ERCIYES JOURNAL OF EDUCATION (EJE)
2022, VOL 6, NO. 1, 80-98
http://dergipark.org.tr/eje

Eğitimsel Sinirbilim: Fırsatlar ve Zorluklar*

Çağrı Kaygısız

Türk Hava Kurumu Üniversitesi

ÖZ

Öğrenme elektrokimyasal tepkimeler sonucu beyinde nörofizyolojik değişimlerin yaşanmasına neden olan bir süreçtir. Dolayısıyla etkin öğretim tasarımı ve beceri gelişimi için, insan beyninin çalışma sistematiğine ilişkin bilginin göz önünde bulundurulması son derece önemlidir. Kaldı ki öğretim süreçlerinin tasarlanıp, pedagojik stratejilerin belirlenmesinde farklı disiplinlerden gelen bilgi aktif biçimde kullanılmaktadır. Bu bağlamda sinirbilim çalışmalarından elde edilen bulguların, öğretim süreçlerinin tasarımında kullanılması; ders içeriklerinin oluşturulmasından, materyal tasarımına, öğrenme güçlüğü yaşayan bireylerin muhtemel sorunlarının belirlenip çözüm önerileri getirilmesine kadar, öğretimle ilgili tüm alanlara bilgi sağlayacaktır. Ayrıca öğrenme güçlüğü yaşayan özel gereksinimli çocukların, öğrenme performanslarının geliştirilmesi de sinirbilim çalışmalarından elde edilen bilgiler doğrultusunda mümkün olabilecektir. Alan yazına bakıldığında sinirbilim çalışmalarının, eğitim alanına yansımalarının giderek arttığı görülmektedir. Bu kapsamda ulusal ve uluslararası nitelikli çalışmalardan edinilen bilgilerin, eğitim alanına entegre edilmeye çalışıldığı ve var olan pedagojik kavramların yeni bilgiler doğrultusunda ele alınarak, öğretim tasarımına ilişkin yeni ilkelerin belirlendiği görülmektedir. Biyolojik, moleküler ve sistemsel düzlemde beynin çalışma dinamiklerini inceleyen sinirbilimleri ile pedagojik stratejilerin belirlenmesini amaçlayan eğitim bilimleri arasında ontolojik farklılıklar olmakla birlikte, bu iki alan arasındaki ontolojik farklılığın alanlar arası iş birliğini zorlaştıracağını düşünmek olası değildir. Zira öğrenme-öğretme süreçlerine ilişkin işlemlerin gerçekleştirildiği nöral sistemin yapısını anlamak, bu sistem üzerinde nörofizyolojik değişimler yaşanmasına neden olan öğretim süreçlerinin planlanması açısından kritik önemdedir. Bu nedenle iki farklı alanı bir araya getiren eğitimsel sinirbilim çalışmalarına ilişkin bulguların, öğrenme-öğretme süreçleriyle ilgili tüm aşamalarda dikkatle incelenmesi gerekmektedir.

Anahtar Kelimeler: Eğitim bilimleri, sinirbilimleri, eğitimsel sinirbilim.

Erciyes Üniversitesi, Eğitim Fakültesi, Kayseri/TÜRKİYE
Erciyes Journal of Education (EJE)
DOI: 10.32433/eje.990407

SCREENED BY iThenticate Professional Plagiarism Prevention

Tür: İnceleme

Makale Geçmişi
Gönderim : 02.09.2021
Kabul : 29.11.2021
Yayınlanma : 31.05.2022

Önerilen Atıf

Kaygısız, Ç. (2022). Eğitimsel sinirbilim: fırsatlar ve zorluklar. *Erciyes Journal of Education*, *6*(1), 80-98. https://doi.org/10.32433/eje.990407

1. Öğr.Gör, Rektörlük, Ortak Dersler Bölümü, cgr.kaygisiz@gmail.com, https://orcid.org/0000-0002-9650-3889

ERCIYES JOURNAL OF EDUCATION (EJE)
2022, VOL 6, NO. 1, 80-98
http://dergipark.org.tr/eje

Educational Neuroscience: Issues and Challanges*

Çağrı Kaygısız

Turkish Aeronautical Association *University*

ABSTRACT

Learning is a process that causes neurophysiological changes in the brain because of electrochemical reactions. Therefore, it is crucial to considering the knowledge of the system through which the human brain operates for effective instructional design and skill development. Moreover, people actively use knowledge from different disciplines when designing teaching processes and determining pedagogical strategies. In this context, using findings from neuroscience studies for the design of teaching processes will provide information to all fields related to teaching—from creating course content to designing materials, identifying possible problems for individuals with learning difficulties, and suggesting solutions for them. In addition, this will make it possible to improve the learning performance of children with special needs who have learning difficulties as per the information obtained from the aforementioned neuroscience studies. The literature evinces an increase in the effects of these studies on the field of education. In this context, researchers attempt to integrate the information obtained from national and international studies into the field of education and determine new principles regarding instructional designs by considering existing pedagogical concepts in line with new information. Despite ontological differences between neurosciences that examine the brain dynamics at the biological, molecular, and systemic level, as well as educational sciences that aim to establish pedagogical strategies, it is unlikely to think that the ontological differences between these two disciplines would complicate the interdisciplinary cooperation. Understanding the structure of the neural system in which the learning and teaching procedures occur is of critical importance in terms of planning the teaching processes that cause neurophysiological changes therein. Thus, the findings of educational neuroscience studies that bring together the two varying fields at all stages of learning–teaching procedures should be carefully examined.

Keywords: Education, neuroscience, educational neuroscience.

Erciyes University, Faculty of Education, Kayseri/TURKEY
Erciyes Journal of Education (EJE)
DOI: 10.32433/eje.990407

SCREENED BY iThenticate Professional Plagiarism Prevention

Type: Review

Article History
Received : 02.09.2021
Accepted : 29.11.2021
Published : 31.05.2022

Suggested Citation

Kaygısız, Ç. (2022). Educational neuroscience: issues and challanges, *Erciyes Journal of Education*, 6(1), 80-98 . https://doi.org/10.32433/eje.990407

1. Lec, Rectorate, Department of Common Courses, cgr.kaygisiz@gmail.com, https://orcid.org/0000-0002-9650-3889

Erciyes Journal of Education 2022, Vol 6, No 1, 80-98

INTRODUCTION

The primary task of the cognitive system is to provide one with the information resources needed to ensure the continuity of life. By doing so, the mind acquires new information after processing environmental stimuli, matches these stimuli with existing knowledge structures in the memory system, and stores it for use when necessary. This process, which is formed with the perception, processing, and, finally, the storage of environmental stimuli in the memory system, is defined as the learning process. In this sense, learning is a mental process that includes acquiring, storing, and recalling the information required for the continuity of life. This process is essentially an information processing procedure that occurs through the mutual interaction within particular learning environments with biological, personal, social, and environmental variables (Lovat et al. 2011).

