The interaction between brain-based learning strategies and patterns of infographics and its influence on the development of information concepts among Saudi undergraduate cybersecurity students [version 1; peer review: awaiting peer review]

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Abstract

The study reported in this paper investigates the impact of the interaction between brain-based learning strategies (spaced repetition and distributed practice - mental models) and patterns of infographics (static/animated) in e-learning environments and its impact on the development of informational concepts among cybersecurity students. The quantitative data were collected by means of Information Concept Test to determine the levels of information concepts according to the Frayer model (1969). The research sample consists of 80 male and female undergraduate students in Qassim University, who were classified into four quasi-experimental groups according to their preferred patterns in the infographic. Quantitative analysis of findings from this study shows an effect for the interaction between the variables of brain-based learning strategies (spaced repetition and distributed practice - mental models) and patterns of infographics (static/animated) in e-learning environments in the test scores of information concepts in the post-administration, where the significance level (.011) is less than the significance level (0.05). Findings also revealed that the repetition of information at increasing intervals of time using the infographics is effective to learning concepts in an organized manner and to improving short memory. Furthermore, the mental model's strategy also helped to retain information. The study recommends encouraging the use of brain-based learning strategies and patterns of infographics (static/animated) in e-learning environments to explore the relationships between different scientific concepts, to expand
students' knowledge, and to discover inter-relationships between different subject elements. The study provides a platform for further research to employ different brain-based learning strategies within e-learning environments to acquire higher-order thinking skills and improve students' memory and mental capacity with the use of modern technological techniques that achieve learning quality.

**Keywords**
Learning, E-learning, E-learning environments, Infographics, Brain-Based Learning Strategies, Mental Models Strategy, Spaced Repetition and Distributed Practice Strategy, Information Concepts, Saudi Undergraduate Students, Cybersecurity

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Introduction
In light of the information revolution and technological development, it has become necessary to use pedagogical, mental and cognitive strategies and modern technologies in adaptive e-learning environments. In addition, there is a need to capitalize on research on how the brain works to introduce strategies for learning, education and training. In this regard, the needs, motives, interests and tendencies of students must be taken into account to help them achieve learning outcomes in a better way and achieve the success of the educational process. Teaching strategies based on brain-based learning are new strategies used by teachers and trainers to enhance and improve learning and memory in the classroom and in e-learning environments for learning quality and memory improvement (Lubis, 2017; Yustitia et al., 2019). Brain-based learning has become a necessity for learner education, as it provides multiple patterns and forms of thinking, and allows for the existence of many diverse, supportive and effective training strategies and applications in the field of thinking and methods of improving memory. Brain-based learning theory is a theory that links brain science, neuroscience, behavioral science, and cognitive science. Brain-based learning strategies help enrich teaching and learning processes and provide an adaptive learning environment by focusing on attention, memory, motivation, the way information is presented, and ways of acquiring conceptual knowledge. Instructional environments and strategies based on brain-based learning are also characterized by the diversity of digital learning resources, sharing of information, obtaining immediate feedback that learners need, as well as developing thinking and creativity skills (Sesmiarni, 2015). Brain-based learning strategies allow the learner to reduce memory loss as well as improve basic learning ability by directly enhancing basic learning processes in the brain. The aspects of learning that rely on the brain are varied (Caine & Caine, 1994; Crow, 2011; Jensen & McConchie, 2020). Similarly, Amit-Danhi (2020) discovered that students recalled more of what they read when it was accompanied by visuals, such as pictures or graphs (Amit-Danhi, 2020). Therefore, infographics would increase knowledge retention can and help improve learning outcomes.

Context of the problem
The previous introduction shows brain-based learning strategies that may help improve students’ memory through the operation of the left and right hemispheres and the optimum using activities, e-learning resources such as infographics (staticanimated). Research studies that dealt with brain-based learning have proven the effectiveness of brain-based learning on developing e-learning environments and improving memory recall and retention of facts and details (Jensen & Mcconchie, 2020). In addition, the integration of brain-based learning strategies and content presentation methods using graphs and models is significant for the improvement in the performance of the e-learning system based on learning environments (Erol & Karaduman, 2018). The Twelve Steps of Brain-Based Learning allow instructors to reach a more diverse group of learners, confirming the idea that not all students learn the same way and allowing instructors to teach in many ways. In addition, results of a pilot study on a sample of cybersecurity diploma students show positive perception toward brain-based learning strategies due to performing a number of active tasks that help them interact and share digital resources. It also allows students to work together to solve problems, both by synchronous and asynchronous communication.

