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From Cognitive to Educational Neuroscience

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Abstract

In recent years, several theoretical discussions as to the relationship between neuroscience and education have been held. Researchers have started to have cooperation over neuroscience and the interdisciplinary researches in which education is included. It was found that there were interactions between cognitive neuroscience and educational researches. It is thought that when the research results regarding the ones carried out on an educational dimension along with neuroscience and the application of their findings into classroom environments are included, then these research results will be given more importance. It is also considered that interdisciplinary researches such as cognitive and educational neuroscience will contribute to the understanding of how one can learn better.

Keywords: cognitive, education, cognitive neuroscience, educational neuroscience

1. Introduction

Neuroscience, consisting of the combination of two words, "Nerve" and "Science", is a discipline involving neurology, psychology and biology (Goswami, 2004). The emergence of neuroscience, a partially new discipline, dates back to 1960s (Wade, 2004). Neuroscience, in general, studies the structure and functioning of the nervous system (Beatty, 1995). For this reason, neuroscience, in a general sense, can be defined as the study of anatomy and physiology of the nervous system (Alonso, 2006). According to Thompson (1986), on the other hand, neuroscience is what neuroscientists perform. A more comprehensive definition over the concept, however, has been done by the Society of Neuroscience, which was founded in 1970 after the occurrence of the concept. The Society of Neuroscience defines neuroscience as studying the nervous system in the way that it will include the brain, the spinal cord and the sensory nerve cells all around the body (Domitrovich & Merlino, 2009).

Although the emergence of neuroscience is not that old, it is seen that interdisciplinary studies in various fields have been conducted, which are now becoming more and more popularized (Alexander, O'Boyle, & Benbow, 1996; McClelland & AL Ralph, 2015). When these studies are reviewed, neuroscience is seen to have found its place among interdisciplinary studies in various fields (Kaufmann & Vogel, 2009). One of the fields in which neuroscience is included as the field of study, such as social and emotional fields, is the cognitive science. Hence, "cognitive neuroscience" appears as an interdisciplinary field.

2. Cognitive Neuroscience

Understanding the neurological bases of cognition is quite important for cognitive neuroscience appearing as an interdisciplinary field (Varma et al., 2008). Therefore, it is understood that cognitive neuroscience studies about cognition in general. At this point, studying "cognition" because of the fact that it forms the origin of cognitive science is thought to contribute to understanding what cognitive neuroscience is and what it examines as the field of study.

Cognition, in the dictionary of Turkish Language Society (TLS), is defined, in its lexical meaning, as "the knowledgeableness and consciousness of a living being over the existence of an object or an event". A different approach as regards cognition, on the other hand, is that it represents the internal structures in the acquisition and use of knowledge involving "sensation, perception, attention, learning, memory, language, thinking and reasoning" (McGraw-Hill, Encyclopedic Dictionary of Science & Technology, 2015). In addition to these skills, it is seen that the skills, such as experience, problem-solving, creativity (Oxford Dictionary, 2015), intelligence, concept formation, language acquisition (Yaycı, 2005), knowledge, paying attention and making decisions (Kandır, 2005), are also included in cognition. When dealt with as a process, however, cognition is seen to cover all the mental processes that involve understanding, knowing and learning the world (Yaycı, 2005). Starting from these definitions, it can be stated that cognition or the cognitive process is quite extensive. As a matter of fact, when concept is examined in different fields like educational science, philosophy or psychology, it is known to have showed different characteristics (Akpunar, 2011). For this reason, the evaluation of concept within the scope of the studied field becomes prominent as an important respect.