As Kintsch (1998) stated, information processing refers to the conversion of stimuli perceived by the sense organs into abstract mental representations through cognitive processes. This transformation operation occurs as a result of neural activation in different cortical regions that specialize in analyzing the perceived stimuli. In addition, the perception process, which is the first stage of information processing, also requires the activation of different cortical areas. In this regard, environmental stimuli are primarily analyzed in terms of their distinctive features in the scanning system; formed with the occipital, temporal, and parietal lobes; and transformed into data structures through their statistical patterns. Subsequently, multi-level mental representations are created to make sense of the perceived data structures (Smith & Kosslyn, 2014).

All these processes require the active use of the memory system. The enzymatic structures of neurotransmitters and the changes that these enzymatic structures cause in cell forms are significant in forming the memory system. For example, the transfer of the processed information to the long-term memory begins with sodium ions entering into the neuron. In this manner, the captain enzyme is secreted, and the electrochemical reaction required for the transfer of information to the long-term memory begins. In addition to the captain enzyme, numerous proteins such as S-100 and vasopressin (Yaltkaya, 2000) play a role in memory formation. Moreover, many studies also show that neural activation procedures required for different cognitive processes use various neurotransmitters. In this context, for example, acetylcholine is active in learning and memory management, dopamine is involved in activities that require planning and attention, and norepinephrine neurotransmitters are employed in stimulation processes (Bruning et al. 2004).

In the interneuron space called the synapse, electrical current, which refers to the information exchange between neurons, occurs with the release of neurotransmitters that activate the next neuron. Therefore, the connection networks between nerve cells can be strengthened or weakened by changing the release of neurotransmitters used in the transfer of information between synapses. In other words, the chemical structure of neurotransmitters makes the cell membrane more permeable to certain ions, while it has the opposite effect for others (Kutas & Schmitt, 2003). Changes in signal strength, which differs depending on cell permeability,

Erciyes Journal of Education 2022, Vol 6, No 1, 80-98

determine the action potential of nerve cells (Bruning et al. 2004), and the literature states that signals with high action potential are more effective in terms of changing nerve cells (Ward, 2020). This situation, which is related to the operation dynamics of the neural system, affects learning outcomes. Namely, if the same synapses of the same neural circuit are stimulated for each instance of the same learning experience, the learning experience becomes more productive (Geake & Copper, 2003). In other words, the intensity and frequency of the electrical charge that is used in the stimulation of nerve cells have a direct effect on the automation of the desired target behavior that one aims to develop. This state of automation, however, influences the flexible and efficient use of limited cognitive resources and contributes to both forming mental patterns and determining the formed patterns for the performance of executive functions underlying goal-directed behaviors. While the concept of patterning is used to generalize the stimuli in the pattern and describe abstract reasoning (Clemenst & Sarama, 2007), it is very important to examine the patterns necessary for information processing in the planning of pedagogical processes (Bock et al. 2018).

Nerve cells are the basic units of electrochemical activity in the brain (Freberg, 2006), and learning mainly involves changes in neural connectivity networks. In this sense, teaching affects brain functions directly by changing the connection networks between nerve cells (Goswami, 2004a). Thus, one can create, strengthen, or weaken neural connections through long-term learning (OECD, 2008). This condition, which is called adaptive plasticity, is related to the human brain's ability to process environmental stimuli and undergo neurophysiological changes. Furthermore, the dimensions of the neurophysiological change that one experiences are directly proportional to the duration of education (OECD, 2008).

The ultimate goal of the learning process is to develop academic qualifications to the highest possible level because only then can an individual exhibit the necessary behaviors for the development of the targeted skill area. There are different cognitive processes when displaying the target behaviors required for each learning area. For example, the main goal of reading is to make sense of the text, which is a cognitive process that occurs between the reader, the text, and the context (Pearson, 2009). In this process, it is necessary to create mental representations of the text with procedures that match the textual information with existing knowledge structures. These cognitive processes require the activation of different cortical areas and the integrated operation of these activated areas while inhibiting neural systems that are not related to the act of reading (Friederici, 2012; Salmelin & Kujala, 2006). Therefore, the act of reading is a complex cognitive phenomenon that requires the coordinated activation and deactivation of large neuron groups. Given that human beings are not born with an innate ability to read, it is essential to ascertain the cortical areas with which the cognitive actions that are required for reading are associated. This is also true for skill development in the different domains of learning.

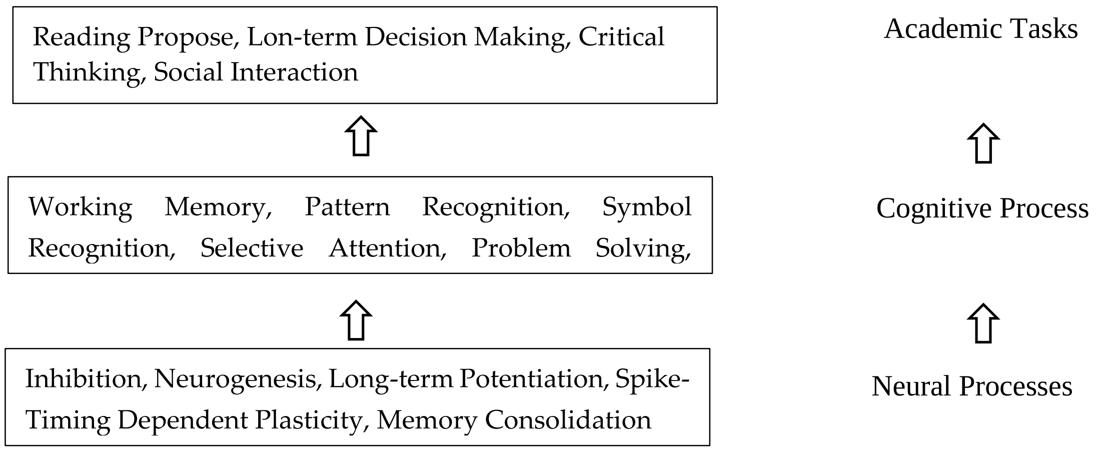

Figure 1. *Forming Academic Tasks (Colvin, 2016: 2)*

In summary, learning is a process that causes neurophysiological changes, which result from electrochemical reactions. For effective instructional design and skill development, considering the knowledge of the system through which the human brain operates is thus crucial. Moreover, people actively utilize knowledge from different disciplines while designing teaching processes and determining pedagogical strategies. In this context, using findings related to neuroscience studies in the design of teaching procedures will provide information on all fields that relate to teaching, from creating course content to designing materials, identifying possible problems for individuals with learning difficulties, and, accordingly, suggesting solutions. Furthermore, knowledge regarding the "operating system" of the brain is currently at a level that enables interdisciplinary cooperation on how learning occurs (Meltzoff et al. 2009). From this perspective, the present study aims to theoretically discuss why the findings obtained from studies in the field of neuroscience should be transferred to teaching environments and what should be considered in the information transfer process.