Problem of the study
There are many previous related studies whose results and recommendations dealt with brain-based learning, its role, importance, and effectiveness in achieving educational and training objectives (Craig, 2003; Green, 2017; Elusura, 2017; Jensen & McConchie, 2020). However, no research has been carried out to investigate the interaction between brain-based learning strategies and infographics for Saudi cybersecurity undergraduate students to improve their low achievement scores in the scientific terminology course, due to the difficulty in understanding the concepts and information of the course and the students’ exposure to memory loss and forgetfulness.

Research questions
The current study pursues to answer the following questions

1. What are the informational concepts that Saudi undergraduate cybersecurity students should have?

2. What are the criteria of designing and producing infographics (staticanimated) to develop informational concepts for Saudi undergraduate cybersecurity students?

3. What is the educational design of an adaptive e-learning environment-based brain-based learning strategies (spaced repetition and distributed practice - mental models) for developing information concepts among Saudi undergraduate cybersecurity students?

4. What is the effect of the interaction between brain-based learning strategies (spaced repetition and distributed practice-mental models) and infographics (staticanimated) and its impact on the development of information concepts for Saudi undergraduate cybersecurity students?
Hypotheses of the study
The present study will examine the validity of the following hypothesis
There is a significant interaction between brain-based learning strategies (spaced repetition and distributed practice - mental models) and patterns of infographics (static/animated) in e-learning setting in the post-measurement of Information Concepts Test after adjusting the pre-measurement effect.

Purpose of the study
Objectives of the study
1. Determine the informational concepts that cybersecurity students should have.
2. Develop acquisition of informational concepts for cybersecurity students.
3. Determine the criteria of designing the adaptive electronic environment based on learning strategies.
4. Introduce a proposed conceptualisation of the e-learning environment based on brain-based learning strategies to develop informational concepts among cybersecurity students.
5. Identify the interaction between both brain-based learning strategies and infographics, and its impact on the development of information concepts among cybersecurity students.

Significance of the study
Three reasons make this research noteworthy. First, it provides insight into a topic that has received a lot of attention from scholars all around the globe. Second, it helps fill a gap in Arab scholarship on the topic of infographics (both static and dynamic) and the role they play in the evolution of conceptual understanding. Third, it keeps pace with global modern trends to develop education and increase the effectiveness of the educational process by making the learner the focus of the educational process. The study would also provide guidelines for presenting a model for designing the adaptive electronic environment based on providing educational situations that remove turmoil, confusion and fear of failure through cooperation with colleagues and participation to take responsibility that can be emulated in the field of e-learning technology applications. Furthermore, the current research may help in providing a framework for developing an educational situation that helps learners enhance their memory and retention abilities.

Literature review and related studies
Brain-based learning is a paradigm of learning which addresses student learning and learning outcomes from the point of view of the human brain. Jensen and Mcconchie (2020) state that brain-based learning refers to teaching methods, lesson designs, and school programs that are based on the latest scientific research about how the brain works, including factors such as cognitive development—how students learn differently as they age, grow, and mature socially, emotionally, and cognitively. The researchers define brain-based learning procedurally as learning compatible or harmonious with the brain according to the way the brain works in order to achieve the best possible excitation of the brain to learn in the best possible way and achieve the best results.

Brain-based learning strategies can be defined procedurally as brain-based learning strategies that include a set of steps, procedures and practices based on the theory of brain-based learning that is compatible with its functions that the instructor uses to improve the concepts of cybersecurity, and it consists of the following five stages: readiness for learning, organized integration, quiet alertness, active processing, increase brain capacity to achieve the best results.

Brain-based learning uses several brain-based strategies, including:

1. With spaced repetition, the time intervals between learning attempts can be increased, and each learning attempt strengthens neural connections, supporting the findings of distributed practice and spaced repetition that distributing learning over time and repeating information over increasing periods strengthens memories and shields against forgetting. As shown in Figure 1, where the student studies a related set of concepts (A), then a set of concepts (B), and so on for a set of concepts (C) and (D), and this spaced repetition is distributed in the week, while the study of concepts is prohibited with these Method (AAAA), (BBBB), (CCCC), (DDDD).

