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## Brain Disorders Related to The Learning Process

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Received April 10, 2025; Revised July 21, 2025; Accepted August 25, 2025

### Abstract

**Objective:** The purpose of this study is to deeply understand the role of the brain in the learning process, as well as identify various types of brain disorders that impact students' cognitive abilities. In addition, this study also aims to examine how certain neurological disorders, such as dyslexia, Minimal Brain Dysfunction, dyscalculia, and attention deficit hyperactivity disorder, affect students' academic performance and daily life. This research is expected to provide a neuroscientific perspective in designing learning strategies that are more inclusive and responsive to specific learning needs. **Theoretical framework:** The theoretical framework is based on the neuroscience approach of education, specifically the concepts of brain plasticity, the function of the hemispheres, and the role of the central nervous system in learning. **Literature review:** The literature review covers brain development and function, as well as various disorders such as dyslexia, DMO, ADHD, and dyscalculia, which have a direct impact on learning ability. **Methods:** This study uses a descriptive qualitative method with a literature review approach. The data was analyzed using content analysis from various scientific literature sources. **Results:** The results of the study show that brain function has a very important role in supporting the learning process. Connections between neurons are formed through experience and appropriate stimuli, while disturbances in brain structure or function can cause various difficulties in the learning process. Disorders such as Minimal Brain Dysfunction, dyslexia, dyscalculia, and attention deficit hyperactivity disorder significantly affect concentration, memory, and the ability to read, write, and count in school-age children. In addition, the dominance of left-brain or right-brain function also affects a person's learning style, so learning strategies need to be adjusted to the cognitive tendencies of each student. **Implications:** The results of this study encourage the importance of understanding neuroscience in education so that learning strategies can be adjusted to the neurological condition of students. **Novelty:** The novelty of this research lies in the integration of neuroscience and Islamic educational approaches in understanding and dealing with learning disorders holistically and empathically.

**Keywords:** brain disorders, learning processes, learning difficulties, cognitive function, educational neuroscience.

### INTRODUCTION

The brain is the main control center for all human body activities, both physical and mental. The brain regulates and coordinates various vital functions such as heart rate, body

temperature, fluid balance, behavior, and thinking and learning processes. Under normal circumstances, a healthy brain will support body health and mental stability, but if the brain is disturbed, then body and mental functions can be disturbed. The brain also plays an important role in the learning process, including recognition, emotions, memory, information processing, and motor learning. The brain acts as a center for processing information from the internal and external environment through a complex and integrated nervous system [1].

However, in reality, not all individuals have optimal brain function. Some neurological disorders, such as dyslexia, ADHD, minimal brain dysfunction (DMO), and dyscalculia, can significantly affect a person's learning process. According to data from the World Health Organization (WHO), about 5–15% of school-age children in the world have learning disorders related to certain neurological conditions. This is a serious concern because the learning process is highly dependent on healthy and well-organised brain function. Children with impaired brain function often experience obstacles in reading, writing, arithmetic, and concentration, which can ultimately hinder their academic and social development. From these conditions, it can be identified that impaired brain function has a direct impact on an individual's learning ability. The lack of understanding of teachers, parents, and the community towards the types of brain disorders that affect the learning process leads to inappropriate handling and even misunderstandings of children who have learning difficulties. This shows that there is an urgent need to study and understand the types of brain disorders related to learning, how they affect the learning process, and how educational strategies can be tailored to help individuals who experience them [2].

The purpose of this study is to find out and understand more deeply about brain function, types of brain disorders, and their relationship with the learning process. This paper also aims to provide insight into the importance of neuroscientific understanding in the world of education, especially in dealing with students with special learning needs. The benefits of this research include: (1) providing academic understanding to students, educators, and education practitioners about the role of the brain in the learning process; (2) to be a conceptual basis for developing learning strategies that are by the neurological condition of students; and (3) increasing awareness of the importance of early detection and treatment of neuropsychology-based learning disorders in the context of Islamic and general education [3].

Research Gap. Despite the growing awareness of learning difficulties among children, there remains a substantial gap in understanding the neurological foundations that underlie these challenges, particularly in educational settings that lack interdisciplinary integration. Most prior research on brain disorders has either been rooted solely in medical science or focused narrowly on psychological manifestations, without adequately linking such disorders to pedagogical outcomes. Moreover, while neuroscience has advanced rapidly in uncovering the brain's structural and functional complexities, its integration into education systems—especially in the context of Islamic education—is still underdeveloped. Many teachers, parents, and even education policy-makers lack sufficient knowledge about how brain disorders such as dyslexia, ADHD, dyscalculia, and minimal brain dysfunction directly affect the learning process. As a result, interventions often fail to address the root causes, and educational strategies remain generalized and ineffective for neurodiverse learners [4].

