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Analogical Thinking and its Relationship to Cognitive Representation among Fifth Scientific Grade Students in the Subject of Biology

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Abstract: *The current research aims to identify the level of analogical thinking and its relationship to cognitive representation among fifth scientific grade students in the subject of Biology. The research sample consisted of 346 male and female students from fifth scientific grade classes in secondary schools within the Al-Aziziyah district of Wasit Governorate, comprising 150 male and 196 female students for the academic year 2023–2024. The researchers adopted an analogical thinking scale consisting of 30 items and constructed another 30-item scale (also with five alternatives per item). Psychometric properties of both instruments were verified to ensure readiness for application. A descriptive methodology was employed to gather the required data. After statistical analysis using the Statistical Package for the Social Sciences (SPSS), the study yielded the following results: Students demonstrated a moderate level of analogical thinking; Students exhibited a moderate level of cognitive representation; strong positive correlation was found between analogical thinking and cognitive representation. Based on these findings, the researchers recommend that organising training workshops for teachers across all educational stages to familiarise them with modern teaching methods and programmes aimed at enhancing students' cognitive processes, particularly cognitive representation, providing students with diverse models for representing knowledge to aid learning, retention, and recall. To extend this research, the researchers suggested that conducting a similar study examining analogical thinking alongside other variables (e.g., motivation, attitudes, and transfer of learning). Further investigations into the same variables across different educational stages.*
KEYWORDS: analogical thinking, relationship, cognitive representation, fifth scientific grade students, Biology

INTRODUCTION

Higher-order thinking skills are fundamental pillars that contribute to building a learner's personality and developing their cognitive abilities, especially given the rapid challenges imposed by the modern era in the

field of education. Analogical thinking is one of the forms of complex cognitive thinking, enabling students to perceive relationships and comparisons between different concepts or situations and transition from one cognitive state to another by identifying structural or functional similarities. This enhances deep understanding and logical comprehension of the subject matter.

As for cognitive representation, it refers to the way a learner stores information within their cognitive structure and the mechanisms they use to organise and retrieve knowledge when needed. Cognitive representation is fundamental to understanding how students engage with scientific concepts, particularly in subjects requiring precise comprehension, such as the natural sciences—including biology. From this perspective, the importance of linking analogical thinking and cognitive representation becomes evident, especially for fifth-grade science students who encounter intricate biological concepts requiring advanced mental skills. Accordingly, this research aims to explore the nature of the relationship between analogical thinking and cognitive representation among these students in biology, seeking to provide educational insights that contribute to the development of teaching methods, the improvement of academic performance, and the design of educational programmes focused on cultivating precise thinking.

First: Research Problem

The secondary stage is one of the most critical phases in a student's life, characterised by providing opportunities for pupils to engage in effective learning processes. This is achieved by addressing their needs, solving their problems through activity-integrated curricula, and enhancing their problem-solving abilities, thinking skills, and creative inclinations in alignment with their capabilities and aptitudes. During this stage, a student's personality is shaped, and the more refined the learner's formation process, the greater the improvement in educational quality.

Schools, as key societal institutions, bear the primary responsibility for education within the community. They must play a major role in equipping students with diverse thinking skills and training them to apply these skills both within the school environment and in their lives beyond its walls. Thinking is a vital human activity necessary for solving daily problems. It is a cognitive process that requires continuous development throughout a person’s life stages, as it enriches them with experiences, skills, and knowledge. To provide learners with new educational experiences—distinct from previous ones in terms of acquired skills and novel academic challenges—they must be taught how to confront and overcome these challenges using new educational variables such as **analogical thinking and cognitive representation. These variables significantly impact academic achievement by fostering critical thinking, enabling learners to process vast amounts of information effectively, and representing knowledge efficiently.

Analogical thinking helps students comprehend underlying phenomena by discerning relationships between their constituent elements. It enhances their understanding of scientific terms and principles, fostering creativity through the formation of new conceptual connections. Consequently, it empowers them to solve problems using innovative approaches. Zayyat (1998) highlights that the efficiency of cognitive representation actively contributes to effective learning by enabling learners to establish meaningful connections between new subject matter and their existing cognitive frameworks, as well as between new and prior knowledge. Given this context, the present research problem stems from the urgent need to study variables that support students' talents and aptitudes—such as cognitive representation and analogical thinking—which may translate into tangible academic and non-academic excellence.

Thus, this research seeks to explore the significance of analogical thinking and cognitive representation among secondary school students and their impact on academic performance, as well as their role in achieving educational objectives. Accordingly, the research problem is defined by addressing the following questions:

1. Do fifth-grade science students possess analogical thinking skills?
2. Do fifth-grade science students exhibit cognitive representation?
3. Is there a correlational relationship between analogical thinking and cognitive representation?

