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LEARNING -EDUCATIONAL DESIGN BASED ON THE COGNITIVE BURDEN STRATEGY AND ITS EFFECT IN PRIMARY SCHOOL PUPILS ACHIEVEMENT TOWARDS MATHEMATICS

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Abstract:
The achievement of elementary school students in mathematics is considered one of the significant educational challenges, partly due to the large amount of information and skills they are required to absorb at once, which increases their cognitive load. This study aims to design an educational-teaching model based on the cognitive load strategy and to study its effect on students' achievement in mathematics.
The study used a quasi-experimental method, involving a sample of elementary school students, divided into 2 sets: an experimental group in which the lesson design was adjusted according to the cognitive load strategy, and a control group that received traditional instruction. The study instrument included a pre- and post-experiment achievement test, along with a questionnaire to measure students' response to the educational design.
The results showed that using the cognitive load strategy in lesson design led to a noticeable reduce in the achievement of students in the experimental set compared to the control set. It also contributed to improving students' ability to understand mathematical concepts and solve problems more effectively.
The study concludes that adopting instructional design based on cognitive load is considered an effective strategy to improve mathematics learning in elementary school, and provides practical recommendations for teachers to reduce cognitive load during teaching, such as simplifying information, breaking lessons into gradual steps, and using supportive educational media.

Keywords: Educational media, Learning–Educational, Primary school, Misan, mathematics

Chapter One: Introduction to the Study

Study Problem

Educational study shows that learning mathematics often faces difficulties related to the nature of the subject itself and its complexity, in addition to the way the content is presented, which

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increases what is known as the learner's working memory load. Cognitive Load Theory indicates that short-term cognitive capacity is limited, and exceeding its limits by presenting complex or unorganized content leads to slower learning and weaker achievement.

Educational studies also confirmed that cognitive load in mathematics can be high among students, and that this increase is associated with lower academic achievement, which necessitates adopting instructional designs that take this aspect into account (Bin Khalifa, 2022: 28.(

Applied study has shown that instructional designs based on cognitive load principles have a positive effect on developing conceptual understanding among elementary school students in mathematics, including the concept of fractions (Al-Hanan, 2024: 56).

Based on the foregoing, the issue of this study lies in the fact that traditional teaching methods in primary schools often do not take into account the principles of cognitive load, which contributes to students' weak understanding and achievement in mathematics.

Study Significance

The significance of this study lies in several aspects:

1- Developing the educational process: The study relies on applying principles from cognitive load theory, which helps organize the educational material according to the working memory capacity of students, thereby enhancing their understanding and comprehension of mathematical concepts.
2- Supporting practical application in primary classrooms: This study is among the applied studies that are not merely theoretical but provide practical suggestions for instructional design that help teachers reduce unnecessary cognitive load.
3- While some local studies focus only on description, this study contributes to linking instructional design with measurable learning outcomes.
4- Improving student achievement: Instructional designs that consider cognitive load can positively affect mathematics achievement and academic self-esteem among students with learning difficulties (Badawi, 2024: 17).

These points emphasize the importance of employing theory in lesson preparation and design to reduce unnecessary cognitive load, thereby improving the quality of learning.

Study Objective

This study aims to:

1- Develop an instructional-learning design based on the cognitive load strategy, so that it reduces unnecessary load on students' working memory and enhances their understanding of mathematics concepts in the primary stage.
2- Measure the impact of applying this design on the academic achievement of primary school students in mathematics compared to traditional teaching methods.
3- Provide practical educational recommendations for teachers on how to organize lessons and divide educational content to reduce cognitive load and improve students' academic performance.

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Study Hypotheses

The researcher assumes the following:

There is no statistically significant difference at the significance level of (0.05) between the average scores of students in the experimental group who will study using the instructional-learning design based on the cognitive load strategy and the control group who will study using the traditional method in the achievement test.

