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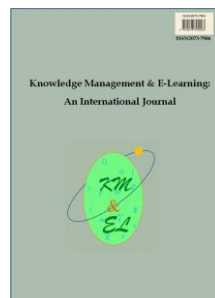
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Brain dominance pattern and creativity thinking in science among students in Jordan

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Abstract: The study aimed to investigate the relationship between students' prevailing brain dominance pattern and their level of creative thinking in science. The study sample consisted of 850 ninth-grade students in Jordan selected by the cluster random method. The brain control scale and the test of creative thinking in science were used to collect data. The study concluded that the student's creative thinking level was medium in Jordan. The results also showed that the average scores of students with integrated brain control were higher, statistically significant, than those of students with left and right brain control. The results also showed that there were statistically significant differences between the arithmetic means of creative thinking due to gender and in favor of males.

Keywords: Brain dominance pattern; Creative thinking; Science

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1. Introduction

In basic education, students are mainly concerned with achieving distinguished academic achievements based largely on acquiring cognitive content in various subjects, including science. Their acquisition of this knowledge is traditionally evaluated through school tests, in which they are classified into graded categories according to their achievement results. In another context, the results of the students in the international tests TIMSS (Trends in International Mathematics and Science Study) and PISA (Programme for International Student Assessment) and the national tests that are held for them periodically and focus on thinking skills in various subjects, of which science is one of the most important, indicate that the general characteristic of the performance of students in the upper basic stage in Jordan is a continuous decline (Ministry of Education, 2019; Mullis, Martin, Foy, & Hooper, 2016). Perhaps this directs the research compass. It is necessary to pay attention to the mechanism and manner in which students think to achieve greater benefit for them in education by raising their efficiency in science learning, as the brain is directly responsible for the individual's tendency to think in a way that distinguishes him from others (Butz & Kutter, 2016), on the one hand, and that the subject of science and its branches enhance thinking skills, including creative thinking, among students (O'Toole, Freestone, McKoy, & Duckworth, 2018).

In a related context, educational literature includes studies that have linked the prevailing pattern of brain dominance to multiple variables, including student achievement, learning style, and motivation in various school subjects. However, none of the previous studies addressed the nature of the relationship between the prevailing pattern of brain dominance and creative thinking among students. In science learning in particular, the problem of the study emerged, which is to investigate the relationship between the prevailing brain dominance pattern among students and their level of creative thinking in science. Hence, the current research seeks to answer the following questions:

- RQ1:** What is the prevailing pattern of brain dominance among ninth-grade students in Jordan?
- RQ2:** What is the level of creative thinking in science among ninth-grade students in Jordan?
- RQ3:** Is there a statistically significant relationship at ($= 0.05\alpha$) between the study sample's response estimates on the total score of the brain dominance scale and their responses to the test of creative thinking in science?

2. Literature review

The progress of countries is linked to the development of the level of education of their individuals and the extent of their belief in the importance of learning and possessing the

necessary skills to improve it by employing everything that enables the achievement of this goal. Perhaps thinking in its various forms, skills, and levels is one of the most important drivers of development in the scientific, economic, and social fields because it contributes to solving problems that the individual or society may face.

2.1. Brain dominance

Concerning thinking and its skills, one of the most important variables associated with the educational learning process is brain dominance, studies related to this have indicated that neural signals are transmitted between the right and left hemispheres of the brain, which is why students, for instance, gain a better understanding in educational contexts. Brain dominance revolves around the ability of the two hemispheres to process types of information and data in different ways. For example, the left side of the brain processes analytical, abstract, and logical information, while the right is concerned with processing intuitive, holistic, symbolic, emotional, creative, and imaginative information (Aburayash, 2021).

The brain is one of the most complex and important organs in the human body, as it constitutes the tool of the mind and the main engine of human behavior. Researchers' interest in the brain began in the fifteenth century when they concluded that the brain is responsible for the individual's perception, awareness, feeling, and proper performance of various tasks. It controls memory, thought, learning, awareness, and many other activities, as well as the storage and processing of information (Meneely & Portillo, 2005).

The human brain can distinguish, think, make decisions, and learn. It is considered the driving center of the human being because it contains 100 billion nerve cells that connect and communicate with each other by sending and receiving nerve signals that enable the body to perform all its functions (McCrone, 1999). Javaid, Roheen, and Afzal (2020) also stated that the brain consists of three main parts: the forebrain, the midbrain, and the hindbrain. The forebrain is the largest and most complex part of the brain, is responsible for speaking and thinking, and acts as a processor. It receives sensory information such as thought, perception, memory, and speech. It contains the brain, which has two types: the right and left hemispheres.

A concept known as Brain dominance first emerged in the early 1970s, which states that one hemisphere of the brain controls an individual's actions, performance, and functions more than the other, there are three types of thinking patterns: right, left, balanced, or integrated, most studies have confirmed that one side of the brain is specialized, it is not possible to separate them, as each one complements the other, and therefore there is no absolute Brain dominance as a result of the functional integration between the parts of the brain (Hughes, Hughes & Hodgkinson, 2017; Alnasraween et al., 2021).