Second: Research Significance

1. Focus on Analogical Thinking, this cognitive tool helps students develop creativity by facilitating new understanding through comparative analysis of similarities and differences between concepts. Consequently, students gain precise comprehension and construct new cognitive schemas for information processing (Glyn, 2007:54).
2. Raising Educators' Awareness, the study highlights the psychological significance of analogical thinking and its positive impact on secondary school students, encouraging educators to integrate it into teaching methodologies.
3. Alignment with Modern Scientific Trends, the research supports contemporary educational approaches that emphasise leveraging analogical thinking to enhance cognitive representation efficiency among secondary students, in line with recommendations from various global studies and projects.
4. Establishing a Theoretical Framework, the study contributes to a deeper understanding of the relationship between analogical thinking and cognitive representation, along with its positive implications for the educational process.

Practical Significance of the Research

1. Guiding Educational Practitioners. The research findings direct educators and teaching professionals to move beyond traditional educational models focused solely on information accumulation and rote memorization. Instead, it promotes the application of analogical thinking in instructional materials and the adoption of teaching methods aligned with students' cognitive representation abilities.
2. Enhancing Knowledge Acquisition. The study contributes to identifying effective approaches for knowledge acquisition and production by examining the relationship between analogical thinking and the efficiency of students' cognitive representation of information.
3. Modernizing Science Education, Effective science teaching and learning require adopting new approaches and contemporary methodologies, particularly at the secondary level. This necessitates treating science as an investigative process and equipping learners with analogical thinking skills.
4. Empowering Science Teachers, the current research may help reveal the crucial role of science teachers in fostering analogical thinking skills among students, thereby enhancing overall learning outcomes.

Third: Research Objectives

The present study aims to:
1. Determine the level of analogical thinking among fifth-grade science students in biology.
2. Assess the level of cognitive representation among fifth-grade science students in biology.
3. Examine the relationship between analogical thinking and cognitive representation among fifth-grade science students in biology.

Fourth: Research Delimitations

1. Population Boundary: Restricted to fifth-grade science students.
2. Geographical Boundary: Limited to secondary schools in Al-Aziziyah District, Wasit Governorate, under the Wasit Education Directorate, specifically: Al-Aziziyah Secondary School for Boys, Abeer Al-Iraq Secondary School for Girls, Ibn Al-Haytham Secondary School for Boys, Al-Aziziyah Secondary School for Girls, Al-Khwarizmi Secondary School for Girls, Al-Aziziya Elite Secondary School for Distinguished Girls & Al-Turath Secondary School for Boys
3. Temporal Boundary: First semester of the 2023-2024 academic year.
4. Cognitive Boundary: Limited to selected topics from the fifth-grade biology curriculum.

Fifth: Research Terminology

I. Analogical Thinking

Theoretical Definitions

- Bransford & Stein (1984): "A mental activity involving two processes: (1) Alignment – identifying concepts or subjects sharing similar or analogous elements, and (2) Focusing – selecting concepts or subjects based on the degree of similarity in their structural composition" (Bransford & Stein, 1984, p. 1).
- Qatami (2013): "The process of drawing comparisons and establishing similarities between two interrelated entities, enabling students to form conceptual relationships" (Qatami, 2013, p. 725).

Operational Definition (Researchers): The total score obtained by secondary school students based on their responses to items on the Analogical Thinking Scale.

II. Cognitive Representation

Theoretical Definitions:

- Shalaby (2001): "The internalization, comprehension, and assimilation of meanings and ideas, allowing them to be retained as part of an individual's cognitive structure—a cumulative framework where knowledge interacts with direct and indirect experiences, thereby enhancing cognitive productivity" (Shalaby, 2001, p. 114).
- Qatami (2005): "The process through which an individual integrates newly acquired experiences into their cognitive framework" (Qatami, 2005, p. 259).

Operational Definition (Researchers):

The total score obtained by secondary school students based on their responses to items on the Cognitive Representation Scale.

Theoretical Framework and Previous Studies

Theoretical Framework

Thinking Styles

Thinking is a distinctive trait with which Allah Almighty has privileged humans over other creatures, as emphasized by numerous Quranic verses. It constitutes a fundamental cognitive process that our Islamic faith prioritizes. This demonstrates that thinking is both a divine imperative and an indispensable human behavior—one that aids in problem-solving and overcoming obstacles that hinder learners from fulfilling their innate needs and motivations. Through thinking, these needs are satisfied, playing a pivotal role in expanding the learner's cognitive scope, enabling clearer perception, fostering positive thought patterns, and ultimately generating novel ideas (Razouki & Jamila, 2019, pp. 5-6).

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Modern education has increasingly focused on thinking and its various styles, with scholars studying specific cognitive patterns as essential components of experiential development. This is achieved by drawing analogies between new and prior experiences. Research indicates that problem-solving behavior develops progressively: a child begins by exploring their surroundings and then establishes analogies between past and present scenarios, thereby enhancing perceptual skills and problem-solving abilities (Alwan, 1995, p. 37).

Analogical thinking refers to a learner's capacity for holistic cognition, allowing them to perceive relationships clearly. It involves connecting concepts or mental operations by applying information from one domain (the source or analogy) to another. Recognized as a vital cognitive style, analogical thinking is frequently employed to resolve problems or comprehend ambiguous phenomena (Razouki & Nabil, 2018, p. 53). This process relies on the cognitive representation of information, integrating new data with existing mental frameworks.