Study Limits

This study is limited to the following limits:

1- Fifth-grade students at Al-Aswad Primary School for Boys, affiliated with the Directorate of Education in Misan Governorate.
2- Chapters (Sixth, Seventh, and Eighth) from the math textbook prescribed for the 5th degree for the academic year (2024/2025).
3- The 2nd semester of the academic year (2024/2025). Definition of terms: The following are definitions of the basic terms in the study:

Instructional-Learning Design: Al-Fil (2015) defined it as: A set of interrelated stages that include analyzing learners' needs, contexts, and objectives, designing and selecting teaching goals and strategies, developing and experimenting with assessment tools, producing educational materials, and evaluating students' performance using learning and teaching theories (Al-Fil, 2015:147). Operational definition: It is a planned and organized process for planning the educational-learning process for the content of the fifth-grade mathematics curriculum.

4- Strategy: Defined by (Al-Hashimi and Taha, 2008) as: It is the set of procedures and practices followed by the teacher inside the classroom to achieve outcomes in light of the objectives they have set. It includes a set of methods, means, activities, and assessment tools that help achieve the objectives. (Al-Hashimi and Taha, 2008: 19)

Operational Definition: It is a set of educational procedures and practices carried out by the researcher in teaching mathematics to fifth-grade primary students, for which plans have been developed according to the specified instructional-design to reduce the cognitive load on working memory, develop closely related cognitive load, and assess its impact on their academic achievement.

Cognitive Load:

Defined by (Qutami, 2013) as:

The total amount of mental activity during processing in working memory over a given period of time and can be measured by the number of cognitive units or elements that enter into mental processing at a specific time (Qutami, 2013: 560).

Operational Definition:

It is the set of procedures followed by the researcher with fifth-grade elementary students to reduce the mental effort on their working memory during a specific period of time, represented by identifying the cognitive elements, activities, and educational tools.

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Achievement

Shahata and Zeinab (2003) define it as:

The fee of info or data that a learner obtains, expressed in scores on a test prepared in a way that can measure the specified levels (Shahata and Zeinab, 2003: 89).

Operational definition:

It is the amount of info that the students in the study sample acquire as a result of studying the content under investigation, which is measured by the achievement test prepared by the researcher according to Bloom's levels and prepared for this purpose.

Chapter Two

Theoretical Framework

The Concept of Cognitive Load:

Cognitive load is considered one of the fundamental concepts in the field of educational psychology, as it is related to the nature of the mental effort exerted by the learner while processing new information. It refers to the amount of mental energy consumed by working memory when dealing with various educational stimuli (Zaghoul, 2012: 145).

Cognitive load is also defined as the volume of cognitive demands imposed on the learner while performing a specific educational task, which may directly affect the level of understanding and comprehension, especially if it exceeds the capacity of working memory (Qatami, 2013: 88).

Adas and Tawq (2010: 211) believe that effective learning is achieved when information is presented in an organized and integrated manner, reducing the load on working memory and allowing knowledge to be built in long-term memory.

The Theoretical Foundations of Cognitive Load

The concept of cognitive load is based on a number of cognitive foundations that explain the nature of learning, the most important of which is the limited capacity of working memory, as the learner cannot process more than a limited number of elements at the same time, which necessitates organizing educational content in a way that aligns with this capacity (Al-Zayyat, 2008: 132)

Learning also relies on building cognitive schemas that represent an internal organization of knowledge, as these schemas help reduce cognitive load when facing new learning situations (Al-Luqani & Al-Jamal, 2013: 175).

Abu Jadu and Nofal (2010: 256) indicate that learning becomes more effective when new information is connected to prior knowledge, which contributes to reducing cognitive load and improving the absorption process.

Types of Cognitive Load

Cognitive load is divided into three main types, each of which plays a role in the learning process:

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1- Essential cognitive load:

It is related to the normal of the educational adjective itself, the intricate of the adjective, and the number of its interrelated elements. This type of load increases in subjects that require complex mental processes, such as mathematics (Al-Zayat, 2008: 140).

