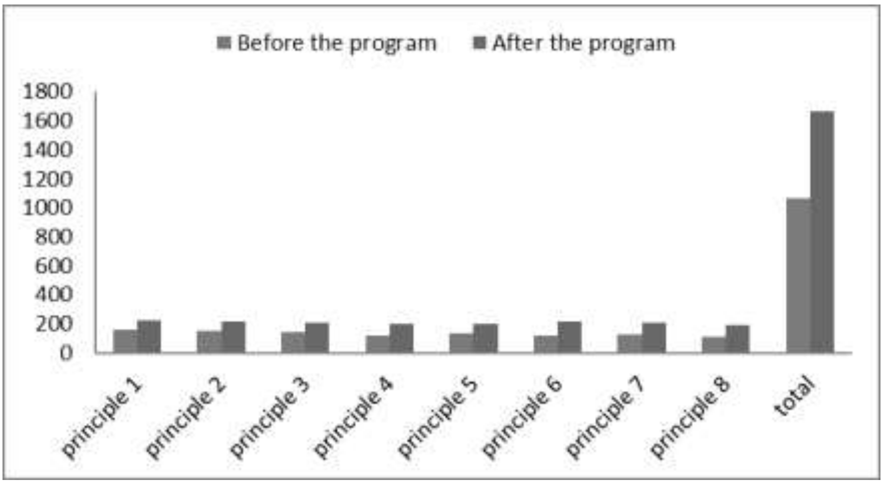

Figure 5. Comparison of Pre and Post-Training Scores

The mean value of the pre-training illustrations did not reach the ratio 70%. This means that the skills of the science textbook graphic designers were deficient. The mean value of the post-training illustrations exceeded the ratio 70%. This means that the designers were able to implant the cognitive principles in the science illustrations.

Table 3 indicates that illustrations that were designed before the training program got the highest score in the first principle (68.6%); however, it is a low percentage, while they got the lowest score in the eighth principle (46.9%). On the other hand, illustrations that were designed after the training program got the highest score in the first principle (95.2%), while they got the lowest score in the eighth principle (83.2%); however, it is a high percentage.

As for the first principle, the mean score of the pre-training illustrations was (160.4); i.e. (68.6%) while the mean score of the post-training illustrations was (222.7); i.e. (95.2%). The t-value (15.7) is significant at 0.01 level. Teachers noticed that some illustrations in the pre-training lessons did not include any words or captions. In the lessons prepared after the training program, most of the illustrations were annotated by a caption. The texts and illustrations were juxtaposed. For example, an illustration of "sink or float", which was designed before the training program, had no corresponding caption to explain its meaning. After the training program, a corresponding caption was added to this illustration to explain its meaning.

Figure 6. The Illustration of "Sink or Float" (A) before the Program and (B) after it.

As for the second principle, the mean score of the pre-training illustrations was (151.5); i.e. (64.7%) while the mean score of the post-training illustrations was (213.3); i.e. (91.1%). The t-value (18.2) is significant at 0.01 level. Teachers noticed that the picture and text in some illustrations in the pre-training lessons were not presented together. In the lessons designed after the training program, most of the text and pictures in the illustrations were presented in an integrated way. For example, text and pictures were not presented together in the illustrations of "floating" which were designed before the training program. After the training program, the text was placed under the pictures.

Figure 7. The Illustration of "Floating" (A) before the Program and (B) after it.

As for the third principle, the mean score of the pre-training illustrations was (143.1); i.e. (61.1%) while the mean score of the post-training illustrations was (210.9); i.e. (90.1%). The t-value (16.7) is significant at 0.01 level. Teachers noticed that some illustrations in the pre-training lessons contained extraneous and redundant information like unnecessary colors and details. In the lessons prepared after the training program, redundancy and extraneous visual features such as unnecessary colors and details were minimized. For example, some bar graphs, which were designed before the training program contained colored backgrounds. After the training program, these unnecessary backgrounds were excluded.

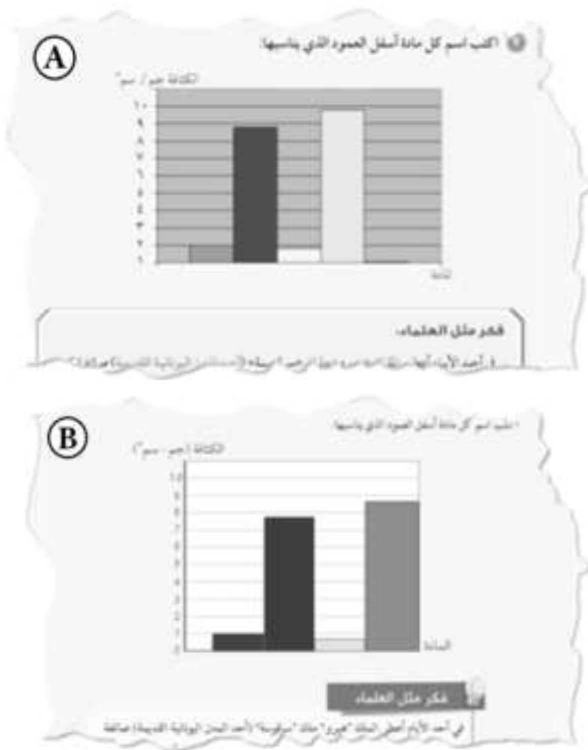

Figure 8. The Bar Graph(A) before the Program and (B) after it.