Far from being a passive or mechanical stimulus-response association, this process is actively mediated by internal cognitive structures that filter and refine incoming stimuli through systematic cognitive activities. Consequently, these structures self-enrich through additive and organizational processes (Qatam, 2005, p. 259). Analogical thinking further facilitates collaborative learning, fostering confidence, peer cooperation, and reduced individualism. It cultivates a sense of group belonging, openness to diverse perspectives, and enhanced linguistic, social, and creative skills (Abdul-Muti, 2000, p. 36).
Moreover, it drives the evolution of cognitive frameworks by constructing new mental models to grasp unfamiliar concepts. Learners synthesize past, present, and future temporal dimensions by leveraging stored knowledge to interpret and acquire new information (Embu Said, 2009, p. 151).

Characteristics of Analogical Thinking
- Contextual Relevance: Analogical thinking bridges academic content and learners lived experiences by connecting new material to familiar situations.
- Differentiated Processing: It operates through discriminative thinking, systematically transferring analogous traits between different contexts via structured mapping that reinforces conceptual similarities.
- Confidence Building: Empowers learners to recognise their self-worth and act decisively, free from hesitation or apprehension.
- Structural Prerequisites: Effective application requires identifiable analogical properties between elements, selected based on shared attributes.
- Mnemonic Activation: Continuously invigorates memory through comparative analysis of prior and new information to construct knowledge (Razouki, 2019, p. 53).

The Teacher's Role in Implementing Analogical Thinking
- Valuing Student Perspectives: It is essential to accept and respect learners' opinions, as each idea they propose serves as a catalyst, prompting them to engage with the subject from alternative approaches (Abdul-Karim & Hilal, 1992, p. 48).
- Deliberate Judgment: Teachers should avoid hasty conclusions, allowing adequate time for thoughtful analysis to identify problems, diagnose strengths and weaknesses, and develop solutions.
- Problem-Solving Focus: Analogical thinking relies on resolving challenges specific to the educational context.
- Promoting Cognitive Flexibility: Learners should be encouraged to think flexibly, avoiding rigidity to examine issues from multiple perspectives.

- Fostering Collaborative Learning: Students ought to be guided toward cooperative learning, exchanging diverse ideas while refining incorrect notions and reinforcing valid ones (Lowsson, 1993, p. 1213).

Types of Analogical Thinking

a. Personal Analogical Thinking (Empathic Projection)

This form of thinking, also termed self-projection or emotional identification, involves learners imaginatively embedding themselves within the elements of a problem. It requires a mental and emotional unification between the learner and the subject of study, demanding active cognitive engagement, imaginative effort, and the mobilization of prior knowledge to construct novel mental representations even of experiences never directly encountered (Razouki & Nabil, 2018, p. 58).

b. Contradictory Analogical Thinking (Juxtapositional Analogy)

Here, contradiction arises from pairing antithetical descriptors of a single entity. Gordon posits that focused contradictions broaden students' insight into new subjects, revealing their capacity to reconcile divergent conceptual frameworks within a unified context (Razouki & Nabil, 2018, p. 59).

c. Symbolic Analogical Thinking

Learners employ words, signs, symbols, or equations to forge relationships between animate/inanimate objects that appear unrelated to conventional observation. This abstracts tangible or intangible subjects into symbolic linkages (Razouki & Nabil, 2018, p. 59).

d. Imaginative Analogical Thinking

This liberates learners from reality's constraints by deploying fantasy and desire beyond traditional logic. It transcends societal conventions through mental imagery that retains sensory attributes of represented information, enabling perceptual mapping onto alternative cognitive schemata (Razouki & Nabil, 2018, p. 60).

Cognitive Representation

Interest in the representation and storage of cognitive information emerged in the 1940s, when psychologists sought to understand cognitive processes encoding, storage, and retrieval. By the early 1960s, Ausubel highlighted representation as the core mechanism through which new information is stored in relation to prior knowledge within a learner's cognitive structure (Mohamed, 2007, p. 122).

Numerous studies confirm a reciprocal relationship between cognitive structures and cognitive representation, where cognitive structures serve as a fundamental concept in cognitive development. This interdependence implies that studying one necessitates studying the other two sides of the same coin. Cognitive structures emerge as the product of representation and its forms, shaped by varied mental processing of represented information (Al-Shami, 2012, p. 43).

Cognitive representation is a complex, foundational process comprising hierarchically organized mental operations:

1. Storage (Base Level): - Retention of raw, input information in the learner's cognitive structure or memory until integrated.
2. Association & Classification (Second Level): - Linking new information to existing memory content and categorizing it for efficient retrieval.
3. Synthesis (Third Level):- Harmonizing new data with prior knowledge in memory.
4. Derivation & Generation (Fourth Level):- Inferring new meanings, ideas, or insights through stored information or synthesized old/new data (Mohamed, 2007, p. 33).

