Available online: https://e-journal.unair.ac.id/jps

Original Research

Teaching Mathematics Using a Strategy Compatible with the Brain Hemispheres Approach and Its Effect on Developing Information Processing Skills Among Eighth Grade Students

Azhar Ali Hussein Ibrahim[1]

[1]Department of Education and Psychology, College of Education, University of Zakho, Kurdistan Region, Iraq

Submitted : April 7, 2025
Revised : June 16, 2025
Accepted : July 1, 2025
Published : July 14, 2025

Correspondence Author:
Email: azhar.hussein@uoz.edu.krd

Abstracts

Introduction: This study investigated the effect of a brain hemispheres-compatible teaching strategy on developing information processing skills among eighth-grade mathematics students. The approach aims to engage both left-hemisphere functions (logical reasoning, sequential processing) and right-hemisphere functions (spatial reasoning, holistic thinking) to enhance mathematical learning during the critical developmental period of early adolescence. **Methods:** The research employed a quasi-experimental design with two equivalent groups at Avro School (2022-2023): an experimental group (30 students) taught using the brain hemispheres strategy and a control group (29 students) taught using traditional instruction. Assessment utilized a validated 25-item test measuring four information processing skills: summarization, application, pattern recognition, and interpretation. The experimental intervention followed six phases: preparation, engagement, learning design, acquisition, memory formation, and functional integration. **Results:** Statistical analysis revealed significant differences favoring the experimental group ($t=5.988$, $p<0.01$) with a very large effect size ($\eta^2=0.38$). The experimental group showed significant improvement across all four information processing skills with effect sizes ranging from 1.19 to 2.19. **Conclusion:** The brain hemispheres-compatible teaching strategy proved highly effective in developing students' mathematical information processing skills by creating organized mental frameworks that facilitate knowledge integration and cognitive development.

Keywords: Strategy Design, Brain Hemispheres Approach, Information Processing Skills

Cite this as: Ibrahim. A. A. H, "Teaching Mathematics Using a Strategy Compatible with the Brain Hemispheres Approach and Its Effect on Developing Information Processing Skills Among Eighth Grade Students". Jurnal Psikiatri Surabaya, vol. 14, no. 2, pp.144-156, 2025. doi: 10.20473/jps.v14i2.72559

INTRODUCTION

Mathematics education plays a crucial role in developing students' cognitive abilities and problem-solving skills. In recent years, there has been growing interest in applying neuroscience findings to educational practices, particularly in mathematics instruction [1]. The brain hemispheres approach aims to engage both left and right hemispheres in the learning process, based on understanding that different cognitive functions are associated with different brain regions and optimal learning occurs when both hemispheres are engaged [2]. Recent studies have shown that language proficiency and cultural factors can significantly impact students' mathematical learning and information processing skills, suggesting a need for more comprehensive approaches to mathematics education [3].

The brain hemispheres approach has gained attention due to its potential to enhance students' information processing skills, which involves the ability to perceive, analyze, and manipulate mathematical concepts and relationships [4]. Research indicates that traditional mathematics instruction often emphasizes left-hemisphere functions (logical reasoning and sequential processing) while underutilizing right-hemisphere functions (spatial reasoning and holistic thinking) [5]. This imbalance may limit students' ability to fully engage with mathematical concepts and develop comprehensive problem-solving strategies.

Several studies have demonstrated the effectiveness of brain-based learning strategies. Ozgen and Alkan [6] found that brain-based learning activities significantly improved high school students' mathematics achievement and attitudes. Mekarina and Ningsih [7] reported positive effects on students' mathematical connection abilities, while Noureen, Awan, and Fatima [8] demonstrated significant improvements in seventh-grade mathematics performance. Suarsana et al. [9] provided evidence for brain-compatible teaching strategies in enhancing conceptual understanding of geometric concepts.

Neuroimaging studies have provided crucial insights into mathematical cognition. Dehaene et al. [10] identified three parietal circuits involved in number processing, while Ansari [11] explored how developmental processes shape neural representations of numbers. The development of mathematical skills involves complex interactions between domain-general cognitive abilities and domain-specific mathematical skills [4], [12]. Matejko and Ansari [13] demonstrated associations between arithmetic and basic numerical processing in children's brains, complementing Price et al.'s [14] findings that early arithmetic skills predict later mathematical achievement.

Recent meta-analyses by Arsalidou et al. [15] and Kaufmann et al. [16] have provided comprehensive insights into how different mathematical tasks engage various brain regions and how these patterns develop over time. The role of spatial abilities in mathematical cognition has gained attention, with Newcombe et al. [17] highlighting the intertwined development of spatial and numerical cognition. Additionally, research has revealed shared neural resources between linguistic and mathematical operations [18], emphasizing the importance of integrated approaches to mathematics instruction.