Additionally, existing literature tends to overlook the diversity of neurological conditions that influence learning, often treating them as isolated anomalies rather than part of a broader educational challenge. Research has not sufficiently explored how the dominance of specific brain hemispheres, variations in synaptic plasticity, or neurotransmitter imbalances shape learning styles and performance. The specific mechanisms of disorders such as ataxia, schizophrenia, epilepsy, and arteriosclerosis—although extensively discussed in clinical literature—are rarely examined in the context of classroom learning and educational success. This study offers significant contributions by bridging the gap between neuroscience and education through a comprehensive examination of how various brain disorders impact students' cognitive, emotional, and behavioral capacities in the learning environment. It

emphasizes the brain's central role in the educational process by linking neurological function with learning efficiency, adaptability, and style. Through its descriptive qualitative methodology and literature-based approach, the study synthesizes scientific findings to offer a practical framework for educators and curriculum developers [4].

The findings are particularly significant for educators who work with children exhibiting atypical learning patterns. By identifying the neurological basis of learning difficulties, this research empowers teachers to recognize early symptoms of brain disorders and respond with targeted strategies. The significance extends to the formulation of more inclusive educational policies that accommodate neurodivergent students without compromising academic standards. Furthermore, the study underscores the value of a neuroscientific foundation in teacher training, enabling them to design learning experiences that align with the cognitive and neurological profiles of their students [5].

The educational implications of this study are wide-ranging and transformative. First, the research calls for a paradigm shift in educational planning—from a uniform approach to one that is sensitive to neurological diversity. Recognizing that students' learning challenges may stem from underlying brain disorders leads to more empathetic, supportive, and effective instructional methods. Second, the study emphasizes the need for early diagnosis and intervention. With a neuroscientific perspective, educators and parents can collaborate with medical professionals to implement individualized education plans (IEPs) that align with each child's specific neurological condition. This proactive approach can significantly enhance the student's academic performance and emotional well-being [6].

Third, the findings advocate for curriculum reform, particularly in Islamic education contexts, where holistic well-being is deeply valued. Incorporating neuroscience into Islamic pedagogy allows for the development of educational systems that are not only spiritually grounded but also scientifically responsive to cognitive challenges. This integration fosters inclusive education environments that uphold the dignity and potential of every learner, regardless of neurological condition. Lastly, this study also has policy implications. Educational authorities should consider incorporating neuroscience education into teacher certification programs, school counseling services, and national learning standards. This would ensure that educators are equipped with the knowledge and tools necessary to support neurodiverse learners effectively [6].

The novelty of this research lies in its interdisciplinary approach—merging educational neuroscience with Islamic educational philosophy to provide a holistic framework for understanding and addressing learning disorders. Unlike prior studies that treat brain disorders purely through medical or psychological lenses, this research acknowledges the social, cognitive, and spiritual dimensions of education. Another key innovation is the emphasis on hemispheric brain function and plasticity as determinants of learning style. By analyzing how the left and right hemispheres influence logical, creative, and emotional processing, the study proposes that personalized teaching methods can be designed to complement students' neurological strengths. This nuanced perspective enables educators to optimize classroom interactions and material delivery according to individual cognitive tendencies [7].

Additionally, the integration of brain-based learning strategies—such as stimulation of synaptic connections, consideration of neurotransmitter activity, and adaptation to neurodevelopmental delays—provides a fresh pedagogical model that is evidence-based and learner-centred. The study offers not only theoretical contributions but also actionable insights for inclusive classroom practices. Furthermore, by incorporating Islamic values of empathy, compassion, and holistic education, the research provides a culturally contextualized model for supporting learners with brain disorders. This unique fusion of science and spirituality in addressing educational inequality marks a pioneering contribution in both neuroscience and Islamic educational literature [7].