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Characteristics of Cognitive Representation

a. Retention Property : Refers to the intentional preservation of acquired or derived knowledge and information for future application or utilisation.

b. Meaning Property: Ensures that the semantic essence of cognitive content both expressed and intended persists within the learner's mind.

c. Derivation Property: Manifests when a learner's cognitive structure generates *novel formulations of information that differ qualitatively and quantitatively from the original input.

d. Synthesis Property: Involves modifying elements to construct distinct cognitive outputs while retaining the foundational "flavour" of the original components.

e. Multi-Format Representation Property: Denotes diversity in frameworks and strategies for cognitive representation, contingent on either episodic (context-driven) or subjective (self-organized) structuring.

f. Cognitive Flexibility Property : Emphasizes varied processing modes for incoming or derived information, rejecting rigid, formulaic approaches.

g. Dynamic Representation Property: Signifies cognitive fluency anchored in the ability to synthesise, derive, and generate knowledge adaptively (Atta & Osama, 2018, pp. 31–32).

Theories Explaining Cognitive Representation

a. Piaget's Theory (1963) views cognitive representation as a mental process parallel to biological assimilation. It involves integrating new elements into an organic system, much like food digestion or photosynthesis in plants. Just as biological assimilation occurs, mental representation consists of linking new information with existing cognitive structures (Qatami, 2005, p. 259). Thus, cognitive representation means adapting perceptions to fit pre-existing cognitive frameworks, making them part of the learner's organised knowledge. In other words, it is the process of receiving information from the environment and Transforming it to align with an individual's cognitive schema (Ghanem, 1995, p. 83; Al-Anani, 2001, p. 112).

b. Novak and Gowin's Theory (1984**)** assert that cognitive representations consist of nodes (representing concepts) and links (illustrating relationships between these concepts). When new concepts or meanings are subsumed under broader categories, this structure forms a hierarchical organisation of concepts, progressing from general to specific levels. As learners acquire new information, they rapidly expand their prior understanding of these concepts. Novak and Gowin emphasise that concept mapping not only reveals the quantity of an individual's knowledge but also its quality, observable through the interconnections each concept forms, the organisational framework it creates (Bellay, 1999, p. 325).

c. Paivio's Theory (1986) Paivio's Dual Coding Theory posits that information in long-term memory is stored in two distinct representational formats:

1. Verbal Representation Primarily processes and encodes linguistically structured information in a sequential manner.
2. Imaginal (Visual) Representation Specialised for processing spatial and non-linguistic information.

Paivio emphasises that encoding efficiency depends on presentation modality. Information presented both verbally and visually is recalled faster and more accurately compared to single-modality input. This theory underscores the pedagogical necessity of multimodal instruction to enhance retention, the role of perceived importance:

- High-importance information is dual-coded (symbolic + verbal),
- Less critical information tends to be single-coded (either symbolic or verbal) (Zaghloul, 2003, p. 199).

According to the two researchers : The acquisition of analogical thinking skills occurs through cognitive processes that differentiate student capabilities. For optimal cognitive performance, a learner's knowledge must be:

- Logically organised within their cognitive structure to enable: Prediction, Inference, Relationship mapping, Higher-order cognitive engagement.

Poorly organised knowledge impedes creative output, as cognitive representation forms the foundational framework for analogical thinking. Thus, both analogical thinking proficiency and efficient cognitive representation critically influence students': Academic performance, Problem-solving efficacy, Decision-making competence, & Achievement outcomes.

Previous Studies/ Studies Addressing Analogical Thinking

A study by Al-Zuhairi (2020) titled "Analogical Thinking and Its Relationship to Creative Problem Solving Among Gifted and Regular Secondary School Students" aimed to identify the level of analogical thinking and creative problem solving among both gifted and regular secondary students, while examining statistically significant differences according to student category (gifted versus regular) and gender. The study also sought to determine the correlational relationship between analogical thinking and creative problem solving.

The research sample comprised 400 male and female students from both gifted and regular streams in secondary schools across Wasit Governorate during the 2019/2020 academic year. The findings revealed that both gifted and regular students possessed analogical thinking skills, with statistically significant differences at the 0.05 level favouring gifted students in terms of analogical thinking ability. No statistically significant differences were found based on gender interaction in analogical thinking performance.

-Studies Addressing Cognitive Representation

Abd El-Mawgoud's Study (2023):"The Efficiency of Cognitive Representation and Its Relationship to Some Creative Thinking Skills Among Preparatory Stage Students"The study aimed to identify the relationship between the efficiency of cognitive representation and some creative thinking skills (fluency and flexibility) among preparatory stage students. The research sample consisted of (60) second-year preparatory students from Al-Ahyaa Preparatory School (30 males and 30 females). The researcher employed the descriptive approach, utilizing two research tools: a cognitive representation efficiency scale developed by the researcher and Torrance's Test of Creative Thinking (measuring fluency and flexibility skills). The results revealed a correlational relationship between cognitive representation efficiency and some creative thinking skills. Additionally, the findings indicated no statistically significant differences in cognitive representation efficiency between males and females, while statistically significant differences in creative thinking skills were found in favor of female students.

RESEARCH METHODOLOGY AND APPROACH

Research Methodology

The researchers adopted a correlational descriptive approach to achieve the study's objectives and characterise the relationship between the two variables.

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Research Population

The research population comprised all fifth-grade science students in government day secondary schools under the Wasit Education Directorate Al-Aziziyah District, Wasit Governorate, for the 2023-2024 academic year.