2- Extraneous Cognitive Load

It results from the way the educational content is presented and may be unnecessary if the educational material is not properly organized, leading to the distraction of the learner's attention (Qattami, 2013: 95).

3- Germane Cognitive Load

It represents the mental effort that contributes to building and organizing knowledge, and it is the desirable type that should be enhanced through effective educational activities (Al-Zaghoul, 2012: 152).

Saada (2015: 118) emphasizes that successful learning depends on reducing extraneous load, managing intrinsic load, and enhancing germane load to achieve balance in the educational process.

Instructional Design - Cognitive Load-Based Learning

Instructional design and learning is one of the fields that greatly benefits from the concept of cognitive load, as it aims to organize educational content By means of helping the one who wants to learn to understand without overloading their cognitive capacity (Abdel Hamid, 2016: 73).

(Salem, 2004: 64) points out that lesson design according to the principles of cognitive load requires dividing the content into small parts, presenting it gradually, and using educational tools that support understanding without causing distraction .

(Zeitoun, 2014: 101) also emphasizes the importance of using worked examples, illustrations, and interactive activities in reducing cognitive load and improving students' learning .

Effective instructional design should take into account individual differences among learners and provide them with opportunities to build knowledge gradually and systematically .

Applications of cognitive load in teaching mathematics:

Mathematics is considered one of the subjects that require precise organization in presenting content, due to its abstract nature and the interrelation of its concepts. Therefore, taking into account the cognitive load in teaching it contributes to improving students' understanding of mathematical concepts (Zaitoun, 2014: 110)

Also, using strategies such as breaking problems into steps and providing gradual examples helps reduce cognitive load and increases students' problem-solving ability (Saada, 2015: 125)

Abdel Hamid (2016: 79) points out that using visual aids such as drawings and charts contributes to distributing cognitive load across different channels, which enhances understanding and increases academic achievement.

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Salem (2004: 70) also emphasizes that organizing the classroom environment and simplifying instructions help reduce unnecessary cognitive load and enhance students' focus during learning.

Previous Studies

1. Study by Hizam (2021)

The study by Hizam (2021: 20) goal to identify the stage of cognitive load through elementary school students with difficulties in learning mathematics, and to reveal the effect of some variables such as intelligence and the difficulty of the material on this load. The study utilized the descriptive theory and was applied to a model of 152 fifth-grade elementary students. The results showed no differences that indicate a sex variable, while a significant effect was found for the variables of intelligence and the degree of difficulty of mathematics on the level of cognitive load, indicating that learner characteristics and the nature of the content directly affect cognitive load.

2. Bin Khalifa Study (2022)

The study by Bin Khalifa (2022: 162) goal to examine the stage of cognitive load through middle school students in mathematics and its relationship with academic achievement. The study utilized the descriptive-analytical theory and was applied to a model consisting of (221) students.

The results showed that the level of cognitive load was high among the students. It also showed that there were statistically significant differences between successful and failing students in mathematics in favor of those with low achievement, indicating an inverse relationship between cognitive load and academic achievement.

3. Badawi Study (2024)

Badawi's study (2024: 59) aimed to verify the effectiveness of an educational program based on Cognitive Load Theory in improving mathematics achievement and academic self-esteem among sixth-grade elementary students with learning-difficulties. The research used a quasi-experimental method and was applied to a model of (22) students. The results showed the effectiveness of the cognitive load-based program in improving students' achievement, in addition to developing their academic self-esteem, reflecting the importance of employing this strategy in teaching mathematics.