Educational Neuroscience

Following developments in brain imaging technologies, neuroscience studies determining the reactions in the cortical regions that are activated during cognitive processes gained momentum, and the subsequent findings brought new perspectives to existing research fields because these results affected several different disciplines. One discipline that such studies affect is education. Given this context, this study aimed to investigate the effects of the operating principles of the brain on learning–teaching procedures and aimed to increase the efficiency of the materials and activities used in teaching processes and the quality of teaching services based on the findings.

The field of educational neuroscience aims to transfer the findings obtained from neuroscience studies to teaching environments. Educational neuroscience aims to test the theoretical conclusions of cognitive psychology, to explain the biological basis of these conclusions (Ansari et al. 2011), and to examine the effects of the teaching–learning process on the neurophysiological structure and vice versa. In this sense, information about cell signaling and the functioning of synaptic mechanisms is crucial for understanding learning and teaching procedures (Goswami, 2004a). In light of this, both educators and neuroscientists prioritize how to optimize the learning–teaching procedures according to the findings based on methods, techniques, and materials that are employed so that maximum benefit is attained. Thus, existing learning theories are reshaped based on the data obtained (Ansari et al. 2011). In addition, explaining the atypical learning performances of children with special needs who have learning difficulties is also a subject of investigation for researchers in this field (Ferrari, 2013). In this context of learning–teaching procedures, Goswami (2008) briefly listed the areas in which researchers in the field of educational neuroscience seek answers:

i. the neural structure for learning,

ii. the interconnections between neural structures,

iii. the time course of neural activation, and

iv. neural correlations versus causation.

According to the literature, the effects of neuroscience studies on the field of education are increasing. Researchers aim to integrate the information obtained from the national and international studies that are carried out, particularly the Brain and Learning Project (OECD, 2017) initiated by the OECD, into the field of education. In addition, new principles are developed for instructional designs as researchers evaluate existing pedagogical concepts in light of the new information. Goswami (2008: 387–394) expressed these teaching principles as follows.

i. Learning is incremental and experience based.

ii. Learning is multi-sensory.

iii. The brain mechanism of learning extracts structure from input.

iv. Learning is social.

v. Learning shows lifelong plasticity and compensation.

vi. Cortical learning can be modulated by phylogenetically older systems.

As stated earlier, educational neuroscience is an interdisciplinary field that explores the biological basis of the theoretical assumptions of cognitive psychology. In this context, neuroscience focuses on biological, cognitive, and behavioral dimensions. The biological dimension includes the electrochemical reactions and neurophysiological changes that occur during neural activation in cortical regions. The cognitive dimension includes cognitive psychology with the mental models that it establishes in relation to how the human mind systematically operates during the processes involved in the perception, separation, and storage of stimuli. Finally, the behavioral dimension includes education and focuses on the development, testing, and transfer of educational practices in classroom environments to bring about the desired behavioral changes. Therefore, educational neuroscience provides explanations for learning–teaching procedures by integrating the knowledge derived from these three aspects. In this respect, information transfer between the education sciences and neuroscience takes place on three different levels, these being the biological, cognitive, and behavioral dimensions (Anderson & Reid, 2009).

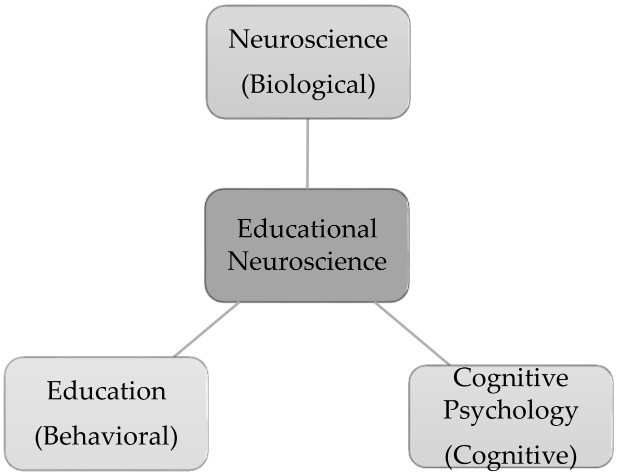

Figure 2. *The Components of Educational Neuroscience*

The essential point of the integration of findings from neuroscience into the education sciences is cognitive psychology. Cognitive theories enable the integration of biological, cognitive, and behavioral data, namely, the matching of neural activation with cognitive functions (Anderson & Reid, 2009; Willingham & Lloyd, 2007). In other words, cognitive theories that model and simulate perception and information processing procedures allow for the conclusions of neuroscience to be carried beyond the biological dimension. In this respect, cognitive psychology is the basis of the knowledge transfer between neuroscience and the education sciences (Bruer, 2008; Ansari & Coch, 2006).

The Implementation Areas of Educational Neuroscience

Educational neuroscience is a strategic discipline open for improvement that would contribute to teaching processes. Therefore, as noted in the OECD (2002) report, a common glossary and methodology should be developed to ensure the conceptual integration between two ontologically different disciplines, neurosciences that examine the brain dynamics at the biological, molecular, and systemic level, and educational sciences that aim to establish pedagogical strategies.

Transferring the findings related to neuroscience studies to the education sciences forms the basis for creating educational policies and designing new methods, techniques, and forms of teaching. In this regard, there is a widespread expectation that such findings will illuminate the neurophysiological changes that occur during the learning process and the implicit aspects that cannot be observed at the behavioral level, such as cortical activation and cell communication, but impact the teaching process. Therefore, researchers state that educational neuroscience can redefine the roles of teachers, parents, and students and even help ensure that the purpose and value of schools is understood (Busso & Pollack, 2015).