The eighth grade represents a critical period for mathematical skill development, as students aged 13-14 transition from concrete to abstract mathematical reasoning [17], [19]. During early adolescence, students undergo significant cognitive changes and establish foundational skills for advanced mathematical thinking. Longitudinal studies have revealed dynamic brain development patterns, with Qin et al. [20] demonstrating hippocampal-neocortical functional reorganization underlying cognitive development, and Rosenberg-Lee et al. [21] showing significant maturational changes in neural activity patterns between grades.

The emotional aspects of mathematical

learning have also received attention. Suárez-Pellicioni et al. [22] reviewed the cognitive consequences and neural bases of math anxiety, while Lyons and Beilock [23] demonstrated that math anxiety could be separated from math performance at the neural level. This research emphasizes the importance of creating supportive learning environments during this critical developmental period.

Despite promising research on brain-based learning, several gaps remain. First, while studies have shown general benefits of brain-based approaches, there is limited research specifically examining brain hemispheres-compatible strategies on information processing skills in mathematics. Second, most existing studies focus on general mathematical achievement rather than specific cognitive processes like information processing skills. Third, the application of neuroscientific insights to educational practice remains challenging [24], with factors such as lack of teacher training, time constraints, and adherence to traditional curricula hindering adoption of innovative teaching strategies [25].

Recent technological advances offer new opportunities for investigation. Artemenko et al. [26] used functional near-infrared spectroscopy (fNIRS) to study neural correlates of mental arithmetic in naturalistic educational settings, while research on digital learning tools has provided insights into different formats of numerical representation [27]. Cultural influences on mathematical cognition have also been identified as important factors requiring consideration [28].

The integration of metacognitive strategies has shown promise, with Houdé et al. [29] exploring neural correlates of metacognitive processes in problem-solving. Furthermore, research on learning disabilities has advanced understanding of neurobiological underpinnings, with Ashkenazi et al. [30] comparing mathematics and reading disabilities, and De Smedt et al. [31] investigating how numerical magnitude processing skills relate to individual differences in mathematical abilities.

The current study addresses these gaps by investigating the impact of a teaching strategy compatible with the brain hemispheres approach on developing information processing skills among eighth-grade students in mathematics. This focus on a specific age group during a critical developmental period, combined with emphasis on particular cognitive processes, fills an important void in the literature.

The research aims to design a teaching strategy compatible with the brain hemispheres approach and investigate its effect on developing information processing skills among eighth-grade female students in mathematics. Two null hypotheses were formulated: (1) there is no statistically significant difference at the 0.01 level between mean scores of information processing skills development for students in the experimental group versus the control group, and (2) there is no statistically significant difference at the 0.01 level between pre-test and post-test mean scores for the experimental group.

The current research is constrained by several limitations. Human limitations include focus on eighth-grade female students in day intermediate schools for girls. Spatial limitations restrict the research to Avro School in Duhok Governorate center. Temporal limitations confine the study to the first semester of 2022-2023. Knowledge limitations include the first three chapters (Rational Numbers, Algebraic Quantities, Equations and Inequalities) from the eighth-grade mathematics textbook.

The integration of neuroscience and education continues to provide valuable insights into mathematical information processing and instructional practices. However, the challenge lies in effectively translating these findings into practical, classroom-based interventions that support diverse learners. The ongoing dialogue between neuroscientists, cognitive psychologists, and educators is crucial for bridging the gap between brain science and educational practice, ultimately leading to more effective and evidence-based approaches to mathematics education.

METHODS

Research Method and Experimental Design

The researcher adopted the experimental method, which aligns best with the study's objectives and hypotheses. The study aimed to design a teaching strategy compatible with the brain hemispheres approach and examine its effect on the dependent variable (information processing skills) among eighth-grade mathematics students. The experimental design employed was a quasi-experimental design with equivalent groups, consisting of an experimental group and a control group, as illustrated in table 1.