In the same context, Springer and Deutsch (2003) described the pattern of brain dominance as one or both hemispheres of the brain assuming responsibility for controlling the individual's behavior and conduct. Torrance (1982) described the pattern of brain dominance as a method in which the individual tends to rely on the functions of others. One or both hemispheres of the brain process information. Both Sousa (2001) and Jensen (2008) indicated that students learn in ways consistent with their dominant brain dominance pattern and that students have the left brain dominance pattern responsible for analytical thinking. Linguistic and logical thinking and the right-handed pattern responsible for creative, synthetic, and relational thinking are neglected due to the

prevailing traditional trend in education. Ganesh, Maharishi, and Jaya (2014), Ha, Roehrig, and Zhang (2023), and Chen (2017) found that the pattern of brain dominance affects both the nature of an individual's scientific abilities and the thinking skills he possesses.

As defined by Aburayash (2021), brain dominance is the tendency to use one hemisphere of the brain in processing information more than the other in an individual, accordingly controlling his actions and behavior. Mazaheri and Ayatollahi (2019) defined it differently as the individual's possession of certain characteristics due to his addiction to one particular part of the brain, which determines his personality, behavior, abilities, mental operations, and thinking skills. Bawaneh, Zain, and Saleh (2011) defined it as the control of one of the right or left hemispheres of the brain over cognitive processes and patterns of thinking and learning in individuals. An individual's tendency to use one half of the brain more than the other half

In light of the above definitions of brain dominance, it can be expressed as the dominance of the right or left hemisphere in the brain, as each half has specific functions such that one dominates the other and has a greater influence on mental and cognitive processes, the individual's behavior, and the processing of information. There have been many theories explaining the patterns of brain dominance, including the theories of Torrance, Sperry, Herman, and others interested in this field. The patterns of brain dominance are divided into the left style, the right style, and the integrated style, as follows:

Left pattern. This is the pattern in which the left half of the brain is used and it controls mental processes such as logical, verbal, and analytical processes. As Bawaneh, Zain, and Saleh (2011) mentioned, Scientists have defined it as how to respond to verbal stimuli, use language to understand facts, remember, interact verbally to understand meanings, deal with information, and have logical and analytical thinking. In addition to Understanding clear facts, solving problems by planning, dealing with one problem at a time, analyzing and criticizing in listening and reading, suppressing feelings and emotions, experimenting in an organized manner, and giving information verbally.

Right pattern. In this style, the right half of the brain is used, which includes non-verbal, complex, pictorial, and emotional processes. It is defined as giving information through motor representation, dealing with moving and pictorial stimuli, remembering using imagination, responding to emotional stimuli, understanding non-specific and new facts, innovatively solving problems, dealing with several problems at the same time, abstract thinking, lack of consistency in learning, experimentation, and thinking, love of change, and initiative (Silagi, Radanovic, Conforto, Mendonça, & Mansur, 2018).

Integrated pattern. It expresses individuals who use both hemispheres of the brain. People with this simultaneously have different thinking and learning patterns from the right and left hemispheres of the brain. They tend toward one of these two types of brain dominance because they can handle situations flexibly and have the same ability to deal with situations that require the intervention of the right brain and the left side, so this style has multiple tendencies and directions for taking advantage of the full potential of the human brain (Oflaz, 2011).

Based on the above, an individual's thinking and the way he deals with the situations and problems he faces are greatly influenced by the extent to which he relies on one of the most effective hemispheres of the brain, as the individual tends to rely on characteristics related to his most effective hemisphere of the brain. Each half is associated with certain features. The right half is better at copying images, distinguishing

between symbols and shapes, spatial perception, geometric comprehension characteristics, reading faces, music, comprehensive processing, understanding, expressing feelings, and reading emotions, while the left half is better at linguistic skills, motor skills also, at the information analysis and logical thinking. It has been well-proven that the dominant hemisphere of the brain is associated with some personality traits. Individuals with left-handed dominance are characterized by having greater control over their impulses, are better at dealing with their tensions, and enjoy creativity and aspiration for the positive aspects of while comparison, individuals with right-handed dominance are characterized as having less control over their impulses, are tense, shy, realistic, and look at negative aspects of life. In contrast, individuals with integral dominance are a balanced and interconnected mix of influences from both hemispheres (Suresh, Poornima, Anjana, & Debata, 2020).