Neuroscience studies provide evidence-based information for educational policies and practices (Ansari et al. 2012; Campell, 2011; Howard-Jones, 2011;). In this regard, it is possible to design training programs that consider the similarities and differences in how the brains of individuals with different proficiencies and learning success operate, particularly for the same skill area,

Erciyes Journal of Education 2022, Vol 6, No 1, 80-98

because curricula constitute a significant component of the teaching process as they contribute to the formation of neural networks (Watagodakumbura, 2017), which make up the permanent knowledge networks of individuals. Neuroscience studies also contribute to the development of curricula for individuals with special educational needs. In this sense, research indicates that by determining the effects of curricula on brain functions, scholars can contribute to the development of curricula as well as of special education methods and techniques for individuals who need special education (Goswami, 2004a). Understanding the operating principles of the neural mechanism, which affects learning–teaching procedures, can also contribute positively to the development of teaching strategies.

The methodological tools of neuroscience are capable of measuring the reactions that occur during cognitive performance. For example, while reading, the reader performs cognitive actions at different levels to understand a text and create a mental model of the text. To this end, the mind directs eye movements during the reading process, and differences occur in the reaction times of the eye movements depending on the difficulty level of the cognitive action. These eye movements, known as oculomotor movements, are data sources for words, sentences, and integrated discourse levels during the review of written language (Radach at al. 2007; Radach & Kennedy, 2004). In this manner, neuroscience provides datasets to help test and understand cognitive models that explain meaning-making procedures (de Smedt et al. 2011) and contributes to understanding the operation dynamics of the mind during cognitive tasks.

Moreover, the research states that neuroscience studies contribute positively to the education sciences with respect to the development of instructional technologies, and the most appropriate field for interdisciplinary cooperation between neuroscience and education is the development of educational technologies (Royal Society, 2011).

All environmental stimuli that are perceived and processed in the sensory system cause electrochemical activities and neurophysiological changes in the brain. Therefore, the design of teaching environments is a factor that affects learning experiences and outcomes. Thus, people should design teaching environments by considering the operating principles of the brain to thereby achieve optimal benefit (Vaninsky, 2017).

Neuroscience studies also contribute to the education field by providing information to determine the connection networks between different cortical areas that are activated during information processing. Identifying cortical connectivity networks is notable because these networks provide knowledge regarding the determination of neural pathways activated in various cognitive processes (Goswami, 2008). This information facilitates the design of activities and practices that activate the cortical regions in which cognitive processes that are related to the targeted skills are developed. In addition, identifying and mapping cortical activation enables the modeling of artificial neural networks (Negnevitsky, 2005), which are delivery models based on the human brain. Furthermore, identifying artificial nerve cells and networks that are similar to biological nerve cells enables the performance of various operations such as pattern recognition, association, classification, data compression, nonlinear signal processing, system modeling optimization, time series analysis, and nonlinear control (Kumova-Metin & Kışla, 2020). In this respect, studies on the determination of cortical areas also contribute to artificial intelligence and machine learning.

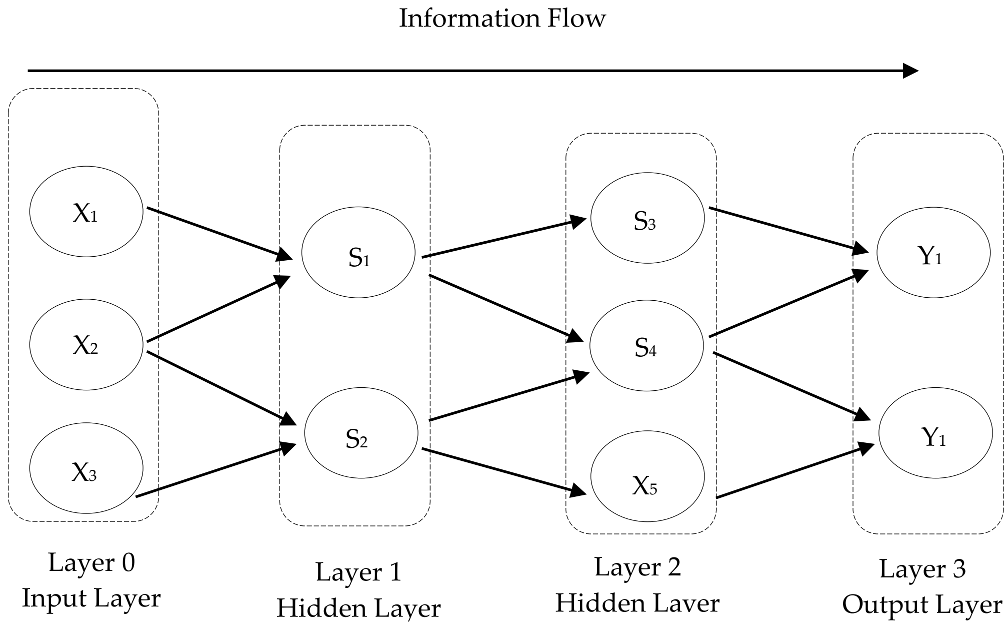

Figure 3. *The Feedforward Neural Network Model (Kumova-Metin &Kışla, 2020: 137)*

Teachers have to be able to understand the nature of educational processes and apply educational neuroscience data to teaching environments (Schrag, 2013) because they are the most significant factor in transferring data related to neuroscience studies to learning environments. Thus, it is essential to develop teachers' awareness of the educational neuroscience approach. In this context, teacher training programs should increase their neuroscience awareness, and teachers should receive training that establishes a connection between neuroscience and education, both before and during their professional lives. In short, teachers should become "neuroscience literate" (Ansari at al. 2011). However, because educational neuroscience contains information obtained from numerous fields, such as cognitive psychology, biology, chemistry, neuroscience, sociology, and anthropology, it is essential to increase awareness about the results of behavioral research as well as awareness about the functioning of the brain in teacher training processes.

The Challenge of Integration

Being an interdisciplinary concept, educational neuroscience, which is related to several different disciplines, such as sociology, anthropology, and biology, is based on two main disciplines: neuroscience and educational science. Therefore, the conceptual position of educational neuroscience depends on the relationship between the two fields and the integration of knowledge between them. However, while neuroscience is considered a descriptive natural science that aims to explore neural structures and functions, educational science is regarded as a normative artificial science that aims to realize designs for teaching processes such as pedagogical strategies and teaching materials (Perkins, 2009; Willingham, 2009). Therefore, owing to the ontological difference between neuroscience and the education sciences, the two disciplines differ in terms of their purpose and research questions, and it becomes difficult to integrate knowledge from these two varying fields. Consequently, the literature indicates that educational neuroscience studies alone cannot produce knowledge that will change teaching practices (Hille, 2011; Howard-Jones at al. 2008).