4.Al-Hanan Study (2024)

Al-Hanan's study (2024: 75) goal to reveal the impact of an educational program depend on Cognitive Load Theory on developing conceptual understanding and fractional sense among fourth-grade elementary students with difficult in learning mathematics. The research used an experimental method and was applied to a model of (29) students divided into 2 sets (experiment, control). The results showed statistically sign differences in favor of the experiment set in conceptual understanding and fractional sense, indicating the effectiveness

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of cognitive load-based instructional design in improving mathematics learning among students.

Commentary on Previous Studies

Through reviewing previous studies related to the topic of cognitive load and learning mathematics, a set of observations and analyses can be derived that contribute to clarifying the position and significance of the current study, as follows:

First: Areas of Agreement among Previous Studies

Previous studies agreed cognitive load is one of the most important factors that directly affect students' achievement. The results of Bin Khalifa (2022: 162) indicated an inverse relationship between cognitive load and academic achievement, which aligns with the findings of Hizam (2021: 20) that an increase in content difficulty leads to a higher cognitive load for students.

Experimental studies such as Badawi (2024: 59) and Al-Hanan (2024: 75) also agreed that using educational programs based on the cognitive load strategy contributes to improving students' achievement in mathematics and developing their understanding of mathematical concepts.

Second: Areas of Difference among Previous Studies

Previous studies varied in terms of:

-The methodology used: Some studies employed the descriptive method (such as Hizam, 2021; Bin Khalifa, 2022), while other studies relied on the experimental method (such as Badawi, 2024; Al-Hanan, 2024).

-The educational stage: Some studies addressed different stages such as intermediate education, while other studies focused on the primary stage.

-The nature of variables: Some studies focused on the relationship between cognitive load and achievement, while others concentrated on the effectiveness of educational programs based on this strategy.

Third: Benefits from previous studies

The current study benefited from previous studies in several aspects, including:

1- Building the theoretical framework related to the concept of cognitive load and its types.

2- Identifying the study problem by emphasizing the existence of a relationship between cognitive load and poor achievement.

3- Selecting the appropriate methodology, as the quasi-experimental method was adopted based on studies that proved its effectiveness.

4- Designing the study tool, such as the achievement test, by utilizing the tools of previous studies.

Fourth: What distinguishes the current study from previous studies?

The current study differs from previous studies in several aspects, including:

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1- Combining instructional and learning design within a single framework based on the cognitive load strategy, rather than merely studying the relationship or partial application.
2- Focusing directly on the elementary stage, which is a crucial phase in building mathematical concepts.
3- Developing a comprehensive educational model that can be applied in classrooms, rather than just a limited program.
4- Concentrating specifically on mathematics achievement, with links to methods of instructional content design.
5- The position of the current study in relation to previous studies This study comes as a continuation of previous efforts in studying cognitive load, aiming to apply the principles of this theory in a comprehensive instructional-learning design and to test its effect on the mathematics achievement of elementary school students, which gives it an applied dimension that contributes to the development of teaching practices.

Chapter Three: Study Procedures

First: Constructing the instructional-learning design

The construction of the instructional-learning design is considered a fundamental step in this study, as it represents the independent variable that the researcher seeks to study its effect on the performance of fifth-grade elementary students in math. This design was constructed in light of the principles of the cognitive load strategy, ensuring the reduction of unnecessary cognitive load and organizes the educational content in a way that suits the students' abilities. In building the design, the researcher relied on a systematic sample consisting of five main phases: assessment, development, analysis, design, and implementation. .

Stages of constructing the instructional-learning design

First: Analysis Stage (Analysis)
The analysis stage is considered the foundation upon which the instructional design is built, as it involves studying the reality of the educational process and identifying its requirements. This stage included the following :
1- Analysis of learners' characteristics: The characteristics of fifth-grade elementary students were identified in terms of age level, cognitive abilities, and previous experiences in mathematics, taking into account the limitations of their working memory, in accordance with the principles of cognitive load.
2- Analysis of Educational Content:
The content of chapters (six, seven and eight) of the mathematics book was analyzed, and the basic concepts and skills were identified, along with determining the relationships between the content elements, with the aim of reducing cognitive complexity.
3- Defining Educational Objectives:
Educational objectives were formulated in a measurable behavioral manner, covering different cognitive levels, and taking into account the progression from easy to difficult.
4- Identifying Educational Problems:

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The most prominent difficulties students face in learning mathematics were identified, such as the difficulty of understanding abstract concepts and the numerous steps in solving problems, which lead to an increased cognitive load.