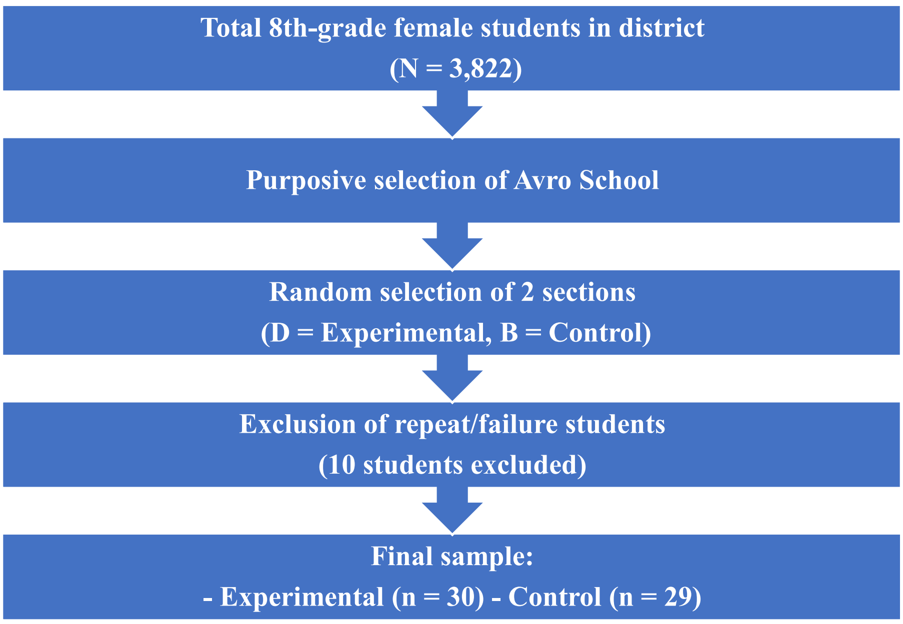
Table 1. Experimental Research Design

Group		Pre-Test	Independent Variable	Dependent Variable (Post-Test)
Experimental	**Group Equivalence**	Information Processing Skills	Brain-Hemispheres-Compatible Teaching Strategy	Development of Information Processing Skills
Control			Traditional Method	

Research Population and Sample Selection

The study population included all eighth-grade female students in day intermediate schools for girls affiliated with the Directorate of Education in Duhok, totaling 3,822 students. The researcher purposefully selected Avro School as the sample site. Using a random sampling method, two sections from the eighth grade were chosen: section (D) as the experimental group and section (B) as the control group. Some students who had previously failed and had prior experience were excluded from both groups, as shown in Figure 1.

Figure 1: Research Sample Selection Process



Equivalence of Research Groups

Before beginning the experiment, the researcher verified the equivalence of both groups across several variables obtained from each student's school records. These variables included:

1. Intelligence Level: The researcher applied the Raven's Progressive Matrices Test, adapted for the Iraqi context on 2/10/2022.
2. General Grade Average: The researcher used the students' average scores from the 2021-2022 academic year.
3. Final Mathematics Grade for Sixth Grade: Each student's mathematics grade from the previous academic year was considered.
4. Chronological Age in Months: The students' ages were calculated in months up to 30/9/2022.
5. Prior Knowledge: A multiple-choice test consisting of 10 items was prepared and administered on 3/10/2022.
6. Information Processing Skills Test: The researcher designed a 20-item information processing skills test and applied it to both the experimental and control groups on 4/10/2022. To confirm the equivalence between the groups, the researcher used the t-test for independent samples on all the aforementioned variables.

Table 2. Comparison of Means, Standard Deviations, and Calculated and Tabulated (t) Values for Equivalence Variables

Equivalence Variables	**Experimental Group N = (30)**		**Control Group N = (26)**		**t-value**	**p-value**	**Significance Level**
	Mean	Standard Deviation	Mean	Standard Deviation			
Intelligence Score	38.028	4.395	29.501	3.336	0.423	0.674	Statistically Significant
General Average	81.813	13.674	78.152	9.146	1.640	0.106	Statistically Significant
Mathematics Score	76.222	16.779	73.115	15.308	0.704	0.484	Statistically Significant
Prior Knowledge	14.222	3.154	13.230	3.154	1.145	0.257	Statistically Significant
Chronological Age	162.851	3.612	163.230	4.104	1.639	0.107	Statistically Significant
Information Processing	13.766	1.612	12.689	1.627	1.753	0.085	Statistically Significant

It is clear from the table above that the calculated value for all variables is less than the tabulated value of (2.021) at the significance level of (0.01) and a degree of freedom of (57). This indicates no statistically significant difference; thus the two groups are considered equivalent in the mentioned variables.

Research Requirements

To conduct the experiment and validate its hypotheses, several requirements were prepared:

- Defining the Academic Content: The researcher reviewed the content of the first three chapters of the eighth-grade mathematics textbook, which were used to teach both groups. These included Chapter 1: Rational Numbers (8 topics), Chapter 2: Algebraic Quantities (6 topics), and Chapter 3: Equations and Inequalities (7 topics). A content analysis list was prepared based on categories such as facts, concepts, principles, and skills.
- Formulating Behavioral Objectives: The researcher prepared behavioral objectives according to Bloom's Taxonomy for the cognitive domain (Remember, Understand, Apply, Analyze), totaling (68) objectives. To ensure their validity, the list was presented to a committee of experts in mathematics teaching methods. Based on expert suggestions, some objectives were linguistically

adjusted, and daily lesson plans were prepared for both groups.