Brain dominance patterns are also characterized by the fact that they reflect the individual's choices and preferences, not his abilities, and thus each of them learns what suits his preferences easily and conveniently, and it is difficult for him to know what contradicts that. Individuals may be able to practice any pattern, but they belong to their choices and preferences and act according to a specific pattern. While daily life events do not oblige an individual to work according to a specific style and do not determine his preferred or unpreferred style, dealing with them requires consistency between the styles, interaction, and integration between them, and individuals who produce one style differ in the intensity of their preference for the tasks of this style, and the styles. They are not only influenced by nature and inherited characteristics, but they are also acquired social behaviors, meaning they grow and change, may become stronger and weaker, and may change over time as an individual can move from one type to another (Inad & Jabbar, 2020). So, by dividing brain dominance into the left pattern, the right pattern, and the integrated pattern, it is easy to study the behavior of individuals, their way of thinking, and their practices related to these patterns, and to identify their dominant pattern.

2.2. Creative thinking

Several studies have specialized in cognitive neuroscience and brain physiology, including A study (Butz & Kutter, 2016) indicated that the brain is directly responsible for an individual's tendency to think in a way that distinguishes him from others, while O'Toole, Freestone, McKoy, and Duckworth (2018) confirmed that the science subject inherently contributes to enhancing students' thinking skills with the concepts and laws it contains theories and their applications.

Creative thinking skills are among the most important skills that are supposed to be focused on in the educational learning process in general and science education specifically, as Liu and Yang (2022) point out that education currently expresses stimulating students' thinking and developing their abilities through strategies followed by the teacher that link their lessons in the reality of their daily lives.

In a related context, preparing the individual practically and mentally to interact with the changes in his society has been it remains one of the most essential goals of science education since the beginnings of scientific education and through the reform movements and the projects that resulted from them, including the 2061 Project, which, despite its magnitude, was born from the womb of the "A Nation at Risk" report, which revealed deficiencies in American students' performance expectations. This project produced important documents, the most prominent of which are the Benchmarks for Science Literacy (BFSL) and the National Science Education Standards (Allred, 2022).

Whereas science, by its nature, is a human endeavor that both includes and guarantees the progress of scientific and technological innovations, contemporary challenges require a scientific approach and modern technological innovations that are based on student's ability to generate creative ideas, test them, interpret them, and apply them within their investigations (Partnership for 21st Century Skills, 2008).

In this regard, O'Toole, Freestone, McKoy, and Duckworth (2018) explain that the creative student in science must possess an investigative mind by reading scientific books with an apparent inclination towards that, in addition to his ability to invent new scientific projects, designs, and ideas, use arguments and evidence to defend his interpretations and decisions, and conduct research. about the relationships between causes and results and formulating scientific hypotheses. It is also characterized by scientific curiosity, flexibility of thinking, and the practice of scientific skills.

Science processes are consistent with the requirements of creative thinking skills, as science processes include the skills of observation, classification, measurement, interpretation, inference, extrapolation, prediction, use of numbers, use of temporal and spatial relationships, controlling variables, testing hypotheses, and experimentation. In contrast, creative thinking skills include fluency, flexibility, originality, insight, and sensitivity to problems. Scientific processes and creative thinking skills have in common that they are organized mental processes that require training and repeated practice so that the student obtains good results by continuing to experiment, discover, ask questions, and apply (O'Toole, Freestone, McKoy, & Duckworth, 2018). In the same context, Trilling and Fadel (2012) stated that creative thinking skills are an essential part of the axis of learning and creativity, which is the most important axis among the skills of the twenty-first century, as it is responsible for distinguishing students who possess the keys to the twenty-first century, as he points out. Kilbane and Milman (2014) point out that creativity is a continuous and reproducible process. Students arriving at a completely new idea or one they did not have previously expressed their ability to innovate, even if others had it.

Dewanto, Agustianto, and Sari (2018) show that creativity is more comprehensive and broader than innovation. Creativity, as the highest level of human activity, includes producing new and useful theoretical ideas, implementing them, and forming relationships between them, while innovation is limited to producing new ideas with an applied dimension. Aikenhead (1996) considered creativity and innovation to be synonymous terms that express the creation of what does not exist.

It includes creative thinking skills, which is primarily a mental process in which the student interacts with the experiences, activities, and educational situations he faces to absorb the elements of this situation to reach a new understanding or new production that enables him to arrive at valuable solutions to questions and problems in his reality, given that creative thinking includes a group Among the skills that indicate mental abilities within a unified composition and organization are fluency, flexibility, originality, generosity, and sensitivity to problems (Dewanto, Agustianto, & Sari, 2018; Lusiana, Suprpto, Andari, & Susanti, 2019).

Fluency. According to Dewanto, Agustianto, and Sari (2018), fluency describes the ability to generate the largest number of alternative ideas, synonyms, or uses in each environment rapidly and easily, and it can be understood based on its multiple types. For example, If many ideas are generated within a brief period on a given topic, this type is referred to as intellectual fluency. Linguistic fluency expresses many meaningful phrases or the ability to place a specific word within many sentences can be explained by this characteristic. Lastly, associative fluency, which indicates the ability to complete

relationships and find meanings, is expressed. Words are classified quickly based on specific criteria.