As for the fourth principle, the mean score of the pre-training illustrations was (121.5); i.e. (51.9%) while the mean score of the post-training illustrations was (199.6); i.e. (85.3%). The t-value (17.3) is significant at 0.01 level. Teachers noticed that essential information in some illustrations in the pre-training lessons was not highlighted; therefore, these illustrations cannot direct the learner's attention towards the most important information. In the lessons prepared after the training program, key ideas in most illustrations were highlighted; so they can attract the learner's attention. For example, the reading of the liquid level in the beaker was not signaled in the illustrations designed before the training program. After the training program, the reading was highlighted.

Figure 9. The Illustration of "Measuring the Volume of a Liquid"(A) before the Program and (B) after it.

As for the fifth principle, the mean score of the pre-training illustrations was (135.9); i.e. (58.1%) while the mean score of the post-training illustrations was (203); i.e. (86.7%). The t-value (14.4) is significant at 0.01 level. Teachers noticed that some illustrations in the pre-training lessons were not familiar to the learners or related to their prior knowledge. In the lessons prepared after the training program, most illustrations were related to the learners' previous experiences. For example, the illustration of "the density of wood and iron" was presented by using two separated pictures; one showed a wood cube and the other showed an iron cube. This presentation cannot help the students to create meaningful learning. After the training program, this illustration was presented by using scales showing that an iron cube is heavier than a wood cube with the same size. This illustration will help the students to create meaningful learning.

Figure 10. The Illustration of "the Density of Wood and Iron" (A) before the Program and (B) after it.

As for the sixth principle, the mean score of the pre-training illustrations was (116.2); i.e. (49.6%) while the mean score of the post-training illustrations was (217.2); i.e. (92.8%).

The t-value (27.7) is significant at 0.01 level. Teachers noticed that some illustrations in the pre-training lessons were complicated with too many elements. In the lessons prepared after the training program, most illustrations were simple with fewer elements. For example, some concept maps of the lessons, which were designed before the training program, contained too many elements such as colors, arrows, and frames. After the training program, these concept maps became simpler with fewer elements and clearer details.

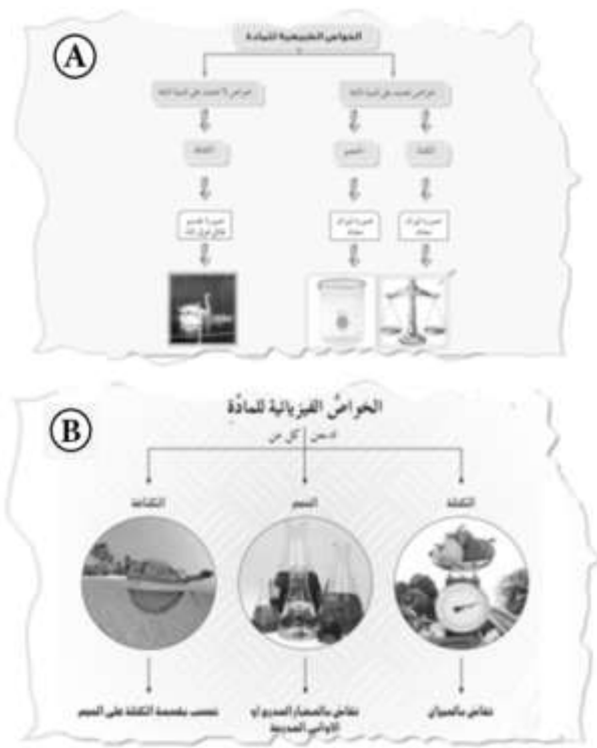

Figure 11. A Concept Map of the Lesson (A) before the Program and (B) after it.

As for the seventh principle, the mean score of the pre-training illustrations was (130.1); i.e. (55.6%) while the mean score of the post-training illustrations was (206.6); i.e. (88.3%). The t-value (18.4) is significant at 0.01 level. Teachers noticed that a significant proportion of the pages in the pre-training lessons had visuals for predominantly decorative purposes, like, colorful borders, drawings, cartoons, boxes and icons. These decorative illustrations were eliminated after the training program. For example, an illustration of "a fishbowl” was used before the training program and was eliminated after it.

