

# **Online Learning, Educational Neuroscience and Knowledge Transformation Opportunities for Secondary Education Students**

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*The improvement of digital technologies and the results of research in the field of distance education have strengthened online learning. Although online learning is seen as an alternative, the COVID-19 pandemic has led the global education community to identify it as the best way to continue the educational process. However, the lack of scientific and empirical knowledge in distance education has led to a version of online education. This version has been identified as emergency remote teaching since it does not share principles or educational planning models of distance education. The article attempts to link research findings from the field of educational neuroscience with the principles of online learning. Ways of active involvement of students are suggested according to educational neuroscience which can facilitate learning and inform teachers concerning their educational practices.*

*Keywords: educational neuroscience, online learning, emergency remote teaching, educational practices*

## **INTRODUCTION**

Digital technologies and the increasing use of the Internet have enhanced distance education in all educational structures since the end of the last century. However, the COVID-19 pandemic alongside the need it brought for educational structures to continue to provide educational opportunities maximized the use of digital tools, resulting in emergency remote teaching (Hodges et al., 2020).

Although many institutions offered distance learning or incorporated additional distance learning activities, the universal transition to distance learning was a particularly demanding undertaking. Thus, emergency remote learning (ERT) is undoubtedly distance learning, but with significant differences. At the same time, the strengthening of research in the field of educational neuroscience has offered useful findings that can serve as a guide for the improvement of educational practices and for the training of teachers in the science of learning.

The next section provides a brief overview of distance education with a focus on ERT to highlight their key differences and highlight the importance of the pedagogical use of digital tools in online learning. Next, an attempt is made to delimit educational neuroscience and discuss how it can assist distance education to reduce pedagogical problems and increase learning opportunities. The work is completed with proposals for educational practices based on the results of research in the field of educational neuroscience and models

for the transformation of knowledge of teachers and students with the ultimate goal of improving the educational process.

## **ONLINE LEARNING**

Online learning is a form of teaching that requires at least one digital device (computer, tablet, mobile phone) and an Internet connection. Online learning can happen in a synchronous or asynchronous mode. In the first case there is live communication between the students and the educator, while in the second case material is provided on the internet for the students to work at their own time and at a pace that suits them.

In addition, because online education is a socio-cultural learning process, a sturdy online education program should not be used as a tool for transferring knowledge through a linear approach. For this reason, it is necessary to offer multiple opportunities for interaction between students, between students and teacher, between students and material (Moore et al., 2002). In addition, online learning needs to take place within an "ecosystem of learner supports". However, building this ecosystem takes time and effort. For these reasons it needs to be supported with funding and mechanisms similar to those offered in the traditional structure of education, such as library resources, career services, social networks, etc. Therefore, "effective online learning results from careful educational planning and design, using a systematic design and development model" (Hodges et al., 2020).

The above prerequisites did not exist in the emergency remote teaching during the pandemic, as they were not foreseen and moreover could not be built in such a short time. On the contrary, what seems to have happened, due a) to the pandemic and b) the need not to interrupt the educational process, led educational systems around the world and educators to change teaching methods almost overnight. Without specific design, but with conventional classroom material, educators adapted to the new reality of the remote teaching. They sought solutions to continue the educational process and needed to use less familiar or even completely new technology. The above approach highlights that what happened in virtual classrooms and virtual schools around the world was not online teaching as it is defined but teaching that took place online due to the pandemic. Despite the good intentions of educators, such efforts can lead to "suboptimal" teaching or to a teaching approach that is far away from synchronous pedagogical and teaching principles (Hodges et al., 2020). Therefore, such efforts should not be considered as online teaching, but should be recognized as emergency remote teaching (ERT), so that they can be properly described and evaluated accordingly.