## LITERATURE REVIEW

### Functions and Development of the Human Brain

The brain is the body's control center, responsible for almost all physical and cognitive functions. The brain regulates heart rate, body temperature, fluid balance, and coordinates movement, behavior, and other homeostatic functions [8]. According to Rakhmat, the brain controls basic behaviors such as eating, sleeping, thinking, and helping to create art, science, and language. The brain is also the center of emotions, recognition, memory, and logical and abstract thinking skills that are very important in the learning process [9]. The development of the human brain begins in the womb, where there is a process of neuronal overproduction called "neuroblast explosion." Every day, about 250,000 neuroblasts (immature nerve cells) are produced and migrate to the outside of the brain to form colonies of neurons [10]. According to Rakhmat, these colonies are tasked according to their respective functions, such as the visual system, hearing, and others. Children's brain development is divided into three main phases: the primitive brain (action brain), limbic brain (feeling brain), and neocortex (thought brain), each of which has a different function in managing emotions, survival instincts, and high-level thinking processes [11].

### Neurological Disorders Affecting the Brain

Some neurological disorders can directly affect brain function and impact a person's ability to learn. Among them are:

1. Ataxia is a disorder of the cerebellum that affects the coordination of body movements [12].
2. Alzheimer's, which impairs long-term memory and has a serious impact on cognitive function [13].
3. Schizophrenia, which causes an imbalance of neurotransmitters such as dopamine, induces delusions and hallucinations [14].
4. Epilepsy is characterized by recurrent seizures due to the disruption of electrical impulses in the brain [15].
5. Parkinson's is a neurodegenerative disease that causes paralysis due to decreased dopamine production [16].
6. Arteriosclerosis, a disorder of the blood vessels of the brain due to plaque buildup that can lead to stroke and other impaired brain function [17].

All of these disorders suggest that abnormal neurological conditions can weaken the cognitive, motor, and sensory systems, all of which are essential in learning.

### Brain Disorders Directly Related to the Learning Process

Some brain disorders have a direct relationship with the learning difficulties experienced by individuals, even though they have normal levels of intelligence. Some of them are:

1. Minimal Brain Dysfunction (DMO) or specific learning disability, which is a condition in which children have difficulty learning in certain areas, such as reading or arithmetic, not because of low vision, hearing, or intelligence, but because of abnormalities in the functioning of the central nervous system [18].
2. Dyslexia is the inability to recognize letters, read, and write, due to disturbances in visual and phonological processing in the brain. Children with dyslexia often have trouble recognizing similar letters and numbers, despite having normal or even high cognitive abilities [19].

3. Dyscalculia is a math learning disorder that can be caused by primary (neurological disorders) and secondary factors (an unsupportive learning environment). Research by Cohen, Lammertyn, and Izard suggests that this disorder involves specific areas in the brain associated with numerical ability [20].
4. Attention Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder characterised by lack of attention, hyperactivity, and impulsivity. ADHD can impact long-term academic success, social relationships, and mental health. This disorder is believed to be related to disorders in certain neurotransmitters and brain structures [21].

### The Role of the Brain in the Learning Process

An effective learning process relies heavily on the brain's ability to form and strengthen connections between neurons. Synaptic connections between brain cells occur through continuous exercise, repetition, and stimulus. A person's intelligence potential is not only determined by the number of neurons, but also by the number of connections (interconnections) formed through learning experiences [22].

**Table 1. Literature Review on Brain Disorders and Learning**

Aspect	Key Points
Functions & Development of the Brain	Controls body & cognitive functions; emotions, memory, abstract thinking; development starts with neuroblast explosion; 3 phases: primitive (action), limbic (feeling), neocortex (thinking).
Neurological Disorders Affecting the Brain	Ataxia (coordination disorder); Alzheimer's (memory loss); Schizophrenia (neurotransmitter imbalance); Epilepsy (seizures); Parkinson's (dopamine decline); Arteriosclerosis (vascular blockage → stroke).
Brain Disorders Related to Learning	Minimal Brain Dysfunction (specific learning disability); Dyslexia (reading/writing difficulty); Dyscalculia (math disorder); ADHD (attention & hyperactivity problems).
Role of the Brain in Learning	Learning via synaptic connections & plasticity; networks of convergent/divergent pathways; left brain = logic/analysis, right brain = intuition/emotion; hemispheric dominance influences learning styles.