Second: Design Phase:

At this stage, a detailed instructional design plan was developed in light of the results of the analysis phase, and it included the following:

-Organizing educational content:

The content was divided into small and progressive units to reduce cognitive load, with concepts arranged from simple to complex.

-Selecting instructional strategies:

Strategies based on reducing cognitive load were adopted, such as:

-Using worked examples

-Gradual learning

-Reducing unnecessary information

-Designing educational activities:

Educational activities were prepared to help students gradually build knowledge and enhance understanding instead of rote memorization.

-Selecting educational media:

Visual and illustrative media (such as drawings and charts) were used to reduce cognitive load and facilitate understanding.

Third: Development Stage

At this stage, the theoretical design was converted into ready-to-implement educational materials, including:

-Preparing lesson plans according to the cognitive load strategy.

-Developing educational materials (examples, activities, worksheets).

-Preparing educational aids supporting the content.

- Reviewing the materials by specialists to ensure their suitability and scientific accuracy.

In all the materials, care was taken to reduce extraneous cognitive load and enhance the gradual understanding of concepts. Fourth: Implementation Stage The instructional design was implemented on the study sample according to the following steps:

- Applying the experiment on fifth-grade students at Al-Aswad Primary School for Boys.

- Teaching the experimental group using the instructional design based on the cognitive load strategy.

- Teaching the control group using the traditional method.

- Conducting the experiment among the 2nd semester of the academic year (2024–2025). The author ensured providing a suitable classroom environment, organizing time, and controlling variables that might affect the experiment results.

Fifth: Evaluation Stage: This stage aims to verify the effectiveness of the instructional design and included the following:

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- Pre-evaluation: A pretest was conducted to measure the students' level before starting the experiment.
- Formative evaluation: Students' performance was monitored during the implementation of the lessons through activities and classroom questions.
- Post-evaluation: An achievement test was applied after the experiment ended to measure the effect of the instructional design on students' achievement.

-Analysis of results :
Appropriate statistical methods were utilized to compare the degrees of the two groups and determine the effectiveness of the educational design based on the cognitive load strategy.

Second: Experimenting with the Proposed Educational – Learning Design
1. Experimental Design
The researcher relied on a quasi-experimental design, using two groups: experiment , control, and the application of a pre-test and post-test to measure the impact of the educational – learning design based on the cognitive load strategy on the academic achievement of fifth-grade primary students.

2.Study Population
The study population consists of 5th stage primary students in primary schools affiliated with the Directorate of Education in Misan Governorate for the academic year (2024–2025). This population represents the target group on which the study seeks to generalize its results.

3. Study Sample
The study sample was purposively selected from Al-Aswad Primary School for Boys, and two sections of the fifth grade were chosen, with each group comprising 30 students:
The experimental group (30 students) was taught using an instructional design based on the cognitive load strategy .
The control set (30 students) was taught utilizing the traditional theory.

4. Equivalence of the research groups
Care was taken to achieve equivalence between the two groups in the basic influencing variables, including:
-The students' chronological age
-Previous achievement in mathematics
Equivalence between the two groups was verified using the T-test, as no statistically sign differences were observed between the sets before the experiment began.

5. External validity of the instructional design
To ensure the generalizability of the study results to similar educational situations, the following measures were taken:

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-A relatively representative sample of primary school students was selected.
-The experiment was conducted in a natural classroom environment without artificial interventions.
-Educational conditions were standardized between the two groups as much as possible.
- Officially prescribed study content was used (the fifth-grade mathematics textbook).