Based on the fact that cognition is associated with the skills such as learning, memory, thinking, intelligence and problem solving or with the mental processes regarding these skills, it can be said that cognitive science, therefore, cognitive neuroscience is fundamentally associated with these concepts. Indeed, cognitive neuroscience studies the neural basics of cognition in the way that it will involve perception, attention, language, memory and decision making, as well (McClelland & AL Ralph, 2015). Therefore, cognitive neuroscience is defined as the science that studies the neurological and genetic basics of a wide variety of psychological processes, such as cognition, emotion, motivation and intelligence (Atherton, 2005). Cognitive neuroscience, in a general sense, aims to describe the structures underlying certain cognitive functions as well as psychological processes (Friedenberg & Silverman, 2006). In understanding these processes, the role of the cognitive theory in which cognitive foundations are formed is really great; since, as was also stated by Frank and Badre (2015), many of the effective studies in neuroscience become comprehensible within the context of cognitive theory.

The emergence of cognitive neuroscience dates back to 1990s (McClelland & AL Ralph, 2015). Basically, it emerged in the process of seeking an answer to the questions as to what the neural basics of cognition are, or how our thoughts, perceptions, beliefs or intentions stem from the neurons in the brain. How neurons function and how they represent information/knowledge, and how information/knowledge is ingenerated through the modification as regards the characteristics of neurons are all among the research subjects of cognitive neuroscience. In addition to these, according to Atherton (2005, p. 5), however, the questions that cognitive neuroscience tried to seek answers to have been summarized as follows:

- How are memory, perception, reasoning and emotion represented in mind?
- What is the interaction between cognition and emotion?
- How are social behaviors organized in the brain?
- Is human cognition a modular or a universal process?
- Do developmental changes affect cognitive and emotional processes?

In the process of seeking solutions to these answers, structural and functional neuroimaging techniques for cognitive neuroscience have been benefited from. These neuroimaging methods were first used by St. Louis group for the purpose of analyzing cognitive functions (Petersen et al., 1988). With the methods started to be commonly used afterwards, the neural mechanisms underlying the human cognitive functioning have been studied (McClelland & AL Ralph, 2015). It is known that functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) are among these functional neuroimaging methods (Dündar et al., 2014). Both fMRI and EGG have both advantages and disadvantages relative to each other. fMRI, for example, has better spatial resolution, yet the same is not true for temporal resolution (Varma et al., 2008). For the temporal resolution, EEG offers better results while for localization fMRI offers better results. Therefore, researchers chose suitable neuroimaging tool by deciding whether they obtain better results in terms of temporal or spatial resolution and then design their studies.

3. From Cognitive Neuroscience to Educational Neuroscience

After neuroscience has also been included in the cognitive field, it is seen that there have been reflections in recent years in the educational field, as well. It can be stated that cognitive neuroscience has made a major contribution to neuroscience permeating into the educational field, because in addition to studying how neural processes lead to cognitive outputs, it is known that the researches regarding the neurological origins of certain learning disorders are also carried out within the scope of cognitive neuroscience (Kaufmann, 2008; Wilson & Dehaene, 2007). It can be said that the researches relative to the learning disorders like dyscalculia and dyslexia take place among these researches and bring cognitive neuroscience together with educational researches for the first time (Kucian & Rotzer, 2009). Such researches contribute to understanding the neurological origins of learning disorders. For instance, the conducted studies suggest that dyscalculia, which is related with a special learning disorder in the field of arithmetic, is associated with the structural and functional abnormalities in the involved region of the brain (Kaufmann & Vogel, 2009; Price, Holloway, Rasanen, Vesterinen, & Ansari, 2007). At this point, it is considered important that knowing different characteristics of students having learning disabilities as dyscalculia and designing teaching materials according to these differences. Since De Jong et al.

(2008) observed that designing teaching materials and environment according to students having difficulties in the learning process increased mental activities of these students and provided positive contributions for the elimination of the difficulties they experienced.