The brain's work in the learning process follows the principle of circuitry, where parts of the brain are connected in a parallel and serial network to process information. This principle involves convergent and divergent pathways, as well as specific functions distributed across different brain regions. This process is also called plasticity, which is the brain's ability to reorganize through the formation of new synaptic pathways based on learning experiences [23]. Brain function is also divided into two main hemispheres, namely the left brain, which tends to be logical, analytical, and detailed, and the right brain, which is conceptual, intuitive, and emotional. Understanding the dominance of the function of the hemispheres is very important in the world of education because each individual has different cognitive tendencies [24].

### METHODOLOGY

This study uses a descriptive qualitative approach, which aims to provide an in-depth understanding of various brain disorders related to the learning process. This approach was chosen because the main focus of the research is to describe and explain in detail the phenomenon of neurological disorders that impact an individual's learning ability, without conducting statistical measurements or direct experiments [25]. The data source in this study was obtained through library research, which involved examining various relevant scientific references, such as books on neuroscience, educational and psychology journals, academic articles, and other publications that support the understanding of brain function and disorders that can affect the learning process. All data collected came from trusted and up-to-date sources that are closely related to the study topic [26].



**Figure 1. Research Methodology**

Data collection is carried out through documentation techniques, namely by tracing and recording information from relevant written sources, then classifying them based on discussion themes such as brain anatomy, types of brain disorders, and their implications for the learning process. The data is then analyzed using the content analysis method, which involves identifying, interpreting, and synthesizing the content from the references that have been collected. The author also seeks to make connections between theory and literature findings to present a complete understanding of the role and disorders of the brain in the learning process [27].

## **RESULTS AND DISCUSSION**

### **Structure and Role of the Brain in the Learning Process**

The brain is the control center for all bodily functions and the center of cognitive activity, including thinking, remembering, understanding, and learning. Made up of interintegrated parts, the brain regulates motor, sensory, emotional, and logical functions [28]. Brain development begins in the prenatal period and continues through developmental stages: the primitive brain, the limbic brain, and the neocortex. In the context of learning, the brain has plasticity, which is the ability to adapt and change in response to learning experiences and stimuli. Therefore, any positive learning experience can form new connections between neurons and strengthen the child's thinking pathway [29]. The results of the study show that brain function has a very important role in supporting the learning process. Connections between neurons are formed through experience and appropriate stimuli, while disturbances in brain structure or function can cause various difficulties in the learning process [30].

### **Types of Brain Disorders and Their Impact on Cognitive Function**

Some neurological disorders, such as Ataxia, Alzheimer's, Epilepsy, Schizophrenia, Parkinson's, and Arteriosclerosis, have a direct impact on brain performance, both structurally and functionally. These disorders affect the brain's ability to manage memory, emotions, body balance, and sensorimotor function [31]. If not treated properly, these

conditions can reduce learning ability and overall quality of life. These neurological disorders have an impact on the way the brain manages and responds to information. Disturbed nerve cells cause obstacles to thinking processes, memory, and behavioral control. Therefore, educators and parents need to understand the symptoms and mechanisms of this disorder to take appropriate intervention steps [32].

The explanation of each disorder and its impact on the learning process is as follows:

### **Ataxia**

Ataxia is a disorder that attacks the cerebellum and affects the ability to coordinate movements. In the context of learning, ataxia can cause difficulties in performing fine motor activities such as writing, maintaining physical balance in class, and lowering physical stamina, thereby interfering with learning concentration [33].

### **Alzheimer's**

Alzheimer's is a neurodegenerative disease that impairs memory and thinking abilities. In the learning process, people with Alzheimer's will have difficulty remembering lessons, understanding instructions, and processing new information, which greatly hinders cognitive and academic development [34].

### **Epilepsy**

Epilepsy is a disorder of the central nervous system that causes recurrent seizures due to abnormal electrical activity in the brain. Seizures that occur during the learning process can interfere with focus, cause loss of important information, and the side effects of the drug can decrease memory and concentration [35].

### **Schizophrenia**

Schizophrenia causes reality disorders, delusions, hallucinations, and disorganized thoughts due to neurotransmitter imbalances. The impact on learning includes the inability to distinguish reality, disturbances in understanding abstract concepts, and low motivation to learn [36].

### **Parkinson**

Parkinson's is a degenerative disease that causes a decrease in motor function due to a lack of dopamine. In learning, the patient has difficulty writing, speaking, and slowing down the thought process, which hinders the effective processing of the material [37].