Erciyes Journal of Education 2022, Vol 6, No 1, 80-98

Moreover, another difficulty that occurs while transferring neuroscience studies to educational practices and teaching environments is the low awareness of teachers about neuroscience and educational neuroscience studies. Hence, the research suggests that the dialogue between teachers and educational neuroscience researchers should be improved so that the design of teaching processes can reflect the findings of such studies and their results (Busso & Pollack, 2015).

The overemphasis on the findings of neuroscience studies is another factor that makes it challenging to establish cooperation between neuroscience and the education sciences. Learning is a concept that includes cultural and behavioral aspects as well as biological ones. Therefore, there is no doubt that findings of neuroscience studies that do not have behavioral implications will be insufficient for explaining the learning process, and it is crucial that the validity of such studies is tested behaviorally (de Smend et al. 2011).

Apart from the reviewed factors, neuromyths are the most damaging factor to the strategic cooperation between neuroscience and the education sciences. The concept of neuromyths, which was first introduced in a report by the OECD (2002), refers to complex phenomena that are related to the "operating system" of the brain (Alfernik & Farmer-Dougan, 2010; Fischer et al. 2010), and the formation, acceptance, and validity of such myths are aspects that are the subjects of research in themselves (Geake, 2008).

The combination of teachers' desire to understand the biological factors underlying learning–teaching procedures with their lack of basic knowledge on the subject can lead to misinterpretations of the results of neuroscience studies (Howard-Jones, 2009), and neuromyths emerge as a result. Thus, neuromyths can arise because of teachers' neuroscience illiteracy and failure to address complex scientific findings critically (Geake, 2008). However, for a healthy exchange of information between neuroscience and education, it is necessary to identify and define these myths. In this context, the neuromyths in question are as follows (OECD, 2002).

i. There is no time to lose because everything important about the brain is decided by the age of three.

ii. There are critical periods in which certain matters must be taught and learned.

iii. However, I read somewhere that we only use 10% of our brain in any case.

iv. I am a left-brain person; she is a right-brain person.

v. Let us face it: men and boys simply have different brains from women and girls.

vi. A young child's brain can only manage to learn one language at a time.

vii. Improve your memory.

viii. Learn while you sleep.

The neuromyths in the OECD report (2002) are based on the findings of neuroscience studies. One of these findings is laterality. Lateralization is a concept used to ascertain the hemisphere of the brain in which given neural processes occur. In relation to learning, laterality refers to the learning situation in different hemispheres that specialize in performing varying skills. However, neuroscience studies do not support the assumption that learning occurs separately in different hemispheres. On the contrary, specialized cortical regions work in an integrated manner to perform different tasks during the learning process. In other words, cognitive tasks require both hemispheres to work in coordination. Thus, for example, while cortical areas such as the orbitofrontal cortex process cognitive information during the learning process, these areas work in coordination with phylogenetically older cortical areas such as the amygdala region wherein sensory processing occurs (Goswami, 2008). Hence, the learning experience necessitates the integrated operation of neuron groups in different cortical areas. Although the source of the concept of laterality is based on studies with split-brain patients, as Hall (2005: 3) stated, it is an overgeneralization to assume that such a situation exists for learning processes. Moreover, the OECD report (2002) drew attention to this situation and stated that, with a few exceptions, the brain hemispheres rarely work in isolation.

In addition, neuromyths are also based on the concept of the critical period hypothesis. The critical period hypothesis, as is known, assumes that an individual must receive the environmental stimuli required for the development of neuron groups at certain time intervals; otherwise, the development of the neuron groups necessary for learning will not be possible. However, the research indicates that no cognitive capacity loss occurs at an early age and that learning will occur even after a period of environmental deprivation (Goswami, 2004b: 11). Similarly, although the report by the OECD (2002) underlined that early education becomes considerably important later on, it also stated that this does not mean that a large part of a person’s education should be concentrated on the childhood years. In contrast to the critical period hypothesis, neuroscience studies emphasize the concept of lifelong learning and highlight that the longer the teaching process is, the more effective it will be (OECD, 2008). Therefore, educational neuroscience studies provide teaching opportunities, particularly for the elderly population.

Third, in addition to laterality and the critical period hypothesis, Purdy (2008) suggested that neuromyths are based on synaptogenesis. Although synaptogenesis refers to the situation of building new synaptic connections between neural cells, the assumption that an enriched classroom environment is necessary for the establishment of neural intercellular connections is not valid. This neuromyth has lost its validity based on neuroscience studies (Purdy, 2008).

DISCUSSION & CONCLUSION

Learning is a complex procedure that begins with the processing of perceived environmental stimuli and electrochemical reactions that occur in this process, which cause neurophysiological changes. Therefore, the success of the teaching process, which aims to develop academic qualifications in different learning areas to the highest level, depends on understanding the operational dynamics of the neural system in which learning-related processes take place and on integrating and using the information obtained in teaching environments. Thus, interdisciplinary collaboration between neuroscience and the education sciences, which investigate these dynamics of the neural system, is of critical importance. Moreover, the existing knowledge on the functioning of the neural system is at a level that enables cooperation between the two different fields. This idea sets the groundwork for the emergence of a new field of study of educational

Erciyes Journal of Education 2022, Vol 6, No 1, 80-98

neuroscience by integrating the findings obtained from neuroscience studies into the field of education.

Educational neuroscience is an interdisciplinary field that examines the biological basis of abstract cognitive processes in learning–teaching procedures and the neurophysiological changes that cause electrochemical reactions, which occur during cognitive processes, at the intersection of neuroscience and the education sciences. In this regard, the main priority of researchers in the educational neuroscience field—whether these scholars are neuroscientists or educational scientists—is how to optimize the knowledge of the operational dynamics of the neural system to provide maximum benefit and use in learning–teaching procedures. Accordingly, teaching environments and existing methods, techniques, and forms of teaching are reshaped based on the findings that are obtained, and new principles are determined to explain the structure of learning–teaching procedures.