It can also be stated that the emergence of cognitive neuroscience and educational research has added a different dimension to the behavioral studies conducted in the educational field, since cognitive neuroscience is seen to have made major contributions to understanding the cases that behavioral datum remains incapable of describing. For instance, it could not be determined exactly whether or not the differences obtained in a group of behavioral studies (Hannula & Lehtinen, 2005; Hannula, Rasanen, & Lehtinen, 2007) where children's attention to focusing on the correct number within a group of elements (Spontaneous Focusing on Numerosity-SFON) was examined were due to the differences at the stage of processing as regards perception or due to the differences in encoding the stimulus. Later on, as the result of the examination performed through EEG, it was understood that the individual differences acquired were due to the differences in encoding the stimulus (Hannula, Grabner, & Lehtinen, 2009). Similarly, in a study conducted by Kaufman et al. (2008), children and adults were seen to have exhibited similar performances in their task to compare a number. However, neuroimaging methods suggest that there are differences between the two groups in terms of neural/cerebral activation although similar results were obtained in terms of behavioral data. The activation of the cerebral region in children mostly through their finger movements puts forward the fact that the children make use of their finger demonstrations to compare the digital quantities, and hence, it indicates the differences in the use of strategy. Therefore, it can be stated that the studies conducted on cognitive neuroscience has added a different dimension to the explanation of behavioral datum due to the fact that differences in strategy use was revealed with neuroimaging tools although any differences were obtained in terms of behavioral data.

Another contribution of cognitive neuroscience to the field of education is that it provides information as to the neural characteristic features of individuals (Dündar et al., 2014). This clearly shows how cerebral structures of the individuals with different characteristics, such as talent and intelligence quotient (IQ), differ from one another, since educational studies can only provide the data with respect to the differences in the performances of these groups. Cognitive neuroscience studies, on the other hand, shed light on the cognitive differences that lead to these performance differences. The studies in which the cerebral activation structures of the individuals showing intellectual giftedness and normal development are examined suggest that there major differences between the groups (Alexander, O'Boyle, & Benbow, 1996; Jausovec, 2000, 1996; N. Jausovec & K. Jausovec, 2000). One outcome that proves to be important in these studies is that the intellectually gifted individuals only activate their cerebral regions concerned with tasks. On the contrary, it was seen that quite different regions were activated in normal individuals. In addition to this, the fact that the intellectually gifted individuals mainly use their right hemisphere while the normal ones use their left hemisphere in the case of a cognitive task is another important finding achieved. These findings suggest that cognitive neuroscience shed light on the individual differences significant for educational researches by providing information as to the characteristic structure of the brain.

As a result of the fact that cognitive neuroscience has provided contributions mentioned above, education has appeared as another field that neuroscience chose for itself as an interdisciplinary field in addition to cognitive neuroscience. Since there is a learning process on the basis of education and learning is a process occurring within the brain, the emergence of neuroscience with the educational field puts forward a probable combination. The increase in the discussions and interests as regards the relationship between neuroscience and education (Ansari & Coch, 2006) can also be seen as the followers of this idea. However, it is also known that there were also researchers in the past years who had stated that education and neuroscience were the fields different from each other and that the bridge between them was rather distant (Bruer, 1997). Despite the fact that those having such a view consider that the emergence of education and neuroscience will bring harm rather than bringing some benefit (Hirsh-Pasek & Bruer, 1997), the educational neuroscience has emerged as the sub-field of neuroscience. In contrast to what has been considered fearful, it is stated that when the time frame between the years 1990-1999 was announced as "The Decade of the Brain" in the USA, educational neuroscience made major contributions to this field along with the increase seen in the researches regarding mind, brain and education (Karakus, 2013).

4. Educational Neuroscience

The educational neuroscience, a new field of research growing rapidly, is defined as "the cognitive neuroscience that studies the educationally inspired research questions" (Geake, 2009). Szucs and Goswami (2007) emphasized the fact that educational neuroscience was an interdisciplinary field, and they also defined educational neuroscience as the combination of cognitive neuroscience and behavioural methods for studying the development of mental representations. Similarly, Fischer et al. (2007) defines it as the integration of different disciplines that study human learning and development. The educational neuroscience, an interdisciplinary field of research, consists of the integration of pedagogy, psychology and neuroscience (Figure 1; Geake, 2009).