The current research focuses on spaced repetition strategies and distributed practice. The Ebbinghaus Forgetting Curve may change Figure 2:
2. Activities such as developing art, instructing others, applying knowledge in real-world situations, writing blog entries, participating in online discussion forums, etc. all fall under the umbrella of “generative learning.” In order to rethink and restructure information, it is necessary to combine new knowledge with previously acquired information. This helps to reinforce what was learned and reveals any gaps in understanding. Recall, comprehension, and the ability to acquire new information in-depth and broadly are all enhanced as a result.

3. The production effect, in which knowledge is replicated vocally or graphically, is a frequent strategy for improving retention of that information. In order to quickly override the brain’s natural inclination to consolidate new knowledge, it is helpful to speak, listen to, or teach the material aloud. One’s ability to remember and memorise information is enhanced.

4. Memorising knowledge, practicing, and the testing impact all go under “retrieval practice.” Because forgetting and remembering are not opposites, this may not prevent people from remembering. Retrieval training and testing are effective learning strategies because they strengthen prior knowledge while also providing an opening for new information to be acquired through the investigation of misconceptions and the accumulation of little successes. Memory may be strengthened in the context of remembering by retrieval exercise. The brain’s optimal state for learning has a distinct profile from that for recall and memory. The capacity to recollect information is crucial for making use of new knowledge. As a result, one’s ability to remember material, feel secure in oneself, and do well under testing conditions.

5. Mental models are depictions of concepts that serve as templates for thinking and provide feedback loops; they are schemas of real-world processes. Stories and comparisons are powerful learning tools because people naturally gravitate toward them. When we utilise a metaphor, we “abstract” and grasp the core of the unknown process because of the contrast it establishes between the identified and unidentified processes.
6. What we mean when we talk about “chunking” is breaking down larger chunks of text into smaller, more manageable chunks that all relate to the same topic. Information can be chunked based on superficial attributes such as colour, similarity, category, relationships, etc. The brain uses networks of information, thus it is simpler to recall several chunks than it is to remember several separate parts. As opposed to relying only on rote memorization, cognitive processes may help you retain complex information, make sense of complex concepts, and make connections between ideas. Figure 3 demonstrates the effectiveness of infographics in elucidating ideas by drawing parallels to the mental models approach.

**Figure 3. Use of infographics to explain concepts through comparisons in mental models strategy.**

**Characteristics of brain-based learning**

Based on a thorough survey of related literature (Blakemore & Frith, 2016; Medina, 2018; Jensen & Mcconchie, 2020; O’mahony, 2021), the basic characteristics of brain-based learning can be illustrated as follows:

1. The theory of brain-based learning is based on the fact that the human being is able to learn and acquire, if the appropriate conditions are provided for him, and his ability to learn increases by stimulating and activating neurons to form the largest possible number of neural connections with other neurons.

2. The human brain can learn best when the left and right hemispheres are involved in information processing, storage and retrieval and teaching is in accordance with the principles and postulates of brain-based learning.

3. Learning according to traditional curricula based on memorization is no longer valid for teaching now. Therefore, teaching and learning methods and strategies should evolve to suit the new challenges, especially the different thinking skills.

4. Principles underlying Brain-Based Learning Theory involve body physiology since the search for meaning is innate and learning occurs through simulation of emotions and the mind processes parts and words simultaneously.
Uses of brain-based learning

Cohen et al. (2003), Willis (2008), Blakemore and Frith (2016), and Masurkar (2021) illustrate many uses for brain-based learning, including:

1. Brain-based learning enhances students’ academic progress and fosters a positive learning environment.
2. Instructors who apply brain-based learning often observe increases in knowledge retention and academic performance.
3. When students develop an intrinsic love for learning and approach the classroom with the right mindset, the classroom will be motivating and exciting.
4. Brain-based learning creates a learning environment and classroom strategy where all students can thrive.

