The Effect of the Information Encoding Strategy on the Productive Thinking of Second- Intermediate Female Students in Biology

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Abstract

The current research aims to identify the effect of using the Information Encoding Strategy on the academic achievement of second intermediate grade female students in Biology and their productive thinking

To achieve the objectives of the research, the following null hypothesis was formulated

"There is no statistically significant difference at the (0.05) level between the mean scores of the experimental group students, who are taught according to the Information Encoding Strategy, and the mean scores of the control group students, who are taught using the traditional method, in the productive thinking scale.

To verify the validity of this hypothesis, an experiment was conducted over the course of a full academic semester during the $2024-2025$ school year. The experimental design adopted was a quasi-experimental design

The study sample consisted of (57) second intermediate grade female students, who were randomly distributed into two groups: an experimental group taught using the Information Encoding Strategy, and a control group taught using the conventional method

The experiment lasted for ten weeks, during which the encoding strategy was applied through interactive educational activities that focused on transforming scientific information into symbols or forms that are easier to understand and recall

To achieve the study objectives, a productive thinking test to measure students' abilities in both creative and critical thinking. The validity and reliability of the tools were ensured through expert judgment and a pilot application

The statistical analysis results revealed statistically significant differences at the (0.05) significance level between the two groups in favor of the experimental group in productive thinking. The experimental group students significantly outperformed their counterparts in generating creative ideas and problem-solving

The research findings indicate a positive effect of teaching using the Information Encoding Strategy, which helps deepen students' understanding of scientific concepts by transforming complex information into simplified, easily assimilated forms. It also contributes to the development of higher-order thinking skills such as creative, critical, and productive thinking

The study recommends the widespread implementation of this strategy in science teaching, emphasizing the importance of training teachers to apply it correctly and effectively. It also suggests conducting further studies to explore the effects of this strategy in other subjects and among different age groups

Keywords: Strategy, Information Encoding, Productive Thinking, Biology.

أثر استراتيجية تشفير المعلومات في التفكير المنتج لدى طالبات الصف الثاني متوسط في مادة الاحياء

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الملخص

هدف البحث الحالي للتعرف على أثر استخدام استراتيجية تشفير المعلومات في تحصيل تحصيل طالبات الصف الثاني المتوسط في مادة الاحياء وتفكيرهن المنتج .

ولغرض التحقق من هدفا البحث وضعت الفرضية الصفرية الاتية :-

لا يوجد فرق ذو دلالة إحصائية عند مستوى (٠.٠٥) بين متوسط درجات طالبات المجموعة التجريبية اللاتي يدرسن وفق استراتيجية تشفير المعلومات وبين متوسط درجات المجموعة الضابطة اللاتي يدرسن على وفق الطريقة الاعتيادية في مقياس التفكير المنتج لديهن .ولاجل التحقق من صحة الفرضية اجرت تجربة استغرقت فصل دراسي كامل للسنة الدراسية (٢٠٢٤-٢٠٢٥) اذ تم اعتماد التصميم التجريبي (ذا الضبط الجزئي) تكونت عينة الدراسة من (٥٧) طالبة من الصف الثاني المتوسط، تم تقسيمهن بشكل عشوائي إلى مجموعتين: المجموعة التجريبية التي درست باستخدام استراتيجية تشفير المعلومات، والمجموعة الضابطة التي تلقت التعليم بالطريقة التقليدية. استمرت التجربة لمدة (١٠) أسابيع ، حيث تم تطبيق استراتيجية التشفير من خلال أنشطة تعليمية تفاعلية تركز على تحويل المعلومات العلمية إلى رموز أو أشكال يسهل تذكرها وفهمها.

ولتحقيق أهداف الدراسة تم استخدام أداة اختبار للتفكير المنتج لقياس قدرة الطالبات على التفكير الإبداعي والنقدي. تم التأكد من صدق وثبات الأدوات من خلال التحكيم العلمي والتطبيق التجريبي وأظهرت نتائج التحليل الإحصائي وجود فروق ذات دلالة إحصائية (عند مستوى دلالة ٠.٠٥) بين المجموعتين لصالح المجموعة التجريبية في التفكير المنتج. حيث تفوقت طالبات المجموعة التجريبية بشكل ملحوظ في توليد الأفكار الإبداعية وحل المشكلات مقارنة بالمجموعة الضابطة.