Research Sample

A stratified random sampling method was employed, selecting a sample of (225) male and female students from (5) secondary schools under the Al-Aziziyah Education Directorate in Wasit Governorate.

Research Instruments

1. Analogical Thinking Scale

Purpose: To measure analogical thinking among fifth-grade science students (the research sample).

The researchers adopted the Analogical Thinking Scale from a study by (Lafta , 2021). The final version of the scale consisted of 30 items, each presenting two alternatives. Students were required to mark (✓) the response that best aligned with their thought process (see Appendix 1).

Validity of the Analogical Thinking Scale

Validity refers to the degree to which a measurement tool achieves its intended objectives, constituting one of the most critical characteristics of educational and psychological instruments (citation, 2011, p. 295).

To ensure validity, the researchers:

- Established face validity by presenting the scale items to a panel of experts for evaluation.
- Determined construct validity through statistical analysis of pilot sample scores.

The results confirmed that all correlation coefficients were statistically significant when compared to Pearson's critical values at a 0.05 significance level and 148 degrees of freedom, as demonstrated in Table 1.

Table (1) Correlation Coefficients Between Item Scores and Total Scores on the Analogical Thinking Scale

Items	Pearson correlation		degree of freedom	Significance at the level of (0.05)
	calculated	Tabulated		
1	0.245 **			Significant
2	0.276**			Significant
3	0.281**			Significant
4	0.392**			Significant
5	0.289**			Significant
6	0.269**			Significant
7	0.303**			Significant
8	0.332**			Significant
9	0.306**			Significant
10	0.258**			Significant
11	0.327**			Significant
12	0.232**			Significant
13	0.211**			Significant
14	0.301**			Significant

15	0.240**	0.160	148	Significant
16	0.399**			Significant
17	0.349**			Significant
18	0.336**			Significant
19	0.395**			Significant
20	0.367**			Significant
21	0.297**			Significant
22	0.242**			Significant
23	0.334**			Significant
24	0.253**			Significant
25	0.241**			Significant
26	0.382**			Significant
27	0.343**			Significant
28	0.323**			Significant
29	0.381**			Significant
30	0.466**			Significant

Discriminatory Power of Items

To measure the discriminatory power of the scale items, the researchers administered the test to the analysis sample consisting of (225) male and female students from the research population. After correcting participants' responses and calculating total scores for each questionnaire, the scores were arranged in descending order from highest to lowest. The top and bottom (27%) were then selected, averaging (41) students in each group.

Following the calculation of mean scores for both groups, the researchers applied an independent samples (T-Test) to examine the significance of differences between the groups. The calculated t-value served as an indicator of discriminatory power between the groups, with each item's t-value representing its discriminatory capability when compared against the critical table value of (1.990) at (80) degrees of freedom and a (0.05) significance level.

The results demonstrated that all items showed statistical significance, with their calculated t-values exceeding the critical table value, as presented in Table (2).

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Table (2) Discrimination Coefficients for Items of the Analogical Thinking Scale

Items	Upper group		Lower group		The calculated value		degree of freedom	Significance at the level of (0.05)
	Arithmetic Mean	Standard Deviation	Arithmetic Mean	Standard Deviation	calculated	Tabulated		
1	2.54	1.306	1.73	0.742	3.431	1.990	80	Significant
2	2.56	1.246	1.66	0.762	3.957			Significant
3	3.59	1.140	2.80	1.436	2.726			Significant
4	3.12	1.364	1.80	1.188	4.662			Significant
5	3.15	1.424	2.24	1.319	2.977			Significant
6	3.22	1.509	2.15	1.542	3.185			Significant
7	2.76	1.469	1.85	1.062	3.149			Significant
8	2.90	1.625	1.71	1.055	3.950			Significant
9	2.85	1.442	1.93	1.212	3.151			Significant
10	2.39	1.464	1.66	1.015	2.630			Significant
11	3.93	1.273	2.90	1.463	3.383			Significant
12	2.95	1.341	2.10	1.241	2.992			Significant
13	3.68	1.213	3.27	1.342	1.467			Significant
14	3.98	0.961	3.12	0.954	4.036			Significant
15	3.10	1.044	2.51	1.186	2.372			Significant
16	3.90	1.136	2.66	1.237	4.742			Significant
17	3.46	1.267	2.20	1.308	4.460			Significant
18	3.34	1.353	2.15	1.352	4.001			Significant
19	3.22	1.458	1.85	1.195	4.639			Significant
20	2.93	1.421	1.78	1.151	4.013			Significant
21	2.85	1.606	1.95	1.322	2.778			Significant
22	2.78	1.441	1.95	1.139	2.891			Significant
23	2.73	1.342	1.68	1.128	3.831			Significant
24	3.83	1.243	2.68	1.507	3.757			Significant
25	3.02	11.93	2.71	1.327	1.137			Significant
26	3.12	1.470	1.83	0.919	4.775			Significant
27	2.85	1.459	1.71	1.101	4.016			Significant
28	2.76	1.513	1.46	0.840	4.784			Significant
29	3.73	1.184	2.88	1.208	3.232			Significant
30	3.56	1.266	2.00	1.095	5.971			Significant

Reliability of the Analogical Thinking Scale

To establish the reliability of the scale items, (Cronbach's alpha) coefficient was employed to measure internal consistency. The results, following administration to the research sample, yielded a Cronbach's alpha value of 0.67.