Figure 12. The illustration of "fishbowl" (A) Existed before the Program and (B) Eliminated after it.

As for the eighth principle, the mean score of the pre-training illustrations was (109.8); i.e. (46.9%) while the mean score of the post-training illustrations was (194.7); i.e. (83.2%). The t-value (15.8) is significant at 0.01 level. Teachers noticed that colors were not used to connect illustrations with the text and distinguish different concepts. In the illustrations prepared after the training program, colors were used effectively to convey information and draw attention. For example, the illustration of "states of matter" before the training program was presented by using the same color to draw the particles of the solid, liquid and gas. After the training program, different colors were used to represent different states of the matter.

Figure 13. The illustration of "States of Matter" (A) before the Program and (B) after it.

Conclusion

Results indicate that the ability of graphic designers to implant the cognitive principles was low before the training program. The teachers pointed out that the illustrations, which were prepared after the training program, were more compatible with the cognitive principles than the illustrations prepared before the training program. The percentage of the mean scores of the illustrations, designed before training program, from the perspective of science teachers, was (57.1%). This low percentage indicates the weakness in the designers' skills. After the training program, the ability of the graphic designers to implant the cognitive principles in science illustrations has increased. The percentage of the mean scores of their illustrations increased to (89.1%). This high percentage indicates the improvement in their skills due to the training program which enhanced their skills. This training program has grabbed their attention to the importance of illustrations for the students and teachers. The cognitive theories and their principles were explained in detail, in the training program, with various examples. The graphic designers had the opportunity to apply what they have learned in the training program by observing and evaluating science textbooks from different countries. This research recommends that the cognitive theories and their principles should be integrated in the programs of preparation and training of textbook graphic designers. In addition, science textbooks in Egypt should be evaluated in light of the cognitive principles. The results of this evaluation should be presented to the science textbook designers to provide them with a continuous feedback about their designs.

References

Foreign References

1. Aro, L. & B. Woodard (2005). Visual images and information literacy. *Reference and User Services Quarterly*, *45* (1), 27-32.
2. Baddeley, A. (2003). Working Memory: Looking back and looking forward. *Nature Reviews Neuroscience*, *4* (10), 829-839.
3. Birisci, S. & Metin, M. (2010). Developing an instructional material using a concept cartoon adapted to the 5E model: A sample of teaching erosion. *Asia-Pacific Forum on Science Learning and Teaching*, *11* (1), 1-16. Retrieved from http://www.ied.edu.hk/apfslt/

4. Carney, R. & Levin, J. (2002). Pictorial illustrations still improve students’ learning from text. *Educational Psychology Review*, *14*, 5-26.

5. Chen, H. (2004). A Review of learning theories from visual literacy. *Journal of Educational Computing, Design, and Online Learning*, *5* (3), 1-8.

6. Cheng, M., Chou, P., Wang, Y., & Lin, C. (2014). Learning effects of a science textbook designed with adapted cognitive process principles on grade 5 students. *International Journal of Science and Mathematics Education*, published online: Jan., 1-22. doi: 10.1007/s10763-013-9471-3

7. Chrosniak, P. (2009). Seeing what we know, knowing what we see: the involvement of visual literacy in learning. In J. Pedersen & K. Finson (Eds.), *Visual data: Understanding and applying visual data to research in education* (pp. 133–150). Rotterdam: Sense

8. Clark, R. & Lyons, C. (2004). *Graphics for learning*. San Francisco: Pfeiffer.

9. Clement, P. (2008). Introduction to the special issue of SEI-relating to critical analysis of school science textbooks. *Science Education International*, *19* (2), 93-96.

10. Cook, M. (2008). Students’ comprehension of science concepts depicted in textbook illustrations. *Electronic Journal of Science Education*, *12* (1), 39–54.

11. DeLeeuw, K. & Mayer, R. (2008). A comparison of three measures of cognitive load: Evidence for separable measures of intrinsic, extraneous, and germane load. *Journal of Educational Psychology*, *100* (1), 223-234.