اشارت نتائج البحث الى وجود اثر إيجابي للتدريس باستراتيجية تشفير المعلومات التي تساعد في تعميق فهم الطالبات للمفاهيم العلمية من خلال تحويل المعلومات المعقدة إلى أشكال مبسطة يسهل استيعابها. وأيضا تساعد على تنمية مهارات التفكير العليا مثل التفكير الإبداعي والنقدي والمنتج .

أوصت الدراسة بتعميم استخدام هذه الاستراتيجية في تدريس العلوم، مع التأكيد على أهمية تدريب المعلمين على تطبيقها بشكل صحيح وفعال. كما اقترحت إجراء مزيد من الدراسات لاستكشاف أثر هذه الاستراتيجية في مواد دراسية أخرى وفئات عمرية مختلفة.

الكلمات المفتاحية: استراتيجية، تشفير المعلومات، التفكير المنتج، مادة الاحياء.

Chapter One: Research Problem

In light of rapid technological advancements, modern teaching strategies have become essential to meet students' needs and enhance their cognitive and creative skills

The Information Encoding Strategy is one of the educational approaches that relies on transforming information into symbols or forms that are easier to remember and understand, thereby helping students grasp concepts more deeply

The educational process is witnessing rapid development in the methods and strategies aimed at fostering different types of thinking among learners. Among the most prominent of these is productive thinking, which represents a fundamental pillar in preparing learners to face challenges, make decisions, and solve problems in creative and effective ways

Within this context, biology is considered one of the subjects that requires high cognitive abilities in linking, analyzing, and interpreting phenomena, making it a suitable environment for developing students' productive thinking. However, the reality indicates that many female students face difficulties in comprehending biological concepts and often rely on memorization and rote learning, which limits their ability to think productively

This highlights the need to adopt alternative teaching strategies that stimulate the mind to reorganize and encode information in a way that facilitates its retrieval and application in new situations

The Information Encoding Strategy is one of the approaches that aims to enhance deep cognitive processing of content and helps learners build logical relationships between concepts, contributing to the development of productive thinking

Accordingly, the research problem is represented in the following central question

What is the effect of the Information Encoding Strategy on productive thinking among second intermediate grade female students in biology?

Research Significance

The significance of this research stems from its alignment with modern educational trends that emphasize the necessity of developing various types of thinking skills, especially productive thinking, as an effective tool for constructing knowledge, solving problems, and making decisions both inside and outside the educational environmen

This type of thinking is considered a fundamental pillar in preparing a generation capable of dealing with the variables of contemporary life with conscious and creative thought

The importance of this study also lies in shedding light on a modern teaching strategy — the Information Encoding Strategy — which has not yet received sufficient attention in local educational contexts, despite research evidence indicating its effectiveness in promoting deep understanding of content, improving memory processes, and developing analytical, associative, and inferential thinking skills

The findings of this research may contribute to providing a practical framework that helps biology teachers — especially at the intermediate stage — diversify their instructional methods in ways that support academic achievement and enhance students' thinking skills. The results may also benefit stakeholders involved in curriculum and training program development by integrating strategies based on cognitive encoding into educational plans

From a research perspective, this study represents an academic contribution to the field of education, as it addresses a topic that bridges modern teaching strategies with productive thinking skills, enriching the scientific literature and paving the way for future research in this area

Research Objective

This research aims to investigate the effect of using the Information Encoding Strategy on productive thinking among second intermediate grade female students in biology, by comparing the level of productive thinking between students who learn using this strategy and those who learn through the traditional method

Research Hypothesis

For the purposes of this study, the following hypothesis was formulated

There is no statistically significant difference at the (0.05) level in the mean scores of productive thinking between students in the

experimental group who were taught using the Information Encoding Strategy and those in the control group who were taught using the traditional method