- Preparing Lesson Plans: The researcher prepared (32) actual lesson plans for each group according to the methods used in the study. The experimental group was taught using the brain hemispheres-compatible strategy steps, while the control group was taught using the traditional method. A model of each lesson plan was presented to a committee of experts in mathematics teaching methods, and they agreed on the appropriateness and comprehensiveness of the plans for the academic material.

Research Tool

The researcher prepared an information processing skills test following these steps:

- Purpose of the Test: The test aimed to measure information processing skills among eighth-grade students.
- Defining Test Skills: The test targeted four core skills: Summarization, Application, Pattern and Relationship Recognition, and Interpretation.
- Formulating Test Items: After reviewing several sources related to information processing skills and the mathematics textbooks for grades (seventh - eighth), (20) items were drafted, distributed across the four information processing skills, including (15) objective items with four alternatives and (5) items requiring sequential steps.
- Scoring the Test: An answer key was prepared for scoring the test. A score of (1) was given for correct answers and (0) for incorrect or unanswered items in the objective section, while for sequential items, scores of (0, 1, 2) were assigned based on the solution steps. The total score ranged from (0 to 25), with the highest score indicating mastery of the skill.
- Test Validity: To ensure test validity, it was presented to a committee of experts in mathematics teaching methods. A minimum of (80%) agreement among experts was required to validate each item. Based on their feedback, some items were rephrased, making the test valid.
- Statistical Analysis of Test Items: To check the clarity of the test items and instructions, and to analyze statistical parameters such as discrimination index and distractor effectiveness, the test was administered to a pilot sample of (100) eighth-grade students from Kazan School. The time required for completion was determined to be (30) minutes. The researcher then analyzed the items by ranking scores in descending order and dividing them into two groups, taking (27%) of the highest and lowest scores, with (27) students in each group. The discrimination index for the test items ranged between (0.34-0.72), within the acceptable range. Distractor effectiveness was verified, with all distractors performing as expected except the correct answer.
- Test Reliability: To calculate the test's reliability, (30) forms were randomly selected from the pilot sample, and Cronbach's Alpha was applied, yielding a reliability coefficient of (78%), making the test stable and ready for final application.

Experiment Implementation

The experiment was conducted during the first semester of the 2022-2023 academic year, starting on Wednesday, (9/10/2022) and ending on Thursday, (15/12/2022), spanning (9) weeks with (5) lessons per week. Official holidays, special occasions, and mid-term exam periods were excluded. The experiment was applied to both groups as follows:

1. Experimental Group: This group was taught according to a brain-compatible teaching strategy, where the classroom environment was prepared before each lesson. A positive relationship with students was built, emotions were considered, and students were encouraged to stimulate their

brains. Visual aids were used to clarify lesson concepts, with the lesson proceeding through the following phases:

- Preparation Phase: Behavioral objectives were written on the board, and mathematical connections between prior knowledge and the lesson topic were established to prepare students' minds for new information. This created a mental image of relationships and concepts tied to the new lesson, fostering a competitive classroom environment.
- Engagement Phase: An educational environment was created to capture students' attention, fostering a broad range of learning experiences and adaptability to engage with the topic.
- Learning Design Phase: The lesson content was expanded through experimentation and feedback to reinforce memory, such as (writing test questions, designing mind maps, or solving varied math problems). This connected the learning situation to other applicable topics.
- Acquisition Phase: Students acquired the lesson topic using various stimuli relevant to their environment through group discussion. The board was divided into two sections: the right side for drawing and visual explanations, and the left side for writing and logical problem-solving. Examples and posters were displayed, and students were encouraged to arrive at mathematical principles, enhancing competition and directing them to correct answers.
- Memory Formation Phase: The importance of time was emphasized, such as stopping work for review, as the brain learns more effectively over time. Teachers provided sufficient breaks, displayed evaluative questions engagingly, offered stretching exercises, and played relaxing music.
- Functional Integration Phase: The lesson topic was connected to the next topic to build accurate connections in the brain. Students were reminded of the lesson's importance and motivated with rewards, encouraged for better interaction in future lessons, and their projects and work were displayed in a fun manner.

2. Control Group: This group was taught using the traditional method as per the teacher's guide, following these steps:

◊ Writing the main points of the topic on the board by the teacher.

◊ The teacher reminded students of the key points in the lesson and asked questions to link the topic with their prior knowledge, allowing students to engage in discussion during explanations.

◊ The teacher solved varied examples with student participation in classroom activities.

◊ The teacher summarized the lesson, with the primary focus on teacher-led instruction.

Applying the Information Processing Skills Test

The information processing skills test was administered after notifying students of the test date. Test forms were distributed to both groups on (18/12/2022). The researcher explained the test instructions and how to answer, guiding students not to leave any item unanswered.