Flexibility. Flexibility expresses the ability to quickly generate ideas that belong to different types of references related to a specific situation and includes two types: Spontaneous flexibility means providing various responses that belong to a category, while adaptive flexibility means responding to some changes in the way something is used or interpreted (Lusiana, Suprpto, Andari, & Susanti, 2019).

Originality. Originality is the ability to present ideas in a specific situation that are rare and novel. It differs from fluency in that it does not refer to quantity but Focuses on ideas' value and quality. It also differs from flexibility in that it avoids repeating what others do. As for elaboration, it expresses the ability to add several new and diverse clarifications and preferences that make the idea more clear and useful to others, while sensitivity to problems expresses the individual's observation of the problems in the situation he faces and realizes the shortcomings, shortcomings, and mistakes, and includes improving and raising the level of awareness (Dewanto, Agustianto, & Sari, 2018).

In this regard, Lusiana, Suprpto, Andari, and Susanti (2019) conducted a study to investigate the effect of the dominant brain dominance pattern on achievement in learning mathematics, adopting a quantitative approach. The sample consisted of 156 students in the seventh grade in Medium. The dominant dominance pattern questionnaire was applied, and the results showed a significant effect on both sides of the brain in favor of the left side.

3. Method

This section details the instruments and techniques utilized to achieve the research aim and answer the research questions. The following subsections provide a comprehensive explanation of the research design, participant selection criteria, and research tools employed.

3.1. The study population and sample

The study population consisted of all eighth-grade students in Salt Directorate in public and private schools numbered (2340).

The study sample consisted of (850) eighth-grade male and female students, divided into (521) female students and (329) male students, they were selected by cluster random sampling method, first, the directorate was chosen purposely, and then the districts were chosen randomly as well as the schools until students of the sample were reached.

3.2. Measures and instruments

3.2.1. Brain dominance scale

Previous educational literature related to Brain dominance and its patterns was reviewed, including Torrence (1990), Jensen (2008), Bara (2011), and Chen (2017). Reviewing tests and measures that sought to determine the pattern of Brain dominance in light of the

theoretical framework of the study, such as the Torrance test to measure Brain dominance, the McCarthy test, the Herman tool, and the McCrone scale, and based on that, the Brain dominance pattern measure was developed in its initial form from the scale developed by John McCrone.

The hemispheric Dominance Inventory (HDI) was created in 1999. It was developed by Carolyn Hopper in 2003 to determine the pattern of brain dominance that affects students' learning and its impact on their scientific abilities (right dominance pattern, left dominance pattern, integrated dominance pattern) based on the results of studies that showed the relationship between the dominance pattern. The single brain performs specific functions when processing information. This scale was presented to a group of specialists in science curricula and teaching methods, psychology, measurement, and evaluation to make comments on the scale's items in terms of clarity and soundness of the scientific and linguistic formulation and its suitability to the target group and its measurement for the purpose for which it was prepared. It consisted of (24) in its final form, to be applied to an exploratory sample from the study population and outside the framework of its sample and possessing the same characteristics as the sample, and the number of its members reached (50) students from the ninth grade, and to verify the stability of the scale, the test and retest method (Test- Retest) by applying it to a reconnaissance sample from outside the study sample and then re-applying it again after two weeks to a group outside the study sample consisting of (50) male and female students, and then calculating Pearson's Correlation Coefficient and the reliability coefficient was calculated using the consistency method. The internal consistency is according to Cronbach's Alpha equation. Table 1 shows the reliability coefficients for the domains and the scale as a whole, and the internal consistency values according to Cronbach's Alpha equation. These values were considered acceptable for the study.

Table 1
Reliability coefficients

Brain domain style	Test-retest	Cronbach-alpha
Right side	0.84	0.85
Left side	0.79	0.80
Integrated Brain	0.82	0.87
Total	0.86	0.89

Table1 displays the internal consistency according to Cronbach's Alpha equation and the test-retest values all of these values were accepted for the study purposes.

The scale was then applied in the second semester of the academic year 2022/2023 to the entire sample, males, and females, who were asked to answer all of its items. Then, the student's data was corrected, transcribed, and analyzed, through which the study sample was classified according to their answers into three types: They are the right brain dominance pattern (creative thinking), the left brain dominance pattern (logical thinking), and the integrated brain dominance pattern (Integrated Brain).