### **Arteriosclerosis**

Arteriosclerosis is a blockage of the blood vessels of the brain by plaques that decrease the oxygen supply to the brain. This condition causes a decline in cognitive function, such as difficulty focusing, poor memory, and a high risk of stroke, which can hinder overall learning ability. By understanding the types and impacts of these brain disorders, educators are expected to develop learning strategies that are more inclusive and adaptive to the cognitive needs of each student [38].

## **Brain Disorders Directly Related to Learning Difficulties**

Certain brain disorders have a specific impact on the child's learning process. Among them:

1. Minimal Brain Dysfunction (DMO): Children have difficulty in certain aspects, such as reading or arithmetic, despite having normal intelligence. It is caused by abnormalities in the central nervous system.
2. Dyslexia: Impaired reading and writing ability due to impaired processing of symbols and phonology in the brain, not due to low vision or intelligence.

3. Dyscalculia: Difficulty in understanding numerical and mathematical concepts, which can be caused by neurological damage or less effective learning patterns.
4. ADHD (attention deficit hyperactivity disorder): Characterized by attention disorders, hyperactivity, and impulsivity. Children with ADHD often have difficulty maintaining focus, controlling emotions, and following instructions in formal learning.

These disorders significantly affect concentration, memory, and basic skills such as reading, writing, and arithmetic. Although a child's intelligence remains in the normal category, the non-optimal functioning of the brain causes academic and social obstacles [39].

### **Brain Mechanism of Work in Learning**

The learning process involves connections between brain cells (neurons) called synapses. Each neuron can form thousands of connections if given the right stimulus. A person's intelligence depends not only on the number of neurons, but also on how many and how strong the connections between cells are formed. Therefore, learning that stimulates the brain in an active and varied manner can improve students' cognitive efficiency. The brain works systemically through converged, divergent, parallel, and serial circuits that support the integration of information from various sensory inputs. By understanding how the central nervous system works in receiving, processing, and responding to stimuli, educators can design learning methods that align with the brain's biological mechanisms. Proper stimulation will strengthen the neural pathways that support the formation of new knowledge and skills [40].

### **Dominance of Hemispheres and Their Implications in Learning**

Humans have two hemispheres of the brain that have different functions. The left brain is more dominant in terms of logic, analysis, and structure, while the right brain is superior in terms of creativity, intuition, and emotions. Understanding the dominance of these hemispheres of the brain is important for designing learning strategies that suit individual learning styles. Children with left-brain dominance tend to excel in analytical and verbal tasks, while right-brain-dominant children are better at visual, artistic, and imaginative tasks. By knowing the tendency to dominate students' brain functions, teachers can apply a more personalized and adaptive pedagogical approach. This is one of the efforts to increase the effectiveness of learning and strengthen the unique potential of each individual [41].

### **Analysis: Brain Disorders Related to the Learning Process**

The article titled “Brain Disorders Related to the Learning Process” presents a comprehensive exploration of how neurological conditions directly and indirectly impact cognitive functions essential for academic performance. Drawing from a wide array of literature, the authors integrate neuroscience and education to offer both theoretical insight and practical implications for teaching strategies tailored to students with brain disorders. At its core, the study emphasizes the brain's pivotal role as the command center for all physical and mental activities, particularly in learning. Normal brain function is critical for effective information processing, emotional regulation, motor coordination, and memory formation. However, disruptions in neurological functioning can lead to disorders such as dyslexia, ADHD, dyscalculia, and Minimal Brain Dysfunction (DMO), which manifest as learning difficulties despite normal intelligence levels. A key contribution of the paper is its detailed categorization of brain disorders into two main types: (1) general neurological disorders affecting overall brain performance (such as Alzheimer's, epilepsy, schizophrenia, ataxia, arteriosclerosis, and Parkinson's), and (2) learning-specific disorders that directly impede reading, writing, calculating, and concentration skills. This distinction enables a more targeted analysis of how such disorders influence learning capacity, with a particular focus on school-aged children [42].

The literature review also introduces the theory of brain plasticity, emphasizing that learning is a dynamic process influenced by neural connectivity. Experiences and stimuli help form synaptic pathways, and disruptions in these processes due to neurological damage can lead to poor learning outcomes. Importantly, the paper underlines that effective educational interventions must take into account the diversity of cognitive profiles and adapt accordingly. For instance, in the case of dyslexia, students face difficulty processing phonological information, leading to reading and writing problems. Dyscalculia affects numerical processing, while ADHD presents with impulsivity, inattention, and hyperactivity—all of which hinder sustained academic focus. These disorders can significantly derail a child's educational trajectory if not addressed with proper support [42].