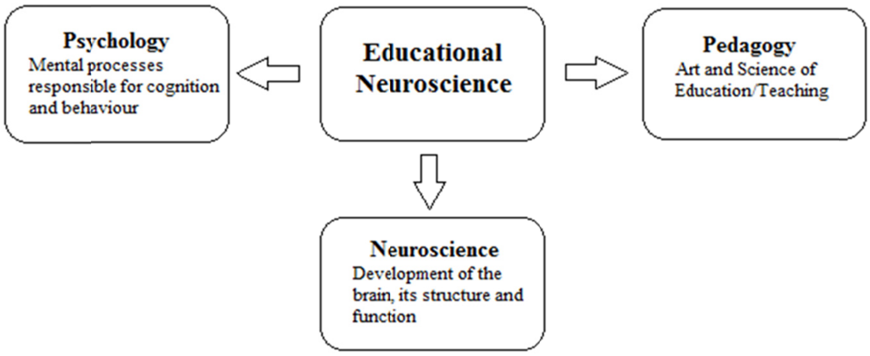

Figure 1. Educational neuroscience

The main objective of the educational neuroscience is to research into how genes and cerebral processes affect learning and teaching (Fischer, Goswami, & Geake, 2010). When the literature is reviewed, it is seen that there are quite a lot of questions in different resources relative to the questions aimed to be answered through educational neuroscience. For instance, according to Atherton (2005), the following questions are found within the research field of educational neuroscience:

- At what accuracy do contemporary/modern educational theories and teaching methods apply to the current research findings in regard to cognitive science?
- Is the understanding as to the structure or the functioning of the brain necessary or useful for the development of educational theories or policies?
- Can neuroscience identify the developmental differences that can be determined by different educational/teaching techniques?
- Are the individual differences in the process of learning and achieving success reflected by the differences that can be observed in the structure and functioning of the brain, or in genes?

In addition to these questions, Geake (2009) touches on some of the questions discussed in the neuroscience and educational workshop of The National Science Foundation (2007) as the research questions of educational neuroscience. Some of these questions comprising quite an extensive list are as follows (Geake, 2009):

- What are the effects of age on the learning process?
- How do the social factors, such as socio-economic status (SES) and home environment, make their relative contributions in different spots to brain development?
- How does the brain build up its structured representations? Is bilingualism an enlightening example?
- What is the nature of the complex imagery in the informative input and representation?
- What are the neural basics of the individual differences in learning and development?
- Can neural connections be used in measuring, for instance, the symbolic, tangible, analogous, contextual and theoretical effectiveness of different interventions?
- What are the roles of the components throughout the whole brain (e.g. amygdale, cerebellum)?

In addition to these questions which the researchers think educational neuroscience should deal with, the teachers were also asked what the questions neuroscientists may deal with could be due to the fact that they are a major part of education (Geake, 2009). In line with the answers received from the teachers involved, four categories were formed: learning cognition/ cognitive learning, learning environment, educational program and school organization. Some of the questions within these categories are as follows:

- *Learning Cognition/Cognitive Learning:* Can students maintain their concentration/focus better by understanding the cerebral functions more clearly in the cases of maintaining and losing concentration/focus?

- *Learning Environment:* Are the social environments where students live, such as insufficiency of books, weak role models and lack of support to be provided by their parents, associated with their learning processes?
- *Educational Program:* There is an internet address which can be benefited from while the music is on so as to increase the performance in certain areas and which claims that brains could be synchronized with a common frequency; Which of them can be benefited from to increase the performance in certain areas while the music is on? And does it have any scientific basis?
- *School Organization:* What is the neuroscientific explanation as to how the highly- intellectual and gifted/talented students undergo their learning processes?