ERT "is a temporary shift of instructional delivery to an alternate delivery mode due to crisis circumstances." (Hodges et al., 2020). It is an idiosyncratic type of teaching as it will dissolve back to F2F teaching once the emergency situation has passed. For as long as it holds though, it attempts to use online teaching formulas that aim at finding instructional solutions as fast as possible so that learning can stay uninterrupted as much as possible. Parameters like short timeframe, often limited technological resources, and limited human resources to support the transition unavoidably come into play. These can further be complicated by political concerns such as the school's image, marketing concerns in the case of private institutions, and/ or centrally imposed mandates from ministries and/ or educational districts. As a result, the outcome might often be a 'pick and mix' approach for instructional methods, implementation tools, as well as learners' needs. ERT will operate in an idiosyncratic context where faculty is learning and/ or training in new technologies, in new lesson designs, while at the same time teaching since schools are still in operation (Nikiforos, Tzanavaris & Kermanidis, 2020).

Therefore, the educators who are called to operate and run ERT face many challenges that the research on online education has solved. One of the first issues is technical support. Support teams find it difficult to meet the diverse needs of educators as opposed to a well-organized online learning system. Educators and students come to ERT with different knowledge and different understanding of the technology they are called to use. Moreover, in these emergency situations it should not be taken for granted that everyone, educators, and students, have the necessary equipment (computers, microphones, mobile phones, tablets etc.) or quality internet connectivity (Czerniewicz & Walji, 2019). Overcoming technological issues, it is possible to find teachers who have difficulty with course planning and teaching methods that are appropriate

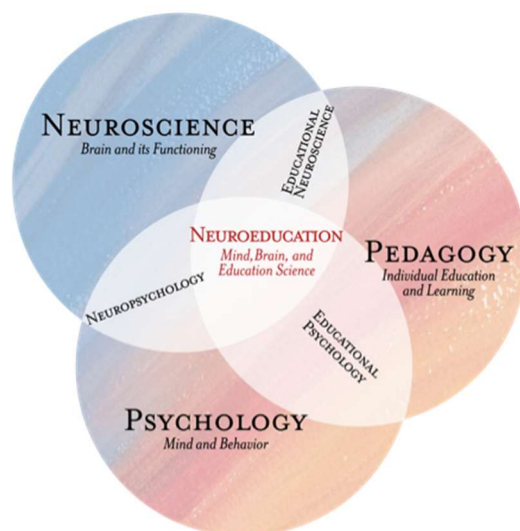
for the online course, as their existing repertoire of skills and knowledge is likely to be inadequate or inappropriate. As a result, they may resort to solutions that ignore the principles of online pedagogy and may not be able to implement a systematic model for lesson planning and teaching. All of the above have a high priority since the confusion of ERT with online learning and the unsuccessful operation of the former may negatively affect online learning in general (Hodges et al., 2020).

The importance of transforming the perspective of educators who do not have empirical and scientific knowledge in distance education is therefore highlighted. The ultimate goal is to enhance the educational process in the context of online learning, with appropriate lesson planning and teaching methods and approaches that will serve the needs of students. The next section will analyze the results of research in the field of educational neuroscience, as it provides findings that can be translated into successful teaching practices and contribute to the transformation of teachers' perspectives on learning sciences.

## **EDUCATIONAL NEUROSCIENCE**

Neuroscience attempts to explain the workings of the brain and connected nervous system, the functional architecture of the mind, and how the brain and mind map work together. The field contributes to our basic understanding of the neural mechanisms underlying human development and learning. Recent development of brain imaging techniques such as electroencephalography (EEG), positron emission topography (PET) and functional magnetic resonance imaging (fMRI) have provided extra opportunity for neuroscientists to explore the functional organization of the human brain. In light of these advances, neuroscience has experienced rapid growth over the last three decades and has formed links with other disciplines. Education is one such discipline since by incorporating neuroscience it can enhance our understanding of the mental and physiological processes involved in learning. The extensive attempts to connect neuroscience, cognitive science, psychology, and education have resulted in a fast-growing interdisciplinary field of study which has been labeled as "Educational neuroscience," "Mind, Brain, and Education science," "Neuroeducation" (see Fig. 1). In this new area, professionals in the field of education, cognitive scientists and neuroscientists collaborate to use the results of neuroscience research in educational contexts (Ansari, Coch & De Smedt, 2011; Nouri, 2016). Educational neuroscience or Neuroeducation, according to Howard-Jones (2011) "better reflects a field with education at its core, uniquely characterized by its own methods and techniques, and which constructs knowledge based on experiential, social and biological evidence." Some research groups have argued the existence of a gulf between the