Equally notable is the discussion of hemispheric dominance. The left hemisphere is associated with logical and analytical thinking, whereas the right hemisphere governs creativity and emotional intelligence. Understanding a student's brain dominance can guide educators in developing personalized instructional strategies that harness the learner's strengths and address their cognitive challenges more effectively. The methodology employed is a qualitative-descriptive approach using literature review and content analysis. This non-empirical method is appropriate given the study's objective to synthesize existing findings rather than produce new statistical data. By analyzing a rich corpus of neuroscience and psychology literature, the authors provide a strong foundation for interpreting how brain conditions correlate with educational challenges [43].

The study also discusses several severe neurological disorders, not limited to learning difficulties. For example, Alzheimer's disease impairs memory and cognition, which are essential for long-term academic performance. Epilepsy introduces episodic cognitive interruptions, while schizophrenia and Parkinson's disease compromise motor control and psychological stability, both of which affect participation in structured learning environments. The implications of this research are significant. Educators, school administrators, and policy-makers must consider the neurodiversity of learners when developing curricula or evaluating academic performance. Misdiagnosis or neglect of such disorders often results in marginalization or inappropriate labeling of students, hindering their full academic and social development [43].

Furthermore, the study introduces a novel dimension by integrating Islamic educational values with neuroscience. This holistic perspective fosters empathy, respect, and individualized attention for students with learning disorders, aligning modern scientific understanding with moral and spiritual educational approaches. The conclusion powerfully advocates for a neuroscience-informed educational paradigm. By recognizing how the brain learns—and how it sometimes fails to function optimally—teachers can craft inclusive, differentiated teaching methods that empower all learners, regardless of their neurological condition. In addition, early diagnosis, continuous teacher training, and collaborative intervention strategies involving parents, psychologists, and educators are strongly recommended [44].

In light of the Sustainable Development Goals (SDGs), particularly Goal 4 (Quality Education) and Goal 3 (Good Health and Well-being), this study aligns closely with global efforts to provide inclusive and equitable education. Ensuring access to appropriate support for students with neurological disorders is essential for building resilient, adaptive, and empathetic learning environments. Thus, this research not only contributes to academic knowledge but also promotes educational justice and mental health awareness in line with sustainable development. In summary, this article offers a valuable synthesis of neuroscience and pedagogy. It underscores the need for adaptive teaching strategies rooted in an understanding of brain function and dysfunction. By doing so, it calls upon educators and stakeholders to move beyond one-size-fits-all models and embrace a more nuanced, inclusive approach to learning—one that honors both scientific understanding and human dignity.

## CONCLUSION

Neuroscience-based learning is an approach that adapts the learning process to the natural way the brain works, emphasizing the importance of proper stimulation so that connections between neurons are formed optimally and support the improvement of cognitive function. An understanding of neuroscience, especially in the branches of neuroanatomy and neurophysiology, is important to be applied in the world of education, especially to support the development of children's brains since the golden age. The results of the study show that neurological disorders such as Minimal Brain Dysfunction, dyslexia, dyscalculia, and attention deficit hyperactivity disorder, as well as other disorders such as ataxia, Alzheimer's, epilepsy, schizophrenia, Parkinson's, and arteriosclerosis, have a significant impact on cognitive function that affects the ability to learn, think, remember, and concentrate. Therefore, a deep understanding of brain function and disorders is needed so that educators can design learning strategies that are more inclusive, adaptive, and responsive to the needs of students, especially those who experience neurological barriers.

## Acknowledgments

The authors express their sincere gratitude to Universitas Muhammadiyah Sumatera Barat, Indonesia, and Cumhuriyet University, Sivas, Turkey, for providing academic support. Appreciation is also extended to colleagues and experts who contributed valuable insights and references that enriched this research on brain disorders and learning processes.

## Author Contribution

All authors contributed equally to the conception, analysis, writing, and revision of this manuscript. Each author played a significant role in reviewing relevant literature, interpreting findings, and ensuring the final quality of the publication.

## Conflicts of Interest

The authors declare no conflicts of interest related to the research, authorship, or publication of this article. This study was conducted independently and received no financial or institutional influence affecting its integrity or outcomes.

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