3.2.2. Test of creative thinking in science

The test of creative thinking in science was developed and included seven items of the type of open-ended essay questions, targeting three creative thinking skills: fluency, flexibility, and originality, through a review of previous educational literature on creative thinking. And skills and access to tests and standards that sought to determine the level of

creative thinking in light of the theoretical framework of the study and the use of the Torrance test to measure the ability to think creatively in verbal form (A), as it is the most common and appropriate for the age stage of the study sample, and then identify the three basic skills for creative thinking mentioned by Torrance (1972); Torrance (1974) to be measured in the test: fluency, which expresses the ability to produce the largest number of ideas, questions, and information in a unit of time; flexibility, which expresses the ability to move and transform from one category of ideas to another; and originality, which expresses the ability to produce ideas that are characterized by uniqueness, novelty, and uncommonness. The test included the sub-activities that Torrance adopted in his tests, which are: guessing the reasons, asking questions, guessing the results, familiar uses, uncommon uses, suggestions for improvement, and forming vocabulary, so that each test question measures the three skills. Simultaneously, after verifying their psychometric properties, a total score for creative thinking was calculated from the sum of these skills. It was presented to a group of specialists in science curricula, teaching methods, measurement, and evaluation to make comments on the test questions in terms of clarity and soundness of scientific formulation. Linguistics and its suitability to the target group and its measurement of the creative thinking skills targeted by the test. It was then applied to an exploratory sample from the study population outside the framework of its sample and possessing the same characteristics as the sample. Its number reached 50 male and female students from the ninth grade. The response time was set at 3 minutes for each test question in light of the time it takes to apply the test to the members of the exploratory sample. To verify the validity of the test, we relied on face validity and content validity by presenting it to a group of arbitrators specializing in science curricula and teaching methods and psychology, measurement, and evaluation, with experience and competence, to estimate the comprehensiveness of the test for creative thinking skills, its validity scientifically and linguistically, and the suitability of the items to measure the three skills that the test aims to measure among the study sample. Factorial validity was also conducted, and it was verified. The normal distribution of students' responses to the creative thinking test using the one-sample Kolmogorov-Smirnov statistical test (K.S.), where its value reached 1.49 and is not statistically significant at the level ($\alpha = 0.05$), indicates that the normal distribution property is achieved, which allowed the completion of factor analysis procedures. This is done by employing first-order exploratory factor analysis on the sample as a whole using the principal components method for individuals' responses to the test items. The rotation process was conducted using orthogonal (Varimax rotation) for the factors with latent root values. If it is greater than (1), the latent root values (Eigen Values) and the percentage of explained variance (Explained Variance) were calculated for each of the factors, and Table 2 shows these results.

The results show that there are six factors whose eigenvalues Exceed one, as the value of the Eigenvalue of the first factor, reached (7.049), the variance explained for this factor reached (33.568%), and the value of the second factor reached (1.936). It explained (9.217%) of the variance, and since the result of dividing the first factor by the second factor exceeds (2) The first factor explained three times what the second factor explained, this is an indication that a unidimensional characteristic has been achieved in explaining performance on this test means that measure creative thinking only. The following graphical representation shows the values of the Eigenvalues of these factors resulting from the factor analysis of the creative thinking test. Fig. 1.

Table 2
Factor analysis results

Factor	Eigenvalue	Explained variance	Cumulative explained variance
1	7.049	33.568	33.568
2	1.936	9.217	42.785
3	1.571	7.480	50.265
4	1.131	5.384	55.649
5	1.072	5.106	60.755
6	1.019	4.852	65.607
7	0.991	4.719	70.326
8	0.945	4.502	74.828
9	0.845	4.022	78.850
10	0.785	3.739	82.589
11	0.764	3.636	86.225
12	0.731	3.482	89.707
13	0.619	2.947	92.654
14	0.374	1.783	94.437
15	0.270	1.285	95.722
16	0.231	1.102	96.824
17	0.213	1.015	97.839
18	0.166	0.788	98.627
19	0.143	0.683	99.310
20	0.129	0.615	99.925
21	0.016	0.075	100.000

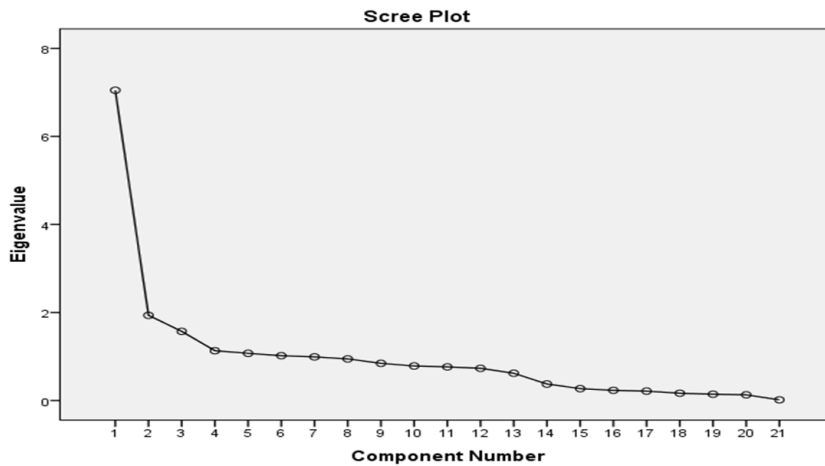


Fig. 1. Graphical representation of the Eigenvalues of the factors that explain performance on the creative thinking test.