Research Limits

This research is confined to the following limits

Human domain: Second intermediate grade female students

Spatial domain: Al-Hashimiyah Intermediate School for Girls, under the Directorate of Education / Al-Karkh Third

Temporal domain: The first semester of the academic year 2024–2025

Subject domain: The study focuses on the effect of the Information Encoding Strategy on productive thinking within selected content from the biology curriculum prescribed for the second intermediate grade

Definition of Terms

Information Encoding Strategy١-

Theoretical Definition

Defined by Aqeel (2020) as

A cognitive strategy aimed at organizing information and transforming it from its initial form into more effective formats for mental processing, making it easier to comprehend and retrieve later

Operational Definition

In this study, it refers to the method applied by the researcher to teach selected concepts from the second intermediate biology curriculum using tools such as mind maps, visual representations, and symbolic summarization, with the aim of facilitating understanding and enhancing productive thinking, as outlined in the instructional plan prepared for the study

2-Productive Thinking

Theoretical Definition

Defined by Sartawi et al. (2011) as

The ability to generate original and effective ideas or solutions characterized by creativity and appropriateness to different situations

Operational Definition

It refers to the score a student obtains on the productive thinking scale developed by the researcher, which includes dimensions such as originality, fluency, effectiveness, and flexibility. The scale is applied pre- and post-intervention to measure the effect of the applied strategy

Chapter Two: Theoretical Framework and Literature Reviewthe theoretical framework includes the following themes

Information Encoding Strategy١-

The Information Encoding Strategy is one of the cognitive learning strategies aimed at enabling the learner to organize scientific content and mentally re-represent it in ways that support deep understanding and long-term memory

In the educational context, it refers to the set of procedures used by the teacher to help students symbolically represent information—such as through diagrams, concept maps, colors, and abbreviations—which enhances memory storage and facilitates later retrieval

Concept of the Information Encoding Strategy

Our senses receive a massive number of stimuli, yet humans are selective in choosing which information to focus on. Human information processing involves both sensory and cognitive aspects. When an individual receives too many sensory signals, it can overload the mind and impair the ability to process all information effectively due to the limited capacity of our processing system

To solve this problem, attention serves as a critical mental process in memory. It is selective and focuses on relevant information, ignoring the irrelevant, thereby transferring it from sensory memory to working memory, which allows the information to become clearer, easier to

retain, and more retrievable. Therefore, attention enhances memory efficiency

)Meece, 1997(

How the Information Encoding Strategy Works

These strategies function in a deliberate manner. That is, when an individual attempts to remember something, they do so consciously, making an effort to retain it by using all possible methods

Attention: The strategy involves focusing attention on the information intended to be remembered. This facilitates the transfer of information from short-term memory to long-term memory, thereby activating it

)Herrmann, 1999(

Information Processing concept

Proponents of this approach argue that behavior is not merely a set of responses to stimuli, but rather a series of cognitive processes that mediate between receiving the stimulus and producing an appropriate response. The nature and type of cognitive processing determine the time gap between receiving the stimulus and producing the response

Human information processing is similar to what happens in a computer system, where inputs are received, processed in the information-processing unit, and then produce outputs. In humans, this processing goes through several stages

Reception → Encoding → Storage

and through various cognitive operations, a response is produced at each stage

This strategy relies on converting complex information into symbols or mental images that facilitate understanding and recall (Smith, 2020)

In the Arab context, a study by Al-Khawalda (2018) showed that applying encoding strategies in science teaching contributed to improving academic achievement among intermediate school students in Jordan

.2-Productive Thinking

Productive thinking is one of the higher-order thinking types and refers to the learner's ability to generate new and effective ideas to solve problems or handle learning situations in a way that goes beyond conventional knowledge

Theories Explaining Productive Thinking

.1-Taylor's Theory

This theory emphasizes that productive thinking is linked to creativity and creative thinking, and supports the student in recognizing problems and finding solutions, helping them adapt to a changing world

According to Schlichter (1993), teaching productive thinking involves developing creative abilities such as fluency, flexibility, originality, and elaboration. The primary aim of productive thinking is idea generation, while critical evaluation is considered a foundational element

)2-Insight Theory (Gestalt Approach

This theory posits that thinking begins with a problem, and solving it requires prior thinking and considering the whole before analyzing the parts within that whole

)Schlichter & Palmer, 1993(

Components of Productive Thinking

First: Critical Thinking

True critical thinking is not about focusing on others' mistakes or criticizing to provoke emotions; rather, such behavior is destructive and undermines the ideas of others.