Identification of neural regions associated with cognitive processes allows for distinctions between learning and skill areas that are closely related but the differences of which cannot be demonstrated behaviorally. Third language acquisition and multilingualism have long come under the umbrella term of second language acquisition; neuroscience studies have contributed greatly in considering third language acquisition as an independent field. Compared to monolingual and bilingual individuals, studies have demonstrated differentiations in the activated cortical and subcortical regions of multilingual individuals, as well as changes in gray and white matter densities. However, one of the most studied aspects of multilingualism is how the neurological system enables the phenomenon of multilingualism and whether the same neural systems are used for all acquired languages. In this context, the findings of neuroscience studies have not only created a distinction between bilingualism and multilingualism, which are closely related to each other, but also contributed to the determination of didactic plans and methods and techniques for teaching processes related to both cases.

The methodological tools of neuroscience studies can provide data on differences in neural activation levels during learning tasks of individuals who have succeeded or failed in education fields related to mathematics, physics, or language. Thus, neuroscience studies contribute to the development of teaching programs, methods, and techniques that help improve the performance of low-achieving individuals by addressing the differences in the regions of neural activation in individuals with different levels of success in these fields of education.

Identifying the neural regions activated during different cognitive tasks also makes it possible to test cognitive models. For example, all cognitive theories on reading skills indicate that there are two cognitive processes, with different difficulty levels, performed, including *text base* and *situation model.* The existence of these cognitive processes, identification of the neural regions where they are carried out, and linguistic tools using which this information is coded and monitored have been revealed thanks to the findings of neuroscience studies. These findings have been decisive in the planning of didactic processes related to reading performance.

The materials used throughout the teaching process play an important role in the development of academic skills in different fields. Therefore, the course materials used in teaching processes should be prepared with consideration for a number of design features for optimal benefit. Studies in the field of neuroscience have shown that two neural network structures that involve different neural regions are used to access the semantic content of written materials: the grapho-phonological and lexical-semantic networks. This proves the importance of neuroscience studies because they provide information both on the structure of the optic neural system, which forms the visual system, and on the processes of making sense of the information obtained from this system. In this context, the findings of neuroscience studies on the design and development of teaching materials will contribute to the process of creation of teaching materials. This applies for the designing of materials that appeal to the sense of hearing, as well.

Because automatic performance involves fewer processing steps compared to algorithmic performance, it helps perform cognitive operations swiftly and easily and enables more efficient use of limited cognitive resources. Furthermore, flexible and selective distribution of mental resources is important in *service of goal-directed behaviors.* For this reason, one of the principles of material designing is to design materials in a way that allows flexible and selective distribution/use of cognitive resources because of the limitations in conscious attention mechanisms. In addition to the visual and auditory properties of the materials used in teaching processes, neuroscience studies also provide information related to the content design of these materials, such as optical focus, spatial perception, and size. This information contributes to the design of teaching materials in a way that *minimizes the intrinsic cognitive load* arising from the design features, reducing the cognitive processing load that occurs on working memory and, thus, ensuring flexible and selective distribution of attention resources.

In addition, determining the causes of atypical learning performances by individuals with learning difficulties and increasing the learning performance of these individuals is another relevant issue that researchers in this field emphasize. In this context, the learning performance of individuals with learning difficulties is examined by using computational imaging methods such as PET (positron emission tomography) scans and fMRI (functional magnetic resonance imaging), educational curricula are developed to ensure the academic development of such individuals, and the effectiveness of the developed curricula is also tested and verified.

Educational neuroscience relates to sociology, anthropology, biology, chemistry, etc., owing to its interdisciplinary nature. However, educational neuroscience primarily interacts with the fields of the education sciences and neuroscience; therefore, the conceptual position of educational neuroscience depends on the information flow and integration between these two fields. However, as noted earlier, there are ontological differences between the descriptive discipline of neuroscience and the normative education sciences, each of which has its own pedagogical purpose. These differences result in numerous points of separation with respect to factors such as the objectives, research questions, and methodology of the two fields. Nevertheless, according to the literature, the separation caused by the ontological differences does not prevent the integration of knowledge between the two fields; rather, it provides new opportunities. Given such a context, despite the differences in theory, method, etc., Table 1 presents the contribution of neuroscience studies to learning–teaching procedures.

Table 1. *Neuroscience: Concern and opportunity (Varma et al. 2008: 141)*

Aspect	Concern	Opportunity
Scientific		
1. Methods	Neuroscience methods do not provide access to important educational considerations such as context.	Innovative designs can allow neuroscience to study the effects of variables of interest to education, such as context.
2. Data	Localizing different aspects of cognition to different brain networks does not inform educational practice.	Neuroscience data suggest different analyses of cognition and may therefore imply new kinds of instructional theories.
3. Theories	Reductionism is inappropriate.	Reductionism is appropriate if it is not eliminative.
4. Philosophy	Education and neuroscience are incommensurable.	Neuroscience may help to resolve som of the incommensurables within education.
Pragmatic		
5. Costs	Neuroscience methods are too expensive to apply to education research questions.	Educationally relevant neuroscience might attract additional research funding to education.
6. Timing	We do not currently know enough about the brain for neuroscience to inform education.	There are already sings of success.
7. Control	If education cedes control to neuroscience, it will never regain its independence.	Ask not what neuroscience can do for education, but what education can do for neuroscience.
8. Payoff	Too often in the past, neuroscience findings have turned into neuromyths.	People like to think in terms of brains, and responsible reporting of cumulative results can help them.

It is unlikely that the ontological differences between the education sciences and neuroscience will hamper cooperation between the two different fields. Moreover, understanding the structure of the neural system in which the processes related to learning–teaching procedures occur is crucial in terms of planning teaching processes that cause neurophysiological changes in this system. Therefore, researchers should carefully examine the findings of educational neuroscience studies that bring together the two different fields at all stages related to learning–teaching procedures.

As with all interdisciplinary disciplines, despite the existing differences, educational neuroscience studies should consider identifying and eliminating the factors that make interdisciplinary cooperation difficult. Thus, it is necessary to carefully determine how to integrate the findings of neuroscience studies, which will positively affect the impact of all educational practices, into learning–teaching procedures with a focus on attaining the maximum benefit possible. The main task of researchers should be to develop teachers' knowledge and awareness of the operational dynamics of the neural system, which is the learning organ, beginning with education faculties. The next step is to ensure that teachers become neuroscience literate. In line with these goals, the knowledge and awareness of prospective teachers about the structure of the brain as a learning organ should be increased by providing lessons on the brain anatomy and the working systematic of the brain, the neural regions that enable learning, and the cognitive processes performed in these regions starting from the first years of teacher education. In addition to such general working principles, it would also be beneficial to raise awareness about neural regions that are activated and deactivated during cognitive processing in the teaching areas of these teachers. As explained previously, neuroscience studies have developed enough to allow cooperation between education and neuroscience. For example, electrophysiological studies have contributed significantly to understanding the neurological basis of *number sense*. Studies in this field have revealed that numerical processing is predominantly performed in the posterior superior parietal region. The frequency, duration, etc. of stimuli that activate the neural regions associated with information learning tasks related to the cortical regions where cognitive processes are performed are extremely important in terms of optimization as per parameters.