Infographics can be defined as a representation of information in a graphical format designed to make data easy to understand. Teachers use infographics to communicate a message to students simplify. Infographics include line charts, graphs, charts, and mind maps.

Infographics are of great importance in the teaching and learning processes, and there are many studies that have confirmed the effectiveness of the infographic in the teaching and learning process. On top of these, Rendgen et al. (2020) who emphasized the importance of employing infographics in e-learning environments, and its effective role in supporting educational content and simplifying complex and large information. In addition, infographics are attractive and exciting in presenting information, improving understanding of information, ideas and concepts that improve information retention and retrieve, enhancing the ability to think critically, attracting attention, making images easy and quick to read, and helping generate large amounts of information (Smiciklas & Wiegand, 2012; Krum, 2014).

Criteria for a successful infographic design are illustrated by (Beegel, 2014; Julien et al., 2020) as organizing the content and categorizing it according to the level of importance. Correct and effective visual coding is a guide for students to focus and follow the flow of information; Determine the audience for which the infographic will be presented, the infographic must be educationally sound; It helps learners to remember information easily, divide complex processes into simpler components and represent them visually and sequentially for ease of understanding, and the infographic should be compatible with the content, reduce text and use visual elements, focus on the most important pieces of information so that they are prominent, organize data and know the most important parts. The information to be included in the infographic, and the infographic to be effective and attractive.

The current study is based on the Constructivist Theory in which students learn better when they participate in learning experiences. Learning is by nature a social process because as it is embedded in a social context where students and teachers work together to build knowledge. The experience can make it easier for students to build their own knowledge. The study is also based on the Information Processing Theory that describes how sensory inputs are received, transformed, stored, retrieved, and used. This theory is based on allowing enough time for the classroom to process information, pay attention to tests, persevere and reduce information (Slate & Charlesworth, 1988; Clark & Paivio, 1991; Steffe & Gale, 1995; Moser & Chen, 2012; Szymanski, 2021).

Methods
Research design
The research design used is quasi-experimental. This design gives detailed information about the data gathered.

Participants
The subjects of this study are Saudi Cybersecurity Diploma Students at Qassim University. They graduated from the high school and have joined the Diploma in Cybersecurity for two years to practice the profession of protecting electronic devices and networks from hacking. The research groups consist of 80 cybersecurity students at Qassim University (40 male and 40 female students). These subjects were randomly chosen from 198 level one students enrolled in the cybersecurity program in Qassim University. They were divided into four groups: experimental (G1, G2, G3, G4), and the number of each group was 20 students studying through the Blackboard system (see Figure 4).
Instruments

To achieve the objectives of the research and verify its hypothesis, the researchers used an Information Concept Test according to the Frayer model (Frayer et al., 1969) “In the Frayer model, the student begins by writing a term in the centre, and in the four boxes that surround the term write the properties of this term, example Figure 5 and identify antonyms or synonyms”. This test was developed and adapted from different sources (Brooks & Al, 2017; Lowe, 2018; Panek, 2020; Steinberg, 2020). The purpose of the test is to measure the knowledge and concepts acquired by cybersecurity students in the content of scientific terms after exposure to brain-based learning strategies and the use of infographic presentation methods. Many test items are largely derived from the scientific terminology and an introduction to cybersecurity courses, which are presented to Saudi first-year undergraduate cybersecurity students. These courses were selected because of their focus on modelling learning concepts using static and infographics graphs to explain some of the basic aspects related to cybersecurity, and the concepts can be modelled by exploiting similar relationships for concept representations. It consists of four topics: Information security, Network security, Operational security, and Application security.

**Figure 4. Experimental research design.**

**Data collection procedures**

To answer the research questions, the following procedures were followed:

1. Preparing the theoretical framework by reviewing the pertinent literature and the related studies aligned with the research variables.
2. Developing the Information Concept Test.
3. Identifying a list of criteria for designing electronic content based on brain-based learning strategies.
4. Choosing a model for designing the e-learning situation compatible with brain-based learning strategies as described in Figure 6.
5. Designing an e-learning situation based on brain-based learning strategies to develop information concepts among cybersecurity students.
6. Linking the e-learning setting that was designed to the Blackboard Learning Management System.
7. Conducting the exploratory experiment to adjust the research instrument.
8. Selecting research groups of cybersecurity students at Qassim University. Eighty students were divided into four groups: experimental (G1, G2, G3, G4), and the number of each group was 20 students, and they were taught through the Blackboard system. These students were divided according to the patterns of infographic to develop the information concepts of the cybersecurity students.