Constructive critical thinking, on the other hand, involves respecting others' perspectives, guiding them toward correcting their thoughts, and encouraging exploration of diverse ideas to improve their current situation and develop their thinking.

)Al-Hassoun, 2003(

Critical Thinking Skills among Biology Teachers at the Intermediate Stage

There are multiple classifications of critical thinking skills due to the variety of definitions and theoretical frameworks. One of the most well-known is the Watson & Glaser (1981) classification, which includes the following skills

Recognizing Assumptions

The ability to distinguish between true and false information or to differentiate between fact and opinion and to understand the intent behind given information

Interpretation

The ability to identify the problem recognize logical explanations, and evaluate whether generalizations and conclusions based on specific data are acceptable

Evaluation of Arguments

The individual's ability to evaluate an idea accept or reject it differentiate between primary and secondary sources strong and weak arguments and judge the adequacy of information

Deduction

The ability to determine logical outcomes based on previous premises or information

Inference

The ability to draw conclusions from given or assumed facts and to judge the accuracy or inaccuracy of those conclusions based on the presented evidence

)Al-Atoom et al., 2009(

Second: Creative Thinking

The scientific, technological, and civilizational advancements we are experiencing today are the result of the efforts of numerous creative

individuals. The continuation of such progress depends on unleashing the latent creative potential within people

Creativity is an advanced cognitive phenomenon through which an individual addresses situations, problems, and experiences in unusual and novel ways, or by developing previous solutions to produce new outcomes

) Qatami, 2004(

Creative Thinking Skills

Fluency

Fluency refers to the ability to generate a large number of alternatives synonyms ideas problems or uses in response to a particular stimulus as well as the speed and ease with which these responses are produced

At its core, fluency represents a process of optional recall of previously learned information, experiences or concepts

It includes several types such as verbal fluency ideational fluency, and figural fluency

)Jarwan, 2007, p. 77(

Flexibility

Flexibility is the ability to produce diverse ideas that are not of the typically expected type and to shift from one type of thinking to another in response to a given stimulus or situation

Flexibility represents the qualitative aspect of creativity and appears in several forms including Spontaneous Flexibility, Adaptive Flexibility.

) Al-Atoom, 2012, p. 256(

Chapter Three

In this chapter, the researcher presents the research methodology and procedures, including the identification of the research population and sample, the steps for constructing the research instruments, and the statistical methods used

First: Research Methodology

The researcher adopted the experimental research method, as it is the closest and most appropriate approach for solving problems scientifically This method reflects control and regulation in order to manage the variables involved in the research, except for the variable whose effect is being studied

To achieve this goal, it is necessary to select a basic plan or design that outlines how the research procedures will be implemented and the steps taken to achieve its objectives in order to reach a solution to the problem Al-Maghribi, 2011, p. 110

Second: Experimental Design of the Research

The researcher chose a quasi-experimental design involving an experimental group and a control group, both subjected to a post-test of productive thinking, as shown in Diagram (1-3)

Table 1-3: Experimental Research Design

Group	Equivalence Variables	Independent Variable	Dependent Variable	Measurement of Dependent Variable
Experimental	- Prior biological knowledge - IQ level - Chronological age (in months)	Information Encoding Strategy	Productive Thinking	Productive Thinking Test
Control	- Prior biological knowledge - IQ level - Chronological age (in months)	Traditional Method	Productive Thinking	Productive Thinking Test

Third: Research Population and Sample

The research population consists of second-grade intermediate female students in intermediate and secondary schools affiliated with the

General Directorate of Education in Baghdad / Al-Karkh Third for the academic year 2024–2025