Ethical Considerations

This research received formal ethical approval from the Ministry of Education of Kurdistan Region-Iraq, General Directorate of Duhok Education, Western Duhok Education Directorate (Reference No. 9351, dated October 5, 2021), and institutional approval from the University of Zakho, College of Education. Since participants were minors (eighth-grade female students), a dual consent process was implemented: written informed consent was obtained from parents/guardians explaining the research objectives and brain hemispheres teaching strategy, while student assent was secured from all participants confirming their understanding and willingness to participate. Both parents and students were informed of their right to withdraw at any time without academic consequences. All data were treated confidentially using coded identification systems, and research procedures were coordinated with school administration to ensure minimal disruption to regular educational activities.

Statistical Methods

The researcher utilized several statistical methods for data analysis, including the t-test for independent and paired samples, Cronbach's Alpha for reliability, Eta squared, and Cohen's (d), in addition to using SPSS software for data processing.

RESULTS

In light of the statistical analysis conducted, the findings are organized and interpreted according to the research hypotheses as follows:

- Results Related to the First Null Hypothesis: "There is no statistically significant difference at the 0.01 level between the mean scores for information processing skills development among students in the experimental group who were taught using a brain hemispheres-compatible strategy and students in the control group who were taught using the traditional method."

To test this hypothesis, the researcher calculated the mean and standard deviation of the differences between the pre-test and post-test scores for information processing skills for both the experimental and control groups. A t-test for independent samples was applied, and the data and results are presented in Table 3.

Table 3. Calculated (t) Value and Effect Size for Information Processing Skills Development between Experimental and Control Groups

Group	N	Mean Scores of Information Processing Skills			Std. Deviation of Difference	t- value	p- value (0.01)	Eta Squared (η^2)	Effect Size
		Pre-Test	Post-Test	Difference					
Experimental	30	13.766	20.133	6.366	0.874	5.988	< 0.01**	0.38	Very Large
Control	29	12.689	14.241	1.551	1.843				

It is clear from Table 3 that the calculated (t) value is 5.988, which is greater than the tabulated value of 2.021 at the 0.01 significance level and with 57 degrees of freedom. This indicates a statistically significant difference in favor of the experimental group. To determine the effect size of the independent variable (brain hemispheres-compatible teaching strategy) on the dependent variable (information processing skills), the researcher applied the Eta Squared (η^2) formula, yielding a value of 0.38, which is considered very large. This suggests that the teaching strategy had a substantial impact on the experimental group's responses, leading to enhanced information processing skills. The researcher attributes this effect to the strategy's role in improving mathematical abilities and interpreting relationships between concepts through diverse activities that engaged students actively and enthusiastically.

- Results Related to the Second Null Hypothesis: "There is no statistically significant difference at the 0.01 level between the pre-test and post-test mean scores for information processing skills among students in the experimental group who were taught using a brain hemispheres-compatible strategy."

To verify this hypothesis, the researcher compared the pre-test and post-test scores for each information processing skill within the experimental group by calculating the mean difference and standard deviation. The t-test for paired samples was applied, with the data and results presented in Table 4.

Table 4. Calculated (t) Value and Effect Size (d) for Information Processing Skills Development within the Experimental Group

Skill	N	Mean Score of Information Processing Skills for the Experimental Group			Std. Deviation of Difference	t-value	p-value (0.01)	Effect Size (d)	Effect Size Description
		Pre-Test	Post-Test	Difference					
Summarization	30	3.933	5.100	1.166	0.874	7.309	< 0.01**	1.33	Very Large
Application	30	3.500	5.301	1.800	1.156	8.523	< 0.01**	1.55	Very Large
Pattern and Relationship Recognition	30	3.300	5.233	1.933	1.617	6.547	< 0.01**	1.19	Very Large
Interpretation	30	2.866	4.600	1.733	1.014	9.355	< 0.01**	1.70	Very Large
Total	30	13.766	20.133	6.366	2.906	11.998	**< 0.01***	2.19	Very Large

It is evident from Table 4 that the calculated (t) value for each information processing skill (Summarization, Application, Pattern and Relationship Recognition, Interpretation) is greater than the tabulated value of 1.699 at the 0.01 significance level and with 29 degrees of freedom. This indicates a statistically significant difference in favor of the post-test. The researcher calculated the effect size (d) for each skill, which showed a very large effect size across all skills. This suggests that the teaching strategy was effective in enhancing each information processing skill. The researcher attributes this to the brain-compatible strategy's ability to create organized mental images that facilitate storage, retrieval, and organization of knowledge in a manner aligned with brain function.