9. Piloting of the Information Concept Test:

10. Administration of the Information Concept Test. Data were obtained by distributing the test to 80 male/female undergraduate cybersecurity students studying at Qassim University during the academic year 2021/2022.

11. Students’ answers were scored; the researchers give a score of 1 for each correct answer of the 60 questions, and 0 for every wrong answer. This can be seen in the raw data of the pre and post-tests.

12. Monitoring, analyzing, statistically processing and interpreting the results.

13. Presenting recommendations and suggestions in light of the research results.
Delimitations
Research is delimited to these strategies: Mental Models, Spaced repetition, Distributed practice, and Spacing Effects. It is also delimited to Saudi undergraduate cybersecurity students at Qassim University.

Ethics and consent
The researchers obtained the approval of both the Committee of the Department of Applied Natural Sciences in the Applied College and the Research Ethics Committee of Qassim University (REC) on April 16, 2021 based on the written consent of all participants in the research, and the participants were notified by the researchers that the data will be published while preserving data privacy and they had no objection.

Results and discussion
The study hypothesizes that “there is a significant interaction between brain-based learning strategies (spaced repetition and distributed practice - mental models) and patterns of infographics (static/animated) in e-learning environments in the post-measurement of the Information Concept Test after adjusting the pre-measurement effect”. To verify the validity of this hypothesis, the ANOVA (analysis of covariance) test was used to find out if there is an effect of the interaction between brain-based learning strategies and patterns of infographics in e-learning environments in the post-measurement of Information Concept Test as shown in Tables 1 and 2 below:

The results in Tables 1 and 2 show that:

1. There are no significant differences between the average scores of students according to the methods of presenting patterns of infographics (static/animated) in e-learning environments, where the significance level (0.740) is greater than the level of significance (0.05), and therefore, it is not a statistically significant value.

2. There are significant differences between the mean scores of students according to brain-based learning strategies in e-learning environments in the post-administration of Information Concept Test since the significance level (0.034) is less than the level of significance (0.05). Therefore, it is a statistically significant

| Table 1. Means, standard deviations, and sample size according to the strategy and patterns of infographics in the dimensional measurement to test the information concepts. |
|----------------|----------------|----------------|-----------------|----------------|----------------|
| Std. Deviation | Mean N         | Strategies     | Patterns of infographics | Dependent variable |
| 1.75919        | 58.6000 20     | Spaced repetition and distributed practice | Static | Informational concepts test |
| 1.57614        | 58.8000 20     | Mental models  |                  |                |
| 1.65173        | 58.7000 40     | Total          |                  |                |
| 0.99472        | 59.6000 20     | Spaced repetition and distributed practice | Animated | |
| 1.41421        | 58.0000 20     | Mental models  |                  |                |
| 1.45355        | 58.8000 40     | Total          |                  |                |
| 1.49872        | 59.1000 40     | Spaced repetition and distributed practice | Total | |
| 1.53255        | 58.4000 40     | Mental models  |                  |                |
| 1.54674        | 58.7500 80     | Total          |                  |                |

| Table 2. The results of the analysis of binary variance associated with the interaction of (strategy × infographics) in the post-administration of Information Concept Test. |
|----------------|----------------|----------------|-----------------|----------------|----------------|
| Sig.           | F               | Mean Square    | df              | Type III Sum of Squares | Source | Dependent variable |
| 0.740          | 0.111           | 0.241          | 1               | 0.241           | Infographics | Informational concepts |
| 0.034          | 4.653           | 10.080         | 1               | 10.080          | Strategies   |
| 0.011          | 6.873           | 14.890         | 1               | 14.890          | Infographics * strategies |
value. The differences in the means were in favor of the students who learned the strategy (spaced repetition and distributed practice) (highest mean = 59.10), and the average scores of the students who learned the strategy (mental models) were (58.40).