Research Sample

A school was selected based on coordination with the General Directorate of Education in Baghdad / Al-Karkh Third. Two sections were chosen out of four available sections in the school. Section (A) represented the experimental group, while section (B) represented the control group. The number of students in the experimental group was 28, and the number of students in the control group was 29, as shown in the table below

Table (1-3): Distribution of the Main Sample Across the Research Groups

Section	Group	Sample Size	Excluded Students	Final Count
A	Experimental	28	None	28
B	Control	29	None	29
Total		57		57

Fourth: Control Procedures

To enhance the reliability of the research procedures and results, the researcher ensured control over the variables that could affect the experiment, and consequently influence the accuracy of the results. The control procedures were implemented as follows

Internal Validity

Internal validity refers to the degree to which the changes observed in the dependent variables after the experiment are due to the influence of the independent variable and not to other unintended external variables. To ensure the highest possible level of internal validity, the researcher sought to equalize the two groups in terms of the following variables

A. Prior Biological Knowledge

The researcher prepared a test to measure prior biological knowledge. The test consisted of 20 multiple-choice items, each with four alternatives: one correct and three incorrect options. To verify the

appropriateness and clarity of the items, the test was reviewed by experts in the fields of biology teaching methods, academic supervisors, and biology teachers. Based on their feedback, the researcher retained all test items as they achieved an agreement rate of 80% or higher

Subsequently, the prior biological knowledge test was administered to both the experimental and control groups on(12-11-2024). After correcting the students answer sheets it was found that the mean score of the experimental group was (7.96) with a standard deviation of (3.294) while the mean score of the control group was (7.86) with a standard deviation of (3.681)

To determine the appropriate statistical test for verifying the equivalence of the two groups, the researcher used Levene's test to examine the homogeneity of variance. The calculated F-value was (0.334), which is less than the tabulated value of (4.0847) at (df = 1, 55), indicating no statistical significance at the (0.05) level. This means that the variances of the two groups are homogeneous

Therefore, the independent samples t-test was the appropriate statistical test. The calculated t-value was (0.11), which is less than the tabulated t-value of (2.029) at (df = 55), and this difference is not statistically significant at the (0.05) level. This indicates that there is no significant difference between the means, which confirms that the two groups are equivalent in the variable of prior biological knowledge, as shown in Table (2-3)

Table (2-3): Means, Standard Deviations, and Calculated and Tabulated t-Values for the Equivalence of the Two Groups in Prior Biological Knowledge

Variable	Group	Sample Size	Mean	Standard Deviation	Degrees of Freedom	t-Calculated	t-Tabulated	Significance
Prior Biological Knowledge	Experimental	28	7.96	3.29	55	0.110	2.029	Not Significant
	Control	29						

B. Intelligence Level

The concept of intelligence generally refers to the general mental ability that serves reasoning processes, the perception of relationships and representations, ease of learning, storing and retrieving information, fluent use of linguistic vocabulary, as well as the ability to classify, categorize, and solve problems in novel situations

To verify the equivalence of the experimental and control groups in intelligence level, the researcher adopted the test developed by Raven, which consists of matrices divided into five sets (A, B, C, D, E), each containing 12 test items. The test was adapted to the Iraqi environment by Al-Dabbagh (1983). Due to the well-established validity and reliability of this test, it is deemed appropriate for the age group of the research sample. The items range in difficulty from easy, to more difficult, to most difficult (Al-Dabbagh, 1983, p.16)

The intelligence test was administered to both groups. After correcting the students' answer sheets and determining the scores, it was found that the mean score for the experimental group was (25.5) with a standard deviation of (5.853), while the mean score for the control group was (24) with a standard deviation of (6.793)

To determine the appropriate statistical test to verify the equivalence of the two groups, the researcher employed Levene's test for homogeneity of variance. The calculated F-value was (0.996), which is less than the tabulated value (4.0847) at degrees of freedom (1, 55), indicating no

statistical significance at the 0.05 level. This means the variances of the two groups are homogeneous

Accordingly, the independent samples t-test was the appropriate statistical test. The calculated t-value was (0.892), which is less than the tabulated t-value of (2.029) at $(\text{df} = 55)$, and is not statistically significant at the 0.05 level. This indicates that there is no significant difference between the means, suggesting that the two groups are equivalent in terms of intelligence level, as shown in Table $(3-3)$