DISCUSSIONS

The research findings revealed compelling evidence about the effectiveness of brain hemispheres-compatible teaching strategies in mathematics education. The data demonstrated substantive improvements across multiple dimensions of mathematical learning and cognitive processing, warranting detailed analysis of each aspect and its implications for educational practice. The experimental group exhibited notable enhancement in their overall information processing skills, revealing the strategy's effectiveness in creating more robust neural pathways for mathematical learning. This improvement manifested through students' enhanced ability to simultaneously process multiple aspects of mathematical problems, suggesting the development of more sophisticated cognitive frameworks. The strategy's success appears to stem from its ability to engage both hemispheres of the brain in complementary ways, allowing students to utilize both analytical and intuitive processing mechanisms concurrently. This dual processing approach seems to facilitate deeper understanding and more effective knowledge integration, as also observed by Mekarina and Ningsih [7] in their investigation of brain-based learning approaches.

The development of conceptual understanding among students in the experimental group showed particularly promising results. Students demonstrated enhanced abilities in abstracting mathematical principles from specific examples and applying these principles to novel situations. This improvement suggests that the brain hemispheres approach facilitates the development of more sophisticated mental models for mathematical concepts. The strategy appears to help students create stronger connections between abstract mathematical principles and their concrete applications, leading to more flexible and adaptable mathematical thinking. These findings echo the observations of

Noureen, Awan, and Fatima [8], though the current study demonstrates even broader implications for conceptual development.

Pattern recognition and relationship understanding showed remarkable advancement under the brain hemispheres approach. Students demonstrated enhanced ability to identify mathematical patterns, understand their underlying structures, and apply this understanding to new situations. This improvement appears to stem from the strategy's success in developing both systematic and intuitive pattern recognition processes. The approach seemed particularly effective in helping students integrate visual-spatial understanding with logical-analytical thinking, leading to more comprehensive mathematical insight. The findings align with and expand upon Suarsana et al.'s [9] research, particularly in demonstrating how integrated cognitive approaches enhance mathematical understanding.

The enhancement in higher-order thinking skills proved especially noteworthy. Students showed improved capabilities in analysis, synthesis, and evaluation of mathematical concepts, suggesting that the brain hemispheres approach is particularly effective for developing advanced mathematical thinking. This improvement manifested in students' enhanced ability to tackle complex problems, develop creative solutions, and articulate mathematical reasoning. The strategy appeared to facilitate the development of more sophisticated problem-solving approaches by enabling students to draw upon both analytical and creative thinking processes, as similarly noted in Salem's [32] findings.

The comprehensive nature of the improvements observed suggests that the brain hemispheres approach fosters balanced cognitive development. Students showed enhanced capabilities across various mathematical skills without the typical imbalances often seen in traditional teaching methods. This balanced improvement indicates that the strategy successfully engages multiple cognitive pathways, leading to more integrated mathematical thinking. The approach appears to help students develop a more holistic understanding of mathematics, where different aspects of mathematical thinking support and reinforce each other.

The implications of these findings extend beyond immediate academic performance. The observed improvements in cognitive processing and understanding suggest potential long-term benefits for students' mathematical development. The strategy appears to help students develop more effective learning strategies and stronger metacognitive skills, potentially enhancing their ability to approach new mathematical concepts independently.

The uniformity of improvement across different skill areas suggests that the brain hemispheres approach may be particularly valuable for addressing the diverse learning needs present in typical mathematics classrooms. The strategy's success in developing multiple aspects of mathematical thinking simultaneously indicates its potential value for creating more inclusive and effective mathematics education environments.

The magnitude of improvement in complex problem-solving and conceptual understanding suggests that this approach might be especially beneficial for preparing students for advanced mathematical study. The strategy appears to help students develop the kind of flexible, integrated thinking that is crucial for success in higher-level mathematics.

These findings also raise intriguing questions about the nature of mathematical learning and cognitive development. The success of the brain hemispheres approach suggests that traditional methods might be underutilizing significant aspects of students' cognitive potential. The strategy's effectiveness in developing integrated mathematical thinking capabilities indicates that mathematics education might benefit from a fundamental shift toward more balanced, brain-compatible teaching approaches.

The research implications suggest a need to reconsider how mathematics is typically taught in schools. The success of this approach indicates that incorporating brain-compatible strategies could significantly enhance mathematics education effectiveness. Future research might productively explore how these approaches could be optimally implemented across different grade levels and mathematical topics, and how they might be adapted to address varying student needs and learning styles.