Cognitive Representation Scale

This scale was designed to assess the level of cognitive representation within the research sample. The researchers developed the scale's 30 items after reviewing relevant literature and previous studies. Each

item presents five response options based on a 5-point Likert scale: (Always applies to me, often applies to me, sometimes applies to me, rarely applies to me, never applies to me).

Validity of the Cognitive Representation Scale

Validity refers to the extent to which a scale measures the construct it is intended to measure. Validity is considered one of the most important characteristics of educational measurement tools. In the present study, indicators of validity were obtained using two methods: face validity and construct validity. Face validity was ensured by presenting the initial version of the scale to a panel of experts and specialists in the fields of education, psychology, and teaching methods. Each expert was asked to provide their opinion regarding the scale's items (see Appendix 2). Construct validity was verified by the researchers through calculating the correlation between each item's score and the total score of the scale, using Pearson's correlation coefficient. The results indicated that all correlation coefficients were statistically significant at a degree of freedom of (148) and a significance level of (0.05), as shown in Table 3.

Table (3): Correlation Coefficients between Each Item Score and the Total Score of the Cognitive Representation Scale

Items	Pearson correlation		degree of freedom	Significance at the level of (0.05)
	calculated	Tabulated		
1	0.262**	0.160	148	Significant
2	0.468**			Significant
3	0.648**			Significant
4	0.685**			Significant
5	0.649**			Significant
6	0.669**			Significant
7	0.324**			Significant
8	0.433			Significant
9	0.454**			Significant
10	0.246**			Significant
11	0.432**			Significant
12	0.396**			Significant
13	0.277**			Significant
14	0.428**			Significant
15	0.477**			Significant
16	0.526**			Significant
17	0.513**			Significant
18	0.452**			Significant
19	0.458**			Significant
20	0.266**			Significant
21	0.587**			Significant
22	0.609**			Significant
23	0.514**			Significant
24	0.617**			Significant
25	0.347**			Significant
26	0.513**			Significant
27	0.487**			Significant
28	0.551**			Significant
29	0.371**			Significant
30	0.505**			Significant

Discriminant Validity of the Items:

The discrimination index for each item of the scale was calculated using the two extreme groups method, with the top and bottom 27% of the sample (41 participants in each group). The calculated t-values ranged between (2.226–9.545), at a degree of freedom of (80), as shown in Table (4).

Items	Upper group		Lower group		The calculated value		degree of freedom	Significance at the level of (0.05)
	Arithmetic Mean	Standard Deviation	Arithmetic Mean	Standard Deviation	calculated	Tabulated		
1	2.54	0.977	2.10	0.539	2.519	1.990	80	Significant
2	3.27	0.807	2.10	0.860	6.355			Significant
3	3.93	0.755	2.34	0.965	8.288			Significant
4	3.83	1.138	1.83	0.771	9.315			Significant
5	3.66	0.825	2.32	0.850	7.253			Significant
6	3.95	1.224	2.05	1.139	7.286			Significant
7	3.07	0.959	2.59	1.024	2.226			Significant
8	3.10	0.944	2.05	1.117	4.593			Significant
9	3.59	0.974	2.02	1.294	6.171			Significant
10	3.20	1.123	2.20	1.229	3.846			Significant
11	3.29	0.680	1.83	0.972	7.899			Significant
12	3.32	1.011	2.12	0.678	6.287			Significant
13	3.05	0.865	2.12	1.029	4.414			Significant
14	3.24	1.044	2.12	0.872	5.284			Significant
15	3.15	0.853	2.05	0.740	6.222			Significant
16	3.20	1.167	1.68	0.907	6.554			Significant
17	3.24	0.888	1.71	0.929	7.657			Significant
18	3.29	0.873	1.85	1.174	6.298			Significant
19	2.90	0.800	1.73	0.867	6.355			Significant
20	2.80	0.980	2.17	1.181	2.645			Significant
21	3.73	0.923	2.44	0.976	6.163			Significant
22	3.88	0.714	2.41	0.948	7.895			Significant
23	3.12	1.249	1.68	0.850	6.100			Significant
24	3.24	0.830	1.59	0.741	9.545			Significant
25	3.24	1.090	2.39	0.666	4.278			Significant
26	3.34	0.728	2.34	0.965	5.297			Significant
27	3.46	1.120	2.51	1.207	3.699			Significant
28	3.80	0.928	2.56	1.205	5.237			Significant
29	3.34	0.728	2.44	1.433	3.595			Significant
30	3.27	0.949	1.71	1.209	6.502			Significant

Reliability of the Cognitive Representation Scale:

The two researchers calculated the reliability coefficient of the Cognitive Representation Scale by determining its internal consistency using Cronbach's Alpha formula. The reliability value was found to be (0.88), which is considered a good level of reliability.