It is noted from Fig. 1 that the slope between the first factor and the second factor was very large when compared to the slope between the second and third factors, then the slope remained close between the remaining factors, which confirms the fulfillment of the assumption of unidimensionality in explaining performance on this test. To verify the reliability, we relied on the scores of the exploratory sample to calculate the reliability coefficient of the test as a whole, and the internal consistency reliability coefficient was

extracted through Cronbach's Alpha equation, where its value reached (0.83), which is appropriate for this study. The test was then applied in the second semester of the academic year 2022/2023 to the entire sample, males, and females, where they were asked to answer all the test questions, and then the test items were corrected by the researchers, where the correction method that was mentioned in studies such as Dewanto et al. (2018), Chen (2017). To ensure a higher degree of accuracy and to avoid random errors in students' grades, the percentage of agreement between the two graders was calculated through the Holsti equation, where it was the correction reliability coefficient is (0.95), which is an acceptable value for the study. The rotated matrix component matrix is presented in Table 3.

Table 3
Rotated component matrix

Item No.	Fluency	Component flexibility loading	Originality
1		0.595	
2		0.447	
3		0.262	
4			0.443
5		0.422	
6		0.231	
7			0.376
8	0.371		
9			0.443
10	0.402		
11	0.548		
12			0.403
13		0.508	
14	0.406		
15	0.355		
16	0.626		
17			0.625
18	0.600		
19	0.389		
20	0.572		
21	0.373		
22		0.196	
23			0.641
24		0.437	
25			0.338

Note. Extraction method: Principal component analysis; Rotation method: Varimax with Kaiser Normalization; Rotation converged in 5 iterations

Considering the content of items forming factors in the rotated component matrix with the Varimax method, as we can see in Table 3 first factor refers to fluency (10 items) the second factor refers to flexibility (8 items) the third factor refers to originality (8 items).

4. Results

In the following subsections, we present the results of our research and a brief analysis of the data collected. We begin by presenting the results as shown below.

4.1. Results related to the first question “What is the prevailing pattern of brain dominance among ninth-grade students in Jordan?”

To answer this question; the frequencies of Brain dominance patterns and the percentage of each were calculated, and Table 4 shows this.

Table 4
Frequencies and percentages of brain dominance patterns

		Frequency	Percent	Valid percent
Valid	Right side	320	41.1	41.1
	Left side	430	42.1	42.1
	Integrated brain	100	16.8	16.8
	Total	850	100.0	100.0

The results show that the left dominance pattern ranked first with a frequency of (430), followed by the right dominance pattern with a frequency of (320), and in last place the integrated brain dominance pattern came with a frequency of (100).

4.2. Results related to the second question “What is the level of creative thinking in science among ninth-grade students in Jordan?”

To answer this question, arithmetic means and standard deviations were extracted for the level of creative thinking in science among ninth-grade students in Jordan. Table 5 shows this.

Table 5
Arithmetic means and standard deviations for the level of creative thinking in science

	Mean	SD
Fluency	5.7327	3.22316
Flexibility	2.3673	1.46766
Originality	0.5327	1.04723
Total	8.6327	4.56802

The results show that the level of creative thinking in science among ninth-grade students was average in terms of the total score and all skills.

4.3. Results related to the Third question “Is there a statistically significant relationship at ($\alpha = 0.05$) between the study sample’s response estimates on the total score of the Brain dominance scale and their responses to the creative thinking test?”

To answer this question, the arithmetic means and standard deviations were extracted for the level of creative thinking in science among ninth-grade students according to the type of brain dominance, and Table 6 shows this.

The results show that there are apparent differences between the arithmetic means of the level of creative thinking in science for ninth-grade students depending on the pattern of brain dominance.

Table 6

Arithmetic means and standard deviations for the level of creative thinking in science according to brain control

Dependent variable	Brain control	Mean	SD	95% CI	
				Lower bound	Upper bound
Fluency	1.00	5.731	.151	5.434	6.028
	2.00	5.632	.150	5.338	5.926
	3.00	6.387	.236	5.924	6.851
Flexibility	1.00	2.397	.070	2.260	2.534
	2.00	2.273	.069	2.137	2.409
	3.00	2.602	.109	2.388	2.816
Originality	1.00	.508	.050	.410	.607
	2.00	.532	.050	.435	.629
	3.00	.574	.078	.421	.728
Total	1.00	8.637	.216	8.214	9.060
	2.00	8.437	.213	8.019	8.856
	3.00	9.563	.337	8.903	10.224

A multiple analysis of variance (Manova) was extracted to determine whether these differences are statistically significant, as shown in Table 7. Arithmetic means and standard deviations were also extracted for the level of creative thinking in science among ninth-grade students according to gender.