CONCLUSIONS

Based on the research findings, the researcher recommends conducting training workshops for mathematics teachers to familiarize them with brain hemispheres-compatible learning in teaching mathematical topics. Teachers are encouraged to focus on both affective and skill-based aspects in mathematics teaching using a brain-compatible strategy to achieve hemispheric integration for learning mathematical concepts. Additionally, the research emphasizes the importance of familiarizing mathematics teachers with various learning theories and utilizing them to develop visual thinking skills through a guide for teachers. For further research, the study proposes investigating the impact of hemispheric brain processes on mathematical creativity skills among basic education students, examining the effectiveness of brain-based learning in developing geometric thinking and academic achievement for tenth-grade science students, and evaluating the effectiveness of a brain-hemispheres-based program in developing inferential thinking skills in mathematics for basic education students.

ACKNOWLEDGMENTS

None

CONFLICT OF INTEREST

None

FUNDING

None

REFERENCES

[1] D. Ansari, B. De Smedt, and R. Grabner, "Neuroeducation – A Critical Overview of An Emerging Field," Neuroethics, vol. 5, pp. 1–13, 2011, doi: 10.1007/s12152-011-9119-3.

[2] D. Sousa and R. Risley, "How the Brain Learns Mathematics".

[3] S. Ali, "Ambiguous Loss, Boundary Ambiguity, and English Learning: How Immigrants' Functionality is Impacted by Language Proficiency," 2020, [Online]. Available: https://scholarworks.bellarmine.edu/tdc/94/%0Ahttps://scholarworks.bellarmine.edu/cgi/viewcontent.cgi?article=1106&context=tdc

[4] L. Cragg and C. Gilmore, "Skills underlying mathematics: The role of executive function in the development of mathematics proficiency," Trends Neurosci. Educ., vol. 3, 2014, doi: 10.1016/j.tine.2013.12.001.

[5] J. Boaler, L. Chen, C. Williams, and M. Cordero, "Seeing as Understanding: The Importance of Visual Mathematics for our Brain and Learning," J. Appl. Comput. Math., vol. 05, 2016, doi: 10.4172/2168-9679.1000325.

[6] K. Özgen and H. Alkan, "The Effects of Learning Activities Corresponding with Students' Learning Styles on Academic Success and Attitude within the Scope of Constructivist Learning Approach: The Case of the Concepts of Function and Derivative," Turkish J. Comput. Math. Educ., vol. 5, p. 1, 2014, doi: 10.16949/turcomat.35299.

[7] M. Mekarina and Y. Ningsih, "The Effects of Brain Based Learning Approach on Motivation and Students Achievement in Mathematics Learning," J. Phys. Conf. Ser., vol. 895, p. 12057, 2017, doi: 10.1088/1742-6596/895/1/012057.

[8] G. Noureen, R.-U.-N. Awan, and H. Fatima, "Effect of Brain-based Learning on Academic Achievement of VII Graders in