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Statistical Methods

The two researchers used statistical methods in conducting the research procedures, analysing the data, and interpreting the results, through the use of the SPSS statistical software, as follows:

1. Independent Samples t-test: Used to calculate the discriminative power of the scale items.
2. One-Sample t-test: Used to test the differences between the hypothetical mean and the actual arithmetic mean.
3. Pearson Correlation Coefficient: Used to identify the relationship between each item score and the total score.
4. Cronbach's Alpha Coefficient: Used to determine the reliability of both scales.

RESEARCH RESULTS AND DISCUSSION

This chapter presents the findings obtained in accordance with the objectives outlined in Chapter One. It also includes a discussion and interpretation of these findings. Based on this, a number of recommendations and suggestions were developed.

First Objective: The Level of Analogical Thinking among Fifth Scientific Grade Students in Biology

When applying the one-sample t-test, it was found that the arithmetic mean was higher than the hypothetical mean, and the calculated t-value exceeded the tabulated value. This indicates that students exhibited a moderate level of analogical thinking. Table (5) illustrates these results.

Sample size	rithmetic Mean	Hypothetical mean	Standard Deviation	The calculated value		Degree of freedom	Level of significance	Statistically
				calculated	Tabulated			
346	96.92	0	15.875	.111	1.649	345	0.05	Significant

Second Objective: The Level of Cognitive Representation among Fifth Scientific Grade Students in Biology

When applying the one-sample t-test, it was found that the arithmetic mean was higher than the hypothetical mean, and the calculated t-value exceeded the tabulated value. This indicates that the students demonstrated a moderate level of cognitive representation. Table (6) illustrates these results.

Sample size	Arithmetic Mean	Hypothetical mean	Standard Deviation	The calculated value		degree of freedom	Level of significance	Statistically
				calculated	Tabulated			
346	97.94	90	15.948	9.260	1.649	345	0.05	دالة احصائيا

Third Objective: The Relationship Between Analogical Thinking and Cognitive Representation Among Fifth-Grade Science Students in Biology

A strong positive correlation was found, with the calculated Pearson coefficient reaching (0.83) compared to the critical table value of (0.105). This comparison indicates a statistically significant positive relationship between the two variables, as clearly demonstrated in Table (7).

Relationship	Correlation coefficient value		degree of freedom	Level of significance	Statistically	Type of correlation
	calculated	Tabulated				
Analogical thinking Cognitive representation	0.83	0.105	344	0.05	Significant	Very high

CONCLUSIONS

1. The research findings revealed a statistically significant relationship between analogical thinking and cognitive representation, indicating that students with a higher capacity for analogical thinking tend to have more organised and clearer cognitive representations in the subject of biology.
2. Analogical thinking contributes to the improvement of students' construction of cognitive models by enabling them to link new information with prior knowledge through comparison and analogy, which positively influences their understanding of complex biological concepts.
3. Analogical thinking serves as an effective cognitive tool in developing mental representation among students, as it helps them utilise analogical examples to explain abstract biological concepts, thereby enhancing their comprehension and deep understanding of the subject.

Recommendations

In light of the findings of the current research, the two researchers recommend the following:
1. Organising training courses for teachers at all educational levels to familiarise them with modern teaching methods and to equip them with the skills necessary to develop programmes aimed at enhancing students' cognitive processes—particularly cognitive representation.
2. Training students in the use of diverse models for representing information and knowledge, which would support their learning, memory, and the retrieval of information from long-term memory.
3. Enriching educational materials with learning situations and activities designed to elevate students' levels of thinking—especially analogical thinking—through the adoption of appropriate methods, models, and strategies that stimulate higher-order thinking.

Suggestions

In continuation of the findings reached by this research and with the aim of building upon its results, the two researchers propose the following:
1. Conducting a similar study to investigate the effect of analogical thinking in relation to other variables, such as motivation, attitude, and transfer of learning.
2. Carrying out further studies and research on the same variables but across different educational stages.
3. Undertaking additional correlational studies aimed at exploring the relationship between the efficiency of cognitive representation and other variables, such as achievement motivation and thinking styles.

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APPENDICES

Appendix (1)

The Final Version of the Analogical Thinking Scale

Answering Instructions

Dear Student,

You are presented with a set of items that represent situations you may encounter in your daily and academic life. Each item is followed by two alternatives. You are required to read each item carefully and respond accurately and objectively by placing a (1) mark next to the option you consider most appropriate.

Please make sure to answer all the items without leaving any unanswered.

As illustrated in the example below:

NO.	Items	Alternatives	Answers
1	I am able to	A- Forgetting what has been learned	✓
		B- Acquiring knowledge and retaining it	

Student's Name……

Class and Section…….

