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Why Neuroscience is Important for Teaching and Learning

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Abbreviations: EEG: Electroencephalography; PET: Positron Emission Topography; FMRI: Functional Magnetic Resonance Imaging; EN: Educational Neuroscience; MBE: Mind, Brain and Education

Introduction

Recent development of brain imaging techniques such as electroencephalography (EEG), positron emission topography (PET) and functional magnetic resonance imaging (fMRI), have advanced our understanding of the brain. We are now able to study the neural processes that underlie learning, memory, cognition, emotions, social behaviour, and even the self and human consciousness. Up until the 1980's, researchers believed that the structure of the brain was developed during childhood and there was little room for change after that. However, researchers now know that the brain possesses enormous capacity for change. The brain's ability to act and react in ever-changing ways is known as neuroplasticity. Learning changes the physical structure of the brain and results in its organization and reorganization. Understanding the brain and how it works is critical for us to become effective teachers. I concur with Willis [1] that Teachers who are knowledgeable with the workings of the brain will have the optimism, incentive, and motivation to apply their findings to the classroom. To become a teacher without understanding the implications of brain-changing neuroplasticity is a great loss to teachers and their future students. I fully agree with the comment below suggested by Whitaker [2]. "To have a student in a class with a teacher who really doesn't understand the implications of brain-changing neuroplasticity is like sending your car in for repair to a mechanic who doesn't understand how the engine works." The brain is responsible for our thinking, learning and memory. If we want to understand the most effective ways to teach and learn, we need to understand the neuroscience of learning. "The brain controls our ability to think, talk, feel, see, hear, remember things, and even our breathing." Educators and schools around the world are increasingly using the knowledge, techniques, and programs developed from how our brains learn, known as neuroscience, in their classrooms. Neuroscience is the scientific study of the nervous systems. It is also known as Neural Science, which is the study of how the nervous system develops, its structure, and what it does. Neuroscientists focus on the brain and its impact on behaviour and cognitive functions. The development of neuroscience helps to promote the basic understanding of the neural mechanism of the learning process. The extensive attempts to connect neuroscience, cognitive science, psychology, and education have resulted in a fast-growing interdisciplinary field of study which has been labelled as "Educational neuroscience," "Mind, Brain, and Education science," "Neuroeducation".

Educational neuroscience is an inter-disciplinary and relatively new subject often associated with the science of learning. The goal of educational neuroscience is to improve educational practice by applying findings from brain research into the classrooms. Educational Neuroscience is also referred to as 'mind, brain and education' and as 'neuroeducation.' [3]. It helps us to shed light on subjects such as why certain types of learning are more rewarding than others; the plasticity of the brain and what happens when we learn new skills at different ages; ways of enhancing our ability to learn, and the role of digital technologies

in learning, along with many others. It has potential impacts to improve educational outcomes by changing factors that influence learning, factors such as motivation, attention, ability to learn, memory, prior knowledge, stress, health, and nutrition [4]. The aim of educational neuroscience is to generate basic and apply research that will provide a new trans-disciplinary account of learning and teaching, which is capable of informing education. According to Petitto & Dunbar [5] educational neuroscience "provides the most relevant level of analysis for resolving today's core problems in education. Educational Neuroscience (EN) can help teachers to teach in several ways Barnes [6]. These include:

- Improved reading.
- Deliver individualized learning for every student.
- Help teachers move closer to creating learning environments, rather than simply delivering curriculum content.
- Build the learning capacity of each student, so they learn more easily.
- Free teachers' time to teach and add higher value learning opportunities.
- Empower teachers with a new understanding about how students learn.
- Help students with a range of learning difficulties.