12. Doolittle, P. E. (2002). *Multimedia learning: empirical results and practical applications*. Irish Educational Technology Users' Conference, Carlow, Ireland. Retrieved from http://scr.csc.noctrl.edu/courses/edn509/resources/readings/multimediaLearningEmpericalResults.pdf

13. Florax, M. & Ploetzner, R. (2010). What contributes to the split-attention effect? The role of text segmentation, picture labeling, and spatial proximity. *Learning and Instruction*, *20* (3), 216-224. doi:10.1016/j.learninstruc.2009.02.021
14. Halkia, Kr. & Theodoridis, M. (2001). Latent aspects in science textbooks pictures, Proceedings of the third International Conference on Science Education Research in the Knowledge Based Society, II, 850-852.
15. Helfand, J. (2012). "What is graphic design?". AIGA | the professional association for design. Retrieved from http://www.aiga.org/what-is-design/
16. Hodges, E. (2003). *The Guild Handbook of Visual illustration.* Second Edition. Hoboken, New Jersey: John Wiley & Sons.
17. Kaptan, A. & Kaptan, S. (2005). Design problems and the effects on students' learning level textbooks. *Journal of 19 Mayıs University, Faculty of Education*, *19*, 59-66.
18. Kirsh, D. (2002). Why illustrations aid understanding. In R. Ploetzner (Ed.), *International Workshop on Dynamic Visualizations and Learning*, *Tubingen*, Germany: Knowledge Media Research Center.
19. Lee, V. R. (2010). Adaptation and continuities in the use and design of visual representations in US middle school science textbooks. *International Journal of Science Education*, *32* (8), 1099-1126. doi:10.1080/09500690903253916
20. Lohr, L. & Gal, J. (2008). Representation strategies. In J. Spector, M. Merrill, J., Van Merrienboer, & M. Driscoll (Eds.) *Handbook of research on educational communications and technology (3rd Ed.)* (pp. 85-96). New York: Lawrence Erlbaum Associates.
21. Mayer, R. (2000). *Multimedia Learning*. Cambridge, UK: Cambridge University Press.

22. Mayer, R. (2008). Applying the science of learning: Evidence-based principles for the design of multimedia instruction. *American Psychologist*, *63* (8), 760-769.

23. Mayer, R. (2009). *Multimedia learning* (2nd Ed.). New York: Cambridge University Press.

24. Mayer, R. (2010). Applying the science of learning to medical education. *Medical Education*, *44*, 543-549. doi:10.1111/j.1365-2923.2010.03624.x

25. Mayer, R. (2014). Research- based principles for designing multimedia instruction in Benassi, V., Overson, C., & Hakala, C. (Eds.) *Applying the science of learning in education: Infusing psychological science into the curriculum* (pp. 59-70). Washington, DC: American Psychological Association.

26. Merriam-Webster's collegiate dictionary (11th Ed.). (2005). Springfield, MA: Merriam-Webster

27. Mikk, J. (2000). *Textbook: Research and Writing*. Frankfurt: Peter Lang GmbH.

28. Pettersson, R. (2003). Gearing communications to the cognitive needs of students: findings from visual literacy research. *Journal of Visual Literacy*, *24* (2), 129-154.

29. Piht, S., Raus, R., Kukk, A., Martin, K., & Riidak, K. (2014). Students´ interpretations of the 6th grade science textbook design. *Procedia - Social and Behavioral Sciences*. 861 - 872. Elsevier. doi: 10.1016/j.sbspro.2014.01.1243

30. Schnotz, W. (2005). *The Cambridge Handbook of Multimedia Learning*. New York: Cambridge University Press.

31. SEG Research. (2008). *Understanding Multimedia Learning: Integrating multimedia in the K-12 classroom*. Pennsylvania: New Hope.

32. Slough, S., McTigue, E., Kim, S., & Jennings, S. (2010). Science textbooks' use of graphical representations: A

descriptive study of four sixth grade science texts. *Reading Psychology*, *31*, 301-325. doi:10.1080/02702710903256502

33. Sorden, S. D. (2005). A cognitive approach to instructional design for multimedia learning. *Informing Science Journal*, *8*, 263-279.
34. Stull, A. & Mayer, R. (2007). Learning by doing versus learning by viewing: Three experimental comparisons of learner-generated versus author-provided graphic organizers. *Journal of Educational Psychology*, *99*, 808-820.
35. Sweller, J. (2005) Implications of cognitive load theory for multimedia learning. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (pp.19-30). New York: Cambridge University Press.
36. Vinisha, K. & Ramadas, J. (2013). Visual Representations of the water cycle in science textbooks, *Contemporary Education Dialogue*, *10* (1), 7-36. doi: 10.1177/0973184912465157

Arabic References

١. الحصري، أحمد (٢٠٠٠٤). مستويات قراءة الرسوم التوضيحية ومدى توافرها فى الاسئلة المصورة بكتب وامتحانات العلوم بالمرحلة الإعدادية. الجمعية المصرية للتربية العلمية. *مجلة التربية العلمية*، ٧ (١)، ١٥-٧٢.

٢. يونس، جمال الدين (٢٠٠٣). تقويم كراسه التدريبات والأنشطه لمناهج العلوم بالمرحله الابتدائيه فى ضوء أساليب الاتصال البصرية وعمليات العلم الأساسية. الجمعية المصرية للتربية العلمية. *مجلة التربية العلمية*، ٦ (٢)، ١-٣٩.