NO.	Items	Alternatives	Answers
1	I prefer the teacher's explanation in biology to be systematic and objective	Brief explanation	
		Detailed explanation	
2	When I encounter a problem or a question	I make a judgement after	

	in biology	knowing its causes	
		I make a judgement without needing to know its causes	
3	I prefer to befriend students who	share my ambitions	
		those who joke a lot	
4	My watching of social media platforms that broadcast biology programmes in order to	to increase my knowledge	
		for fun and entertainment	
5	My behaviours and actions during the biology lesson	Contrary to my true personality	
		In line with my true personality	
6	I have the ability to control my emotions	Completely	
		Partially	
7	In biology class, I am able to	forget the knowledge and information I have learned	
		retain the knowledge and information I have learned	
8	I take exams in Biology in order to	just to pass	
		success and excellence	
9	When my biology teacher assigns me a task, I..	I don't care about completing the task	
		I make sure to complete it perfectly	
10	What I study at school in other subjects relates to biology	It is always useful to me in my daily life	
		It is sometimes useful to me in my daily life	
11	Choosing what indicates the interaction between the elements of concepts	Only through my new experiences	
		Through both my past and new experiences	
12	able to solve the problems I face through	linking new experiences with previous ones	
		applying only new experiences	
13	When my classmate is absent from school, I..	I contact him to find out the reason for his absence	
		I wait for his return and find out the reasons for his absence	
14	When I fail the exam, I..	I object and look for the reasons	
		I only object	
15	I try to achieve my goal through	Continuous work, and mistakes do not stop me	
		Stopping work when a mistake occurs	
16	When I prepare to take the biology exam, I...	"I memorise only the new topics.	

		I memorise by linking new topics with old topics	
17	When reviewing my daily homework, I..	I read all the assignments	
		I focus only on the essence of the subject	
18	When I do not understand the teacher's explanation of a topic in biology, I...	I listen to the discussion and explanation of my classmates with the teacher	
		I ask the teacher to explain the lesson again	
19	Conducting an experiment in the biology lab makes me feel...	Tired and bored	
		Joyful and happy.	
20	My memorisation of the lesson and understanding of the biology homework through	Studying aloud	
		Studying quietly and silently	
21	Make decisions concerning me in a ___ way	Deliberate	
		Quickly and without needing to think	
22	When I discuss with my classmates to solve a certain issue, I...	I respect and accept my classmates' solutions	
		I provide new and unique solutions	
23	I consider school rules and regulations to be for me..	Flexible	
		Strict	
24	When I go to school, I..	I wait for all my classmates even if I am late	
		I go early without waiting	
25	I choose my clothes according to...	what suits my body	
		what my friends wear	
26	I propose a solution to the problem of environmental pollution	During its occurrence	
		Prior to its occurrence	
27	I would like classmates who have...	who have high academic ambition	
		who have low academic ambition	
28	I make my decisions	I make my decisions based only on my own opinion	
		I make my decisions by considering others' opinions	
29	I face new life situations through..	My old and new experiences together	
		My previous experiences only	
30	Achieving my goals through...	Helping my fellow students	
		By my own effort and self-reliance.	

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Appendix (2)

The Final Version of the Cognitive Representation Scale

Dear Student,

You are presented with this scale, which consists of a set of statements, each followed by several options. Please read each statement carefully and thoroughly, and respond by placing a tick (√) under the option that best applies to you from the five given alternatives.

Please note that your responses will be used for scientific research purposes only,As shown in the example below.

NO.	Items	Alternatives				
1	I strive to apply what I have learned in my everyday life	Always applies to me	Often applies to me	Applies to me to some extent	Does not apply to me	Never applies to me

Student's Name……

Class and Section…….

NO.	Items	Alternatives					
		I strive to apply what I have learned in my everyday life	Always applies to me	Often applies to me	Applies to me to some extent	Does not apply to me	Never applies to me
1	I repeat the information to reinforce my memorisation						
2	I try to break the topic into several parts to make it easier to memorise						
3	I memorise the information in the textbook exactly as it is						
4	I am attracted to questions based on recall and retrieval						
5	I prefer to connect new information with previous knowledge when reading						
6	I view the information in the subject as an integrated whole						
7	I focus on understanding the relationships within the topics I read						
8	I try to connect the theoretical and practical aspects in my study of Biology						

9	I usually look for evidence and illustrative examples to support the information I read						
10	I find it difficult to make connections between the concepts in the scientific subject						
11	I tend to add some information stored in my memory to the new information						
12	I tend to rephrase the main ideas in my own way and style						
13	I have the ability to understand the main idea in the material and connect it with other ideas to arrive at a new concept						
14	I strive to find a way to address the weaknesses found in the material						
15	I am attracted to questions based on inference						
16	I focus on studying topics that are directly related to my future career						
17	I pay attention to the information in the subject that can benefit me in my daily life						
18	I memorise the diagrams related to the biology subject well						
19	I feel the importance of using illustrations to facilitate my memorisation and recall of scientific material						
20	I forget the information I memorised as soon as the exam is over						

21	I prefer to understand the experiment well before applying it practically						
22	I look for connections between topics when I read them						
23	I derive a new meaning from the context addressed by the topic						
24	I organise the relationships between scientific topics to produce a coherent structure						
25	I approach the topic from all its aspects to make it easier for me to understand						
26	I feel that my knowledge in Biology is scattered and extensive, and its structure is not coherent						
27	I transform my knowledge from its theoretical form to its practical form						
28	I use all my senses when conducting scientific experiments						
29	I see that my cognitive structure in Biology is continuously increasing						
30	I continuously interact with new scientific information						

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