Educational neuroscience can be delivered to students with or without technology. The demand for EN comes from two directions: neuroscientists emphasize that their work has the potential to improve education, and educators are keen to understand what neuroscience can provide for their practice (Howard-Jones, 2014). According to Kaufer [7] there are several important aspects of biological aspects of learning, including neuroplasticity and neurogenesis. Plasticity, the capacity of the brain to change and develop, is both synaptic and dendritic. Kaufer [7] argues that changes may occur regarding the connections between neurons (synapses) or in the neurons themselves (dendrites). That means we can both reorganize our knowledge and change the quality and nature of the knowledge itself. Neurogenesis is the ability of the brain to generate new neurons. It suggests that some areas of the brain, including the hippocampus, can create new cells throughout a person's lifetime. This reverses an earlier hypothesis that neurogenesis ends after a certain age, that by adulthood we have all the brain cells we will ever possess and that they slowly die off. Newly generated neurons are recruited into existing networks, strengthening, or developing pre-existing connections in the brain. Kaufer [7] argues that behaviours and conditions such as sleep, nutrition, exercise, stress (cortisol levels), and happiness (dopamine levels) influence plasticity and neurogenesis. These exist in dynamic relation to one another. For example, voluntary exercise can counter the effects of stress. That is, high levels of stress tend to correlate with low performance - but low levels of stress also correlate with low performance. A moderate amount of stress results in the highest performance. What constitutes a "moderate amount," however, varies greatly between individuals. Kaufer [7] also argues that Active Learning (volitional control) is advantageous for learning because distinct neural systems related to executive functions (planning or predicting, attention and object processing) are dynamically activated and communicate with the hippocampus, to enhance its performance. Neuroscience research also supports the efficacy of tools like Bloom's taxonomy which describes cognitive tasks in ascending orders of complexity [7].

Although neuroscience research usually focuses only on learning, there is a developing subfield within neuroscience called "Mind, Brain and Education" (MBE) that attempts to link research with teaching. MBE researchers consider how to take advantage of the natural human attention span, how to use studies about memory systems to inform lesson planning, and how to use research on the role of emotions in learning.

In neuroscience, when a person understands something, the neural pathway that was created in the process needs to be reinforced if the pathway is to become permanent, as well as enhancing effective memory and learning. But this reinforcement is compromised by factors such as sleep, stress, diet, skills, mind-set, movement, and the physical environment. All of these can impact negatively or positively on how people process information, and their brains learn. It is knowing how the brain functions which is the significant factor and by aligning learning provision with it will ultimately help us to learn better. The brain's ability to create, strengthen and eliminate connections is believed to underlie the cognitive processes of memory required for learning.

My colleague and I have applied the principles of neuroscience in online learning of physics [3]. Our research shows us that Principles of neuroscience can be used by teachers to help students to learn better. Firstly, understanding how the brain works helps the teacher to plan lessons and choose methods that align with neuroscience research for learning. Secondly, research from neuroscience can help teachers to understand how the behaviour of students is influenced by how the brain works and environment, genetics, and perceptions. Thirdly, research from neuroscience enables us to shed light on important topics related to how the brain learns such as neuroplasticity, memory, metacognition, mindfulness, retrieval strategies, reflection, motivation, and prior knowledge. Fourthly, neuroscience helps us to understand how students' brains are affected by factors such as emotion, exercise, sleep, motivation, and social encounters, to help us to choose the best help to give to students [8]. Our research found the following principles from neuroscience are important in enhancing online learning for our physics students: Active engagement is necessary for learning; Prior knowledge is important; Use images to help students to understand abstract concepts; Rehearse information regularly; Attention is important in learning; Pay attention to stress and anxiety; motivation is

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important; Break content into bite-sized chunks; Enhance the relevancy of learning; space out learning and trigger the right emotions. Because of the importance of neuroscience for teaching and learning, I was invited by Frontier in Psychology to edit a special issue on the subject. The special issue 'Enhanced Learning and Teaching via Neuroscience' was published [3]. The papers in the special issue highlight the emerging field of educational neuroscience for teaching and learning. These papers emphasize that using research from neuroscience, psychology, and cognitive science, can provide more effective teaching methods and techniques that can be used in a wide variety of educational settings to improve learning by students. The Nine papers are:

- Asymmetry of interlimb transfer: Pedagogical innovations in physical education.
- Empirical model of teachers' neuroplasticity knowledge, mindset, and epistemological belief system.'
- 'Transmedia storytelling usage of neural networks from a Universal Design for Learning perspective: A systematic review
- 'Integrated science, technology, engineering, and mathematics project-based learning for physics learning from neuroscience perspectives.
- 'Prevalence of neuromyths among psychology students: small differences to pre-service teachers.'
- 'Neural pathways of attitudes toward foreign languages predict academic performance.'
- 'Implementing digital neuroscience in special-needs-teacher education: exploring student-teachers' multifaceted learning outcomes related to teaching children with neurodevelopmental disorders,
- Radical Neuro constructivism: A framework to combine the how and what of teaching and learning?
- A Theory of Mental Frameworks.

Teaching and learning involve changing the brain. Neuroplasticity is when experiences change both the structure and function of the brain. It is my belief that understanding neuroscience will give us educators a tool to help our students to learn better [9,10]. Teachers should be familiar with neuroscience, how the brain learns to help us to teach more effectively and help students to learn better.

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