6. Procedures for Implementing the Experiment

The experiment was implemented according to the following steps:
-Dividing the students into two groups (experimental and control), each containing 30 students.
-Administering the pre-test to both groups.
-Teaching the experimental group using the instructional-design-based learning strategy based on cognitive load.
-Teaching the control set utilizing the traditional theory.
-Continuing the experiment throughout the second semester of the academic year (2024–2025)
-Monitoring students' performance during lessons to ensure the educational process proceeds correctly.
-Administering the post-test to both groups.
-Collecting data and analyzing it statistically to extract results.

7. Statistical Tools

The researcher used the following statistical tools:
-The T-test for two independent samples to compare the results of the experimental and control groups.
-The arithmetic mean and standard deviation to describe the data of both groups.
-The difficulty and discrimination indices for the achievement test items.
- The reliability coefficient (Cronbach's alpha) to guarantee the test's reliability.

Chapter Four: Presentation and Interpretation of Results

Presentation of Results

The results of the pre-test and post-test for the experiment , control sets were analyzed utilizing the independent two-model, T-test, and the following results were obtained:

dimensional standard deviation	Post-average	pre-standard deviation	Pre-average	group
2.1	18.7	2.5	12.3	Experimental
2.3	14.3	2.4	12.1	officer

Statistical Analysis (T-test):

- Differences between the 2 sets in the pre-test: Not statistically significant, confirming the equivalence of the 2 sets before the experiment.

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- Differences between the two groups in the post-test: Statistically significant in favor of the experimental group ($t = 6.45$, $p < 0.01$), indicating the effectiveness of the instructional-learning design based on the cognitive load strategy in improving student achievement.

Interpretation of results:

The results indicate that the proposed instructional design reduced the cognitive load on students, contributing to improved achievement in mathematics. These results can be interpreted in several ways:

1- Organizing the educational content and dividing it into small units facilitated information absorption.

2- Using solved examples gradually enhanced students' understanding of mathematical concepts.

3- Presenting information in a simplified manner and minimizing unnecessary information helped reduce the external cognitive load.

4- Guided and interactive learning activities enhanced mathematical thinking and problem-solving skills. This confirms the findings of previous studies, such as Badawi's study (2024, p. 59) and Al-Hanan's study (2024, p. 75), which demonstrated the effectiveness of instructional design based on the cognitive load strategy in improving academic achievement.

Conclusions

Based on the results and analysis, the researcher reached the following conclusions:

1- Instructional-learning design based on the cognitive load strategy has a clear positive impact on the achievement of fifth-grade students in mathematics.

2- There is an inverse relation between the level of cognitive load and academic performance; the lower the cognitive load, the better the students' academic performance.

3- Good organization of educational content and the use of progressive examples and interactive activities are effective tools for reducing cognitive load and improving learning.

4- Designing lessons according to modern scientific strategies helps develop students' thinking and problem-solving skills.

Recommendations

Based on the results and conclusions, the studyer offers the following recommendations:

1- Encourage teachers to adopt instructional-learning designs that reduce cognitive load when teaching mathematics.

2- The necessity of organizing educational content and dividing it into small, progressive units to facilitate learning.

3- Enhancing the use of solved examples and interactive activities in the educational process.

4- Including training programs for teachers on strategies to reduce cognitive load in all subjects.

5- Developing educational materials and supporting learning media that increase cognitive load and reduce the effectiveness of learning.

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Recommendations

The researcher suggests the following:

1- Applying instructional design based on cognitive load to other educational stages, such as middle and high school.

2- Studying the impact of instructional design on Higher-order thinking skills, such as problem-solving, synthesis, and analysis.

3- Comparing the effectiveness of instructional design in different curricula, such as science and Arabic language.

4- Conducting longitudinal studies to measure the impact of instructional design on students' long-term achievement.

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