Mathematics Effect of Brain-based Learning on achievement of VII Graders 86," 2017.
[9] I. M. Suarsana, N. Widiasih, and I. N. Suparta, "The Effect of Brain Based Learning on Second Grade Junior Students' Mathematics Conceptual Understanding on Polyhedron," J. Math. Educ., vol. 9, 2017, doi: 10.22342/jme.9.1.5005.145-156.
[10] S. Dehaene, M. Piazza, P. Pinel, and L. Cohen, "Three Parietal Circuits for Number Processing," Cogn. Neuropsychol., vol. 20, pp. 487–506, 2003, doi: 10.1080/02643290244000239.
[11] D. Ansari, "Effects of development and enculturation on number representation in the brain," Nat. Rev. Neurosci., vol. 9, pp. 278–291, 2008, doi: 10.1038/nrn2334.
[12] V. Menon, "Working memory in children's math learning and its disruption in dyscalculia," Curr. Opin. Behav. Sci., vol. 10, 2016, doi: 10.1016/j.cobeha.2016.05.014.
[13] A. Matejko and D. Ansari, "The neural association between arithmetic and basic numerical processing depends on arithmetic problem size and not chronological age," Dev. Cogn. Neurosci., vol. 37, 2019, doi: 10.1016/j.dcn.2019.100653.
[14] G. Price, M. Mazzocco, and D. Ansari, "Why Mental Arithmetic Counts: Brain Activation during Single Digit Arithmetic Predicts High School Math Scores," J. Neurosci., vol. 33, pp. 156–163, 2013, doi: 10.1523/JNEUROSCI.2936-12.2013.
[15] M. Arsalidou, M. Pawliw-Levac, M. Sadeghi, and J. Pascual-Leone, "Brain areas needed for numbers and calculations in children: Meta-analyses of fMRI studies," Dev. Cogn. Neurosci., vol. 30, 2017, doi: 10.1016/j.dcn.2017.08.002.
[16] L. Kaufmann, G. Wood, O. Rubinsten, and A. Henik, "Meta-Analyses of Developmental fMRI Studies Investigating Typical and Atypical Trajectories of Number Processing and Calculation," Dev. Neuropsychol., vol. 36, pp. 763–787, 2011, doi: 10.1080/87565641.2010.549884.
[17] N. S. Newcombe, S. C. Levine, and K. S. Mix, "Thinking about quantity: the intertwined development of spatial and numerical cognition.," Wiley Interdiscip. Rev. Cogn. Sci., vol. 6, no. 6, pp. 491–505, 2015, doi: 10.1002/wcs.1369.
[18] T. Nakai and K. Sakai, "Neural Mechanisms Underlying the Computation of Hierarchical Tree Structures in Mathematics," PLoS One, vol. 9, p. e111439, 2014, doi: 10.1371/journal.pone.0111439.
[19] W. Fias, V. Menon, and D. Szűcs, "Multiple components of developmental dyscalculia," Trends Neurosci. Educ., vol. 2, 2013, doi: 10.1016/j.tine.2013.06.006i.
[20] S. Qin, S. Cho, T. Chen, M. Rosenberg-Lee, D. Geary, and V. Menon, "Hippocampal-neocortical functional reorganization underlies children's cognitive development," Nat. Neurosci., vol. 17, 2014, doi: 10.1038/nn.3788.
[21] M. Rosenberg-Lee, M. Barth, and V. Menon, "What difference does a year of schooling make? Maturation of brain response and connectivity between 2nd and 3rd grades during arithmetic problem solving," Neuroimage, vol. 57, no. 3, p. 796—808, Aug. 2011, doi: 10.1016/j.neuroimage.2011.05.013.
[22] M. Suarez Pellicioni, M. Núñez-Peña, and À. Colomé, "Math anxiety: A review of its cognitive consequences, psychophysiological correlates, and brain bases," Cogn. Affect. Behav. Neurosci., vol. 16, 2015, doi: 10.3758/s13415-015-0370-7.
[23] I. Lyons and S. Beilock, "Mathematics Anxiety: Separating the Math from the Anxiety," Cereb. Cortex, vol. 22, pp. 2102–2110, 2011, doi: 10.1093/cercor/bhr289.
[24] B. Butterworth, S. Varma, and D. Laurillard, "Dyscalculia: From Brain to Education," Science, vol. 332, pp. 1049–1053, 2011, doi: 10.1126/science.1201536.
[25] J. Bano, Z. Jabeen, and S. Qutoshi, "Perceptions of Teachers about the Role of Parents in Developing Reading Habits of Children to Improve their Academic Performance in Schools," J. Educ. Educ. Dev., vol. 5, 2018, doi: 10.22555/joeed.v5i1.1445.

[26] C. Artemenko, M. Soltanlou, A.-C. Ehlis, H.-C. Nuerk, and T. Dresler, "The neural correlates of mental arithmetic in adolescents: A longitudinal fNIRS study," Behav. Brain Funct., vol. 14, 2018, doi: 10.1186/s12993-018-0137-8.

[27] R. Merkley, A. Matejko, and D. Ansari, "Strong causal claims require strong evidence: A commentary on Wang and colleagues," J. Exp. Child Psychol., vol. 147, pp. 82–163, 2017, doi: 10.1016/j.jecp.2016.07.008.

[28] I. Berteletti, J. Prado, and J. Booth, "Children with mathematical learning disability fail in recruiting verbal and numerical brain regions when solving simple multiplication problems," Cortex, vol. 57, 2014, doi: 10.1016/j.cortex.2014.04.001.

[29] O. Houdé, S. Rossi, A. Lubin, and J. Marc, "Mapping numerical processing, reading, and executive functions in the developing brain: An fMRI meta-analysis of 52 studies including 842 children," Dev. Sci., vol. 13, pp. 876–885, 2010, doi: 10.1111/j.1467-7687.2009.00938.x.

[30] S. Ashkenazi, J. Black, D. Abrams, F. Hoeft, and V. Menon, "Neurobiological Underpinnings of Math and Reading Learning Disabilities," J. Learn. Disabil., vol. 46, 2013, doi: 10.1177/0022219413483174.

[31] B. De Smedt, M.-P. Noel, C. Gilmore, and D. Ansari, "How do symbolic and non-symbolic numerical magnitude processing relate to individual differences in children's mathematical skills? A review of evidence from brain and behavior," Trends Neurosci. Educ. ISNN 2211-9493, vol. 2, pp. 48-55., 2013, doi: 10.1016/j.tine.2013.06.001.

[32] A. Salem, "Engaging ESP Students with Brain-Based Learning for Improved Listening Skills, Vocabulary Retention and Motivation," English Lang. Teach., vol. 10, p. 182, 2017, doi: 10.5539/elt.v10n12p182.