Table 7

Arithmetic means and standard deviations for the level of creative thinking in science according to gender

Dependent variable	Gender	Mean	SD	95% CI	
				Lower bound	Upper bound
Fluency	Male	6.496	0.152	6.198	6.794
	Female	5.338	0.136	5.070	5.605
Flexibility	Male	2.528	0.070	2.391	2.666
	Female	2.319	0.063	2.196	2.443
Originality	Male	0.510	0.050	0.411	.609
	Female	0.566	0.045	0.478	.655
Total	Male	9.534	0.216	9.110	9.959
	Female	8.224	0.194	7.843	8.605

The results show that there are apparent differences between the arithmetic means of the level of creative thinking among ninth-grade students according to gender.

To determine whether these differences are statistically significant, multiple analysis of variance (Manova) was extracted as shown in Table 8.

The results show that there are statistically significant differences between the arithmetic averages of the level of creative thinking among ninth-grade students, according to gender, on the total score and the dimensions of fluency and flexibility, as the significance values for the “*f*” values reached less than (0.05) for each case. Returning to the table of arithmetic averages, it is noted that these differences are attributed to males. The results also showed that there were statistically significant differences between the arithmetic averages of the level of creative thinking among ninth-grade students depending on the pattern of brain dominance on the total score and the dimensions of fluency and flexibility, as the significance values for the “*f*” values reached less than (0.05).

For each case, to determine the significance of these differences, the Scheffé post-test was extracted, as shown in Table 9.

Table 8
Results of multiple analyses of variance

Source	Dependent variable	Type III sum of squares	df	Mean square	<i>f</i>	Sig.
Gender	Fluency	353.874	1	353.874	35.337	0.000
	Flexibility	11.524	1	11.524	5.395	0.020
	Originality	0.840	1	0.840	0.765	0.382
	Total	453.252	1	453.252	22.279	0.000
Brain_control	Fluency	76.902	2	38.451	3.840	0.022
	Flexibility	14.127	2	7.063	3.307	0.037
	Originality	0.560	2	0.280	0.255	0.775
	Total	166.975	2	83.488	4.104	0.017
Error	Fluency	10675.172	846	12.61841		
	Flexibility	2276.952	846	2.691433		
	Originality	1170.945	846	1.384096		
	Total	21686.764	846	25.63447		
Total	Fluency	46270.000	850			
	Flexibility	8299.000	850			
	Originality	1476.000	850			
	Total	102047.000	850			
Corrected Total	Fluency	11105.555	849			
	Flexibility	2302.655	849			
	Originality	1172.355	849			
	Total	22306.655	849			

Table 9
Results of the Scheffé test

Dependent variable	Brain control	Mean	1	2	3
Fluency	Right	5.731	-	0.099	-0.656*
	Left	5.632	-	-	-0.755*
	Integrated	6.387	-	-	-
Flexibility	Right	2.397	-	0.124	0.205
	Left	2.273	-	-	0.329-*
	Integrated	2.602			
Total	Right	8.637	-	0.200	0.926-*
	Left	8.437		-	0.126-
	Integrated	9.563			

The results show that the differences between the arithmetic averages of the level of creative thinking among ninth-grade students depending on brain dominance pattern are attributed to students with integrated brain dominance when compared to other students on the total score and dimensions.

5. Discussion

The study concluded several interconnected results considering its questions, including that the left pattern of the brain is dominant among students, followed by the right, then the integrated.

The researchers attribute this result to the left pattern that controls various Logical, verbal, and analytical processes, using language to understand and remember facts, and solving problems sequentially by planning, analyzing, and criticizing in listening and reading, as stated by Bawaneh, Zain, and Saleh (2011), is the pattern that is developed by employing it by increasing the neural synapses in it during the educational-learning process, where it is focused. To understand, comprehend, analyze, and logic.

This result may also be attributed to the fact that this pattern, which can affect how the student responds to educational tasks, may also be affected by genetic and environmental factors, including upbringing, the learning environment, motivation for achievement, and interest in studying, which is represented by achieving understanding and solving problems.

The results also showed that the level of creative thinking in science among ninth-grade students was average regarding the total score and all skills. The researchers attribute this result to the students' modest possession of basic creative thinking skills, as they noticed during their follow-up application of the creative thinking test that a sizable percentage of students were unable to express their ideas fluently, in addition to the presence of stereotyping in presenting ideas and a low ability to generate original ideas. This result may also be attributed to most students being directly accustomed to indoctrination and repetition, which necessarily leads to a reduction in their creative abilities, in addition to the clear weakness in the basic skills that are a requirement for learning, not just creativity, for some students, which is the ability to read and write, which prevented them from being able to express their ideas.

This result may also be attributed to the normal and direct curriculum pattern of presenting information that students can investigate and access, and the teacher's endeavor and interest in completing the assigned academic material within a specific time, which diverts his interest from asking thought-provoking questions. What makes the matter worse is that students' evaluation is still based on This has a significant impact on achievement, in addition to the stereotype that students are accustomed to in school tests and the presence of one specific answer, which is often based on recalling scientific knowledge without practicing higher thinking skills, which prompts students to keep pace with the curriculum pattern in presentation and the teacher's method of teaching to obtain the mark that is considered a goal for him.