3. There is an effect for the interaction between the variables of brain-based learning strategies and patterns of infographics in e-learning environments in the test scores of information concepts in the post-administration, since the value of \( P = 6.873 \), where the significance level \( (0.011) \) is less than the significance level \( (0.05) \), and therefore it is a statistically significant value.

The results presented in Figures 7 and 8 are consistent with Erol and Karaduman (2018) who found that brain-based learning raised the efficiency of students with difficulties in numerical cognition and that Graphic design has a positive effect on the cognitive achievement and skill performance of secondary school students. Also, Sesmiarni (2015) and Solomon (2020) concluded that brain-based learning helped in acquiring students’ higher-order thinking skills, writing skills, and develop students’ creativity, due to the optimal use of diverse learning materials compatible with the brain, and significantly improved students’ academic participation, and enhanced their ability to critical thinking. The results are in line with Johnson and Mayer (2009) who found that infographics increased academic achievement and helped acquire visual thinking skills and increased willingness to learn on university students, distinguish and perceive visual objects, improve writing, comprehension and retention, and enhance information comprehension speed. In addition, Smiciklas and Wiegand (2012) confirms the research results by concluding that brain-based learning helped increase cooperation, participation and understanding among students, and the results also showed the effect of using infographics on developing creative thinking skills for educational technology students, which helped in enhancing children’s visual-motor memory, and the use of drawings.

The results of the current study can be attributed and interpreted in light of the following considerations:

- Good design of static and animated infographics, adaptive e-learning environment in light of design and production standards, choosing a model for designing e-learning environment compatible with brain-based learning strategies,
- Effective design of educational tasks and activities, related to the objectives and educational content that help the student to remember,
- Good design of media and electronic resources and employing them within the learning environment in proportion to the learning objectives, and consistent with the learning environment,

![Estimated Marginal Means of Test](image)

**Figure 7.** Means according to the strategy and patterns of infographics in the dimensional measurement to test the information concepts.
Implementing a strategy of spaced repetition and practice distributed in four steps based on regular planning of study sessions that helped students remember previous information, study and review information constantly, presenting content in infographic patterns (static/animated), helped students to retain information for a longer period.

Using an Information Concept Test according to the Frayer model.

On-going assessment of the students through discussions, questions and participation in interactive activities available via the blackboard system.

The student’s recall of information at spaced intervals according to the schedule based on spaced repetition and distributed practice in retrieval.

The use of a brain-based learning strategy (mental models), which encouraged the student, through discussion and group work across forums, to think and mentally visualize informational concepts related to the field of cybersecurity.

The use of the infographic pattern (static/animated) in the formation of mental images about similarities and comparisons between known and unknown concepts to link previous information and new information, which significantly helped the students to retain the information.

**Conclusion and implications**

Findings reveal that the use of spaced repetition and distributed practice strategy with static and infographics infographic content presentation style had more impact on learning and information retention in the field of cybersecurity, than mental models strategy with the use of static and infographics infographic content presentation style. Where the strategy of spaced repetition and distributed practice helped students to train the mind to remember information and concepts through the learning schedule and multiple learning sessions extended for three months, the student’s permanent review of information at regular intervals, and the use of training tests a better way to learn by focusing on the salient points; Which helped to remember a large percentage that may reach 100%, the mental models strategy with the use of static and infographics infographic content presentation style had the least impact on learning and retaining informational concepts in the field of cybersecurity in an attempt to link old information with modern information.
Recommendations and suggestions
The present study recommends
1. Employing brain-based learning strategies in different teaching situations to address individual differences among students.
2. Employing static or animated infographics in electronic learning environments to develop informational concepts and activate memory for students with poor memory.
3. Holding courses for teachers to train the skills of applying brain-based and infographic learning strategies in the classroom and within e-learning environments.
4. Conducting further research on the effect of brain-based learning strategies on developing types of thinking.
5. Conducting further research on the effect of brain-based learning strategies in e-learning environments to increase students’ mental capacity.

Data availability
Underlying data
Figshare: https://doi.org/10.6084/m9.figshare.20455503.v4 (Yasser Mohammed et al., 2022)
This project contains the following underlying data:
- Raw data.xlsx
- Pre-Test
- Post-Test
- Strategies Data

Extended data
This project contains the following extended data:
- Information Concept Test - (full test items).

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).

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