Table $(3-3)$: Means Standard Deviations, and Calculated and Tabulated t-Values for the Equivalence of the Two Groups in Intelligence Level

Variable	Group	Sample Size	Mean	Standard Deviation	Degrees of Freedom	t-Calculated	t-Tabulated	Significance
Intelligence Level	Experimental	28	25.50	5.85	55	0.892	2.029	Not Significant
	Control	29	24.00	6.79				

C. Students' Chronological Age (in Months)

The researcher determined the birthdates of the students by day month and year and subsequently calculated their chronological age. It was found that the mean age of students in the experimental group was (170.75) months with a standard deviation of (3.545) while the mean age of students in the control group was (169.62) months with a standard deviation of (3.7840)

To determine the appropriate statistical test for verifying the equivalence of the two groups, the researcher used Levene's test to assess the homogeneity of variance. The calculated F-value was (0.15) which is less than the tabulated value (4.0847) at degrees of freedom $(1, 55)$ indicating that it is not statistically significant at the (0.05) level. This means the variances of the two groups are homogeneous

Therefore, the independent samples t-test was the most appropriate test. The calculated t-value was (1.162), which is less than the tabulated t-value of (2.029) at (df = 55), and is not statistically significant at the (0.05) level. This indicates that there is no significant difference between the means, which confirms that the two groups are equivalent in the variable of students' chronological age, as shown in Table (4-3)

Table (4-3): Means, Standard Deviations, Calculated and Critical t-values for the Equivalence of the Two Groups in Chronological Age (Months)

Variable	Group	Sample Size (n)	Mean	Standard Deviation (SD)	Degrees of Freedom (df)	Calculated t-value	Critical t-value
Chronological Age (months)	Experimental	28	170.75	3.54	55	1.162	2.029

2-External Validity of the Research

a. Confidentiality of the Experiment

b. Experimental Attrition

c. Experiment Location:

d. Measurement Tool (Productive Thinking Test)

Fourth: Preparation of Research Requirements

1-Determining the Instructional Material: The instructional material used during the experimental period (first semester of the academic year (2024-2025)

2-Formulation of Behavioral Objectives: A behavioral objective is defined as a verbal statement that describes the learner's behavior after the completion of a learning experience, and it must be observable and measurable. The researcher analyzed the content of the chapters taught during the experiment and formulated 160 behavioral objectives based

on the first four levels of Bloom's taxonomy in the cognitive domain (knowledge, comprehension, application, and analysis). These objectives were distributed according to the scientific content and the specified cognitive levels

Sixth: Research Instrument

To achieve the aims of the current research, the researcher constructed a tool, namely the Productive Thinking Test, following specific steps and procedures

First Tool: The Productive Thinking Test

1-The test aims to measure the productive thinking skills of second intermediate female students in the research sample

2-Based on the review of educational literature related to the subject, the Productive Thinking Test was developed to include two domains

Critical Thinking Domain, consisting of 25 items distributed across five skills: Identifying Assumptions (5 items), Interpretation (5 items), Evaluation of Arguments (5 items), Deduction (5 items), and Inference (5 items.(

Creative Thinking Domain, composed of three skills: Fluency, Flexibility, and Originality. This section includes six items, each with two prompts or statements, designed to measure creative thinking ability

The items were developed based on expert and jury feedback to ensure their clarity, appropriateness for the students' level, and alignment with the intended learning objectives

3-Test Instructions Formulation: The researcher prepared a set of instructions for the test, explaining how to respond to the items, including an illustrative example

Test Scoring: The critical thinking section comprised 25 items, each scored as (1) for a correct response and (0) for an incorrect one The total score for each respondent was calculated by summing the scores from all five subskills. The creative thinking section consisted of six open-ended items

5-Productive Thinking Test Implementation

First Pilot Test: The test was initially administered to a pilot sample of 30 second intermediate students from a selected school to verify the clarity of the items and instructions and to estimate the time required to complete the test. The results indicated that the items and instructions were clear, and the average time taken by students to complete the test was 60 minutes. This was calculated by averaging the time taken by the first and last five students