Moreover, another crucial factor that hinders cooperation between neuroscience and the education sciences is using findings from neuroscience studies while ignoring information about behavioral, environmental, and cultural characteristics that the education sciences are related to and that have as much effect as the neural system on learning–teaching procedures. Emphasizing only neuroscience studies without integrating knowledge from other fields to which the education sciences are related hinders the appropriate applications of critical information that is obtained from neuroscience studies that explain the biological aspect of the learning–teaching procedure. Therefore, while designing learning–teaching procedures, one should account for the fact that learning has cultural and behavioral aspects as well as biological aspects.

Neuromyths constitute the greatest obstacle to the positive contribution of neuroscience studies to learning–teaching procedures. Neuromyths are based on the results of neuroscience studies, such as those related to the concepts of lateralization, the critical period hypothesis, and synaptogenesis, and emerged with the teachers' lack of knowledge about the biological processes underlying learning–teaching procedures; these myths have become a research topic in their own right. Consequently, it will prove extremely valuable to identify and eliminate both neuromyths and the false assumptions and overgeneralizations that cause them to emerge.

Educational neuroscience, which emerged from the interaction between neurosciences and educational sciences, is an interdisciplinary field that aims to explain the functioning of neuroscience studies on the learning processes of the brain and use the obtained findings in the optimization of teaching processes; it provides value-added information to the field of education. Therefore, the cooperation between neurosciences—the study of the working systems of the brain, our learning organ—and educational scientists, whose mission is to train the brain, will help achieve the skill levels aimed through education. It is of utmost importance to increase the areas of interaction between researchers in these fields and promote cooperation and exchange of information between these fields.

Conflict of Interest Statement: The author has not declared any conflict of interest.

Ethics Committee Report: Ethics committee report was not needed for this study.

REFERENCES

Anderson, M., and Reid, C. (2009). Don't Forget About Levels of Explanation. *Cotex, 45*(4), 560-561. doi:10.1016/j.cortex.2008.06.005

Allison, M. B., Kelly, B. C., McKnight, P. E., Patterson, A. B., Shriver, A. M., Learf, B. M., . . . Pasnak, R. (2018). Patterning, Reading, and Executive Functions. *Frontier in Psychology*, 1-10. doi:10.3389/fpsyg.2018.01802

Alfernik, L. A., and Farmer-Dougan, V. (2010). Brain- (not) Based Education: Dangers of Misunderstanding and Misapplication of Neuroscience Research. *Exceptionality, 18*(1), 42-52. doi:10.1080/09362830903462573

Ansari, D., and Coch, D. (2006). Bridges Over Troubled Waters: Education and Cognitive Neuroscience. *Trends in Cognitive Science, 10*(4), 146-151. doi:10.1016/j.tics.2006.02.007

Ansari, D., Coch, D., and de Smedt, B. (2011). Connecting Education and Cognitive Neuroscience: Where Will the Journel Take US? *Educational Philosophy and Theory, 43*(1), 37-42. doi:10.1111/j.1469-5812.2010.00705.x

Ansari, D., de Smedt, B., and Grabner, R. (2012). Neuroeducational a Critical Overview of an Emerging Field. *Neuroethics, 5*, 105-117. doi:10.1007/s12152-011-9119-3

Bruer, J. T. (2008). Building Bridges in Neuroeducation. In. K. W. A. M. Battro, & P. L. Lebna (Eds.), *The Educated Brain: Essays in Neuroeducation* (pp. 43-58). Cambridge: Cambridge Universirty Press.

Bruning, R. H., Schraw, G. J., Norby, M. M., and Ronning, R. R. (2004). *Cognitive Psychology and Instruction* (4th ed.). Pearson: Upper Saddle River: Nj.

Busso, D. S., and Pollack, C. (2015). No Brain Left Behind: Consequences of Neuroscience Discourse for Education. *Learning, Media and Technology, 40*(2), 168-186.

Campell, S. R. (2011). Educational Neuroscience: Mativations, Methodology, and Implications. *Educational Philosophy and Theory, 43*(1), 7-16. doi:10.1111/j.1469-5812.2010.00701.x

Colvin, R. (2016). Optimising, Generating and Integrating Education Practice Using Neuroscience. *Science of Learning, 1*(16012), 1-4.

Clements, D. H., and Sarama, J. (2007). Early Childhood Mathematics Learning. F. K. Lester içinde, *Second Handbook on Mathematics Teaching and Learning* (s. 461-555). Charlotle: NG: Information Age Publishing.

de Smedt, B., Ansari, D., Grabner, R. H., Hannula-Sormunen, M., Schneider, M., and Verschaffel, L. (2011). Cognitive Neuroscience Meets Mathematics Education: It Takes Two to Tango. *Educational Research Review, 6*, 232-237. doi:10.1016/j.edurev.2011.10.002

Ferrari, M. (2011). What Can Neuroscience Bring to Education? *Educational Philosophy and Theory, 43*(1), 31-36. doi:10.1111/j.1469-5812.2010.00704.x

Fischer, K. W., Goswami, U., and Geake, J. (2010). The Future of Educational Neuroscience. *Mind, Brain, and Education, 4*(2), 68-80. doi:10.1111/mbe.2010.4.issue-2

Freberg, L. A. (2006). *Discovering Biological Psychollogy.* Boston: MA: Houghton Mifflin Company.

Friederici, A. D., and Gierhan, S. (2013). The Language Network. *Current Opinion in Neurobiology, 23*(2), 250-254. doi:10.1016/j.conb.2012.10.002. Epub 2012 Nov 9. PMID: 23146876.

Geake, J. (2008). Neuromythologies in Education. *Educational Research, 50*(2), 123-133. doi:10.1080/00131880802082518

Geake, J., and Cooper, P. (2003). Cognitive Neuroscience: Implications for Education? *Westminster Studies in Education, 26*(1), 7-20. doi:10.1080/0140672032000070710

Goswami, U. (2004a). Neuroscience, Education and Special Education. *British Journal of Special Education, 34*(4), 175-183.