It is possible to say that the educational neuroscience seeking answers to the above mentioned research questions is quite closely associated with cognitive neuroscience. It is even seen that the educational neuroscience is defined as ‘’the applied cognitive neuroscience’’ (Campbell, 2011). Similarly, cognitive neuroscience is evaluated as the sub-field closest to the educational research of neuroscience (De Smedt et al., 2010), because the main task of cognition is to build a bridge between neuroscience and education or between the brain and behaviour (Howard-Jones, 2008). Separately, the fact that cognitive neuroscience sheds light on the data which the behavioural datum in educational researches fails to explain and that it also adds a different perspective in understanding the individualistic differences was once discussed, as well. For this reason, it can be said that the two sub-fields of neuroscience are closely associated with each other due to the fact that cognitive neuroscience builds a bridge between education and neuroscience and that educational neuroscience comprises the application of the obtained findings. A situation or a problem that occurs in an educational environment is tackled through cognitive neuroscience, and the adaptation of the findings put forward to the educational environment constitutes the educational neuroscience. This situation was exemplified by Geake (2009) as follows:

Education Problem: Decrease in the second language studies in secondary schools.

- Neuroscientific research: Neural distributions and connectivity among the writing/spelling and phonemic representations of the first and second languages.
- Probable educational training: Devising a more effective educational program for acquiring a second language in primary schools.
- Education Problem: How to optimize creative thinking in schools.
- Neuroscientific research: Neural connections of fluent analogous reasoning.
- Probable educational training: Pedagogies making use of the analogies so as to enhance creative thinking in all the fields of educational programs.

Despite the fact that the two sub-fields are closely associated with each other, the fact that the outputs of the educational neuroscience are not as clear as those of the cognitive neuroscience and that the educational neuroscience is only a relatively newer field cause researchers to be unable to specify what the benefits of brain researches exactly are (Keleş & Çepni, 2006). Separately, the educational neuroscience is thought to be still challenging in practice. However, when the literature is reviewed, it is seen that there are suggestions in different resources that can be practically performed in classrooms, some of which are as follows: (Karakus, 2013, p. 20):

- Action improves memory and learning (Sibley & Etnier, 2003; Winter et al., 2006). A number of studies report that there is a positive correlation between physical activity and school success; physical exercises enhance the progress of the developing brains while preventing older brains from regressing (Zervas et al., 1991; Jensen, 1998; Blakemore, 2003).
- Sleep is important in terms of memory, since memory is strengthened throughout the sleep period (Marshall and Born, 2007; Capellini et al., 2009; Maquet et al., 2000; Potkin & Bunney, 2012). Therefore, a regular and adequate amount of sleep is indispensable for the brain to learn things effectively (Howard Jones, 2007).

In the conducted studies, it is known that there is a growing interest among teachers in applying the findings of neuroscientific researches in educational practices (Dekker, Lee, Howard-Jones, & Jolles, 2012). Some researchers have stated that the field of neuroscience is quite complicated and that it is hard to transfer the research findings into the class environment (Ansari, Grabner, Koschutnig, Reishofer, & Ebner, 2011). Thus, this gap between education and neuroscience has brought with it several perceptions and illusions as to misconception (Goswami, 2006).

5. Conclusion

When the practices performed are analyzed, the educational neuroscience can be said to build a bridge between mind and body (Campbell, 2011). On the other hand, cognitive neuroscience puts the information received from mind into behavior, in other words, practice, which puts forward the importance of cognitive neuroscience in the educational field. Similarly, it is hard to consider cognitive neuroscience as being independent of the learning environment (Diamond & Amso, 2008), since the educational backgrounds of the participants, just as their physical and social environments, are of significance. For this reason, it can be stated that there is an interaction/interrelationship between cognitive neuroscience and educational neuroscience (De Smedt et al., 2010).

With this study, the relationship between cognitive neuroscience and educational neuroscience has been put forward. Even though brain researches are on the increase with each passing day, the researches carried out and the reflection of their findings into educational environments are seen to be on rather insufficient levels. It is thought that when the research results regarding the in-class application of the researches and findings to be performed along with neuroscience on an educational dimension are included, then these research results will be taken into consideration. Otherwise, it is foreseen that educators will have some difficulty in perceiving and understanding the results of brain researches.

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