Second Pilot Test: The test was then administered to a second pilot sample of 100 second intermediate students from Al-Hashimiyah Girls' School, who wereConstruct Validity

After selecting 27% of the highest scores to represent the upper group and the same percentage of the lowest scores to represent the lower group, the item discrimination index of the test was calculated using the two extreme groups method. The t-values for the items ranged between (0.41 (- 0.77), which are higher than the tabulated t-value of (2.01) at a significance level of (0.05). Therefore, all items were considered discriminative

Additionally internal consistency of the test items was determined by calculating the correlation coefficients between each item score and the total test score using Pearson's correlation coefficient. The correlation values ranged from (0.32 to 0.45), while the tabulated correlation coefficient was (0.19). Hence, all items were deemed acceptable,

indicating that the test achieved internal consistency and thus confirmed its construct validity

Item Discrimination Index

This refers to the item's ability to distinguish between students with higher levels of knowledge and those with lower levels in identifying knowledge, as follows

1-Critical Thinking

The item discrimination index was calculated using the appropriate formula. The discrimination indices of the test items ranged between $(0.29 - 0.63)$, therefore all items in the critical thinking test were considered acceptable. An item is regarded as good when its discrimination index is (0.20) or higher

.2-Creative Thinking

The mean and standard deviation of the students' scores for each test item were calculated. The calculated t-values ranged from $(2.88 - 5.67)$, while the tabulated t-value was (1.977). The statistical analysis showed that each item was significant at the (0.05) significance level and a degree of freedom of (109), as the calculated values exceeded the tabulated value. Hence, all items were considered discriminative

Test Reliability

The reliability of the test was determined using Cronbach's Alpha coefficient. This coefficient provides a good estimate of reliability in most situations. The test reliability coefficient was found to be (0.79), which is considered good. According to Hills, a test is considered reliable when is reliability coefficient ranges between $(0.60 - 0.85)$

Final Version of the Productive Thinking Test

After establishing validity, conducting a pilot study of the test, statistically analyzing the items, and calculating the reliability coefficient, the final version of the test was composed of (31) items designed to measure productive thinking skills

Research Tool Application

The researcher administered the research tool by applying the productive thinking test to both research groups, according to the instructions attached to the test. The researcher then corrected the tests to obtain the scores of the students in the research groups and to present the results

Chapter FOUR

Independent Variable	Dependent Variable	Effect Size	Impact
Information Processing Strategy	Productive Thinking	1.25	Large

Discussion of Results

The results of the study revealed a statistically significant difference in the productive thinking test between the students in the experimental group, who were taught using the Information Encoding Strategy, and those in the control group, who were taught using the conventional method. The difference favored the experimental group

This finding clearly indicates that the Information Encoding Strategy contributed to the development of productive thinking skills among the students. This positive effect can be attributed to the nature of the strategy, which activates the learner's role through reorganizing information and linking new knowledge with prior concepts in a manner that requires engaging multiple cognitive abilities. These mental processes help develop skills of deep understanding, interpretation, and innovation—all of which are integral components of productive thinking

Teaching biology using this strategy provided a distinctive learning environment that enabled students to engage more deeply with the subject matter and to interact with concepts flexibly

From an educational perspective, this finding supports the trend of integrating modern cognitive strategies into teaching methods at the

intermediate stage, particularly in scientific subjects that require high-level mental activity, such as biology. The results reflected that learners presented with content in a way that demands mental interaction and organized information processing are more capable of producing unconventional ideas and approaches to educational situations

Accordingly, the results of this study highlight the effectiveness of the Information Encoding Strategy as an educational tool for developing one of the most important higher-order thinking skills—productive thinking. This calls for serious consideration of generalizing its use within teacher preparation programs and curricula in biology and other scientific subjects

Conclusions

1-The Information Encoding Strategy is effective in improving students' achievement in **science**

2-The strategy contributes to the development of productive thinking among students

3-It is recommended to generalize the use of the Information Encoding Strategy in teaching science to achieve better educational outcomes

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