Goswami, U. (2004b). Neuroscience and Education. *British Journal of Educational Psychology, 74*, 1-14. doi:10.1348/000709904322848798

Goswami, U. C. (2008). Principles of Learning, Implications for Teaching: A Cognitive Neuroscience Perpective. *Journal of Philosophy of Education, 42*(3-4), 381-399. doi:10.1111/j.1467-9752.2008.00639.x

Hall, J. (2005). *Neuroscience and Education: A Review of the Contribution of Brain Science to Teaching and Learning.* Glasgow: Scottish Council for Research in Education.

Hille, K. (2011). Bringing Reseach Into Educational Practice: Lessons Learned. *Mind, Brain, and Education, 5*(2), 63-70. doi:10.1111/j.1751-228X.2011.01111.x

Howard-Jones, P. (2009). Specticism is Not Enough. *Cortex, 45*(4), 550-551. doi:10.1016/j.cortex.2008.06.002

Howard-Jones, P. A. (2011). A Multiperspective Approach to Neuroeducational Reseach. *Educational Philosophy and Theory, 43*(1), 24-30. doi:10.1111/j.1469-5812.2010.00703.x

Howard-Jones, P. A., Winfield, M., and Grimmins, G. (2008). Co-Constructing an Understanding of Creativity in Drama Education that Draws on Neuropsychological Concepts. *Educational Reseach, 50*(2), 187-201. doi:10.1080/00131880802082674

Kintsch, W. (1998). *Comprehension A Paradigm for Cognition.* Cambridge: Cambridge University Press.

Kumova-Metin, S., and Kışla, T. (2020). Yapay Sinir Ağları. In. G. Tolga, Y. Halil, & Y. Soner (Eds.), *Eğitsel Veri Madenciliği ve Öğrenme Analitikleri* (pp. 127-146). Ankara: Anı Yayıncılık.

Kutas, M., and Schmitt, B. M. (2003). Language in Microvolt. In. M. T. Banich, & M. Mack (Eds.), *Mind, Brain, and Language Multidisciplinary Perpectives* (pp. 171-210). Mahwah: NJ - London: Lawrence Erlbaum Associates Publisher.

Lovat, T., Dally, K., Clement, N., and Toomey, R. (2011). *Values Pedagogy and Student Achievement: Contemporary Reseach Evidence.* Dordrecht - Heidelberg - London - New York: Springer. doi:10.1007/978-94-007-1563-9

Meltzof, A. N., Kuhl, P., Movellan, J., and Sejnowski, T. J. (2009). Foundaditons for a New Science of Learning. *Science, 235*(5938), 284-288. doi:10.1126/science.1175626

Negnevitsky, M. (2002). *Artifical Intelligence: A Guide to Intelligent System* (1st. ed.). Addison Wesley Press.

OECD. (2002). *Understanding the Brain: Towards a New Learning Science.* Paris.

OECD. (2008). *Understanding the Brain: the Birth of a Learning Science New Insights on Learning Through Cognitve and Brain Science.* Centere for Educational Research and Innovation.

OECD. (2017). *Center for Educational Research and Innovation (CERI).* https://www.oecd.org/education/ceri/.

Pearson, P. D. (2009). The Roots of Reading Comprehension Instruction. In. S. E. Israel, & G. G. Dufy (Eds.), *Handbook of Research on Reading Comprehension* (pp. 3-33). New York - London: Routledge.

Perkins, D. (2009). On Grandmother Neurons and Grandfather Clocks. *Mind, Brain, and education, 3*(3), 170-175. doi:10.1111/j.1751-228X.2009.01067.x

Purdy, N. (2008). Neuroscience and Education: How Best to Filter Out the Neurononsense From Our Classrooms? *Irish Educational Studies, 27*(3), 197-208. doi:10.1080/033233101802242120

Radach, R., and Kennedy, A. (2004). Theoretical Perspective on Eye Movements in Reading: Past Controversies, Current Issues, and an Agenda for the Future. *European Journal of Cognitive Psychology, 16*(1/2), 3-26. doi:10.1080/09541440340000295

Radach, R., Reilly, R., and Inhoff, A. (2007). Models of Aculomotor Control in Reading: Toward A Theoretical Foundation of Current Debates. In. R. P. Gompel, H. M. Fischer, W. S. Murray, & R. L. Hill (Eds.), *Eye Movements: A Window on Mind and Brain* (pp. 237-269). Amsterdam: Elsevier.

Royal Society. (2011). *Brain Waves 2: Neuroscience Implication for Education and Lifelong Learning.* London : Royal Society.

Salmelin, R., and Kujala, J. (2006). Neural Representation of Language: Activation Versus Longrange Connectivity. *Trends in Cognitive Sciences, 10*(1), 519-525. doi:10.1016/j.tics.2006.09.007

Schrag, F. (2013). Can This Marriage be Saved? The Future of 'Neuro-Education'. *Journal of Philosophy of Education, 47*(1), 20-30. doi:10.1111/1467-9752.12015

Smith, E., and Kosslyn, E. (2014). *Cognitive Psychology Mind and Brain.* Essex: Pearson.

Vaninsky, A. (2017). Educational Neuroscience, Educational Psychology, and Classroom Pedagogy as a System. *American Journal of Educational Research, 5*(4), 384-391. doi:10.12691/education-5-4-6

Varma, S., McCandliss, B., and Schwartz, D. (2008). Scientific and Pragmatic Challenges for Bridging Education and Neurocsience. *Educational Researcher, 37*(3), 140-152. doi:10.3102/0013189X08317687

Ward, J. (2020). *The Student's Guide to Cognitive Neuroscience* (4 b.). London - New York: Routledge.

Watagodakumbura, C. (2017). Principles of Curriculum Desing and Construction Based on the Concepts of Educational Neuroscience. *Journal of Education and Learning, 6*(3), 54-69. doi:10.5539/jel.v6n3p54

Willingham, D. T. (2009). Three Problems in the Marriage of Neuroscience and Education. *Cortex, 45*(4), 544-454. doi:10.1016/j.cortex.2008.05.009

Willingham, D. T., and Lloyd, J. W. (2007). How Educational Theories Can Use Neuroscientific Data. *Mind, Brain, and Education, 1*(3), 140-149. doi:10.1111/j.1751-228X.2007.00014.x

Yaltkaya, K. (2000). Bellek Bozuklukları. *Bilim ve Teknik*, 42-44.