If we look at this average result for the level of creative thinking in science among students in a positive way, it can be interpreted that the nature of the investigative sciences subject, stimulates students to practice different types of thinking, such as creative thinking with its various skills. Also, the age stage expressed by the study sample has moved -according to what Piaget's studies explained -from formal thinking to abstract thinking that reflects Necessity at the level of student's creative thinking.

As the result showed, we believe that the level of creative thinking in science among students should improve and that requires clear and deliberate procedures from teachers, including employing teaching strategies that develop creative thinking skills and are consistent with the investigative nature of science, such as Project-Based Learning, which relies on assigning students to real scientific projects that force them to do so. It includes research, experimentation, and creativity to solve problems, in addition to Inquiry-Based Learning, where students are encouraged to ask questions and explore scientific concepts through research and inquiry. Perhaps brainstorming is one of the best strategies for developing creative thinking, as its sessions include generating new ideas, collecting them, filtering them, determining the best among them, and justifying them.

This develops students' thinking on the one hand and contributes to solving the realistic problems they face.

Depending on the pattern of Brain dominance the results showed that there are significant differences between the means of the level of creative thinking in science for ninth-grade students on the total score and the dimensions of fluency and flexibility, attributed to students with integrated brain dominance when compared to other students on the total degree and dimensions.

The researchers believe that this is a logical result that is consistent with scientific studies that indicate that the integrated brain is characterized by comprehensive thinking, which includes divergent (creative) and convergent (logical) thinking (Ganesh, Maharishi & Jaya. 2014). This result may be explained in harmony with the inability of traditional education to Activating the role of the right side of the brain, which enhances the creative skills of students, in addition to the nature of presenting content in scientific curricula, which does not play its role in developing creative thinking skills as it should (Al-Awidi & Al-Mughrabi, 2022), in addition to the decline in teachers' possession of the skills that enable them to enhance creative thinking among students.

In another context, the results showed, that there are statistically significant differences between the means of the level of creative thinking among ninth-grade students, on the total score, and the dimensions of fluency and flexibility, according to gender, in favor of males.

This result can be explained by relying on some studies on the differences between males and females as they affect the psychological, emotional, biological, and hormonal aspects without affecting the mental aspect and its functions and processes, considering that the lifestyle has become similar between males and females. Interests and distractions were almost equally distributed between them, despite the presence of some differences in personal interests, as female interests may branch out more between learning and the social status it builds as a result of the interest that arises from women's freedom, liberation, and independence, their family duties, and so on. The time when males' interest may be limited to a particular field of learning as a result of their inclination and interest in it, which makes their level of creative thinking better than that of females.

In addition, we believe that academic and societal trends in Jordanian society are directed towards encouraging males to excel in science, while females may be encouraged in other fields related to work that suits their nature according to the prevailing culture so far, which can improve creative thinking skills among Males to do better in science fields than females.

Similarly, the opportunities for participation in scientific activities such as science clubs, scientific competitions, and research projects are more abundant, for males than for females, helping them improve their creative skills in science. taking into account the better opportunities available to males in the future, the family support provided to males in science may be greater than that provided to females.

Among the things that can be done to reduce these differences, is to provide learning environments that promote and encourage both genders to engage in scientific activities, provide inspiring role models for both genders, and provide equal opportunities to participate in scientific projects and extracurricular activities. Females can also be encouraged through special support programs and confidence in their scientific and creative abilities can be enhanced.

6. Limitations

The study was limited to male and female ninth-grade students in schools affiliated with the University District Education Directorate in Amman within the public and private sectors during the second semester of the 2022-2023 academic year. It was also limited to three basic skills of creative thinking: fluency, originality, and flexibility. The generalization of the results of the study in the study population is determined by the extent of the validity and stability of the tools used, knowing that the psychometric properties of each of them were verified, as well as the extent of the validity, objectivity, and accuracy of the study sample in responding to the study tools.

7. Conclusion and recommendations

The research investigated the relationship between students' prevailing brain dominance pattern and their level of creative thinking in science. The study concluded that the student's creative thinking level was medium. The results also showed that the average scores of students with integrated brain control were higher, statistically significant, than those of students with left and right brain control. The results also showed that there were statistically significant differences between the arithmetic means of creative thinking due to gender and in favor of males. Based on the results of the study; it recommends; paying attention to developing creative thinking among students mainly through developing scientific curricula and focusing on their skills, including strategies and activities directed towards acquiring creative thinking skills. Also, conducting qualitative and quantitative studies to investigate the level of creative thinking among students and its relationship to other variables that were not addressed in this study.

Author Statement

The authors declare that there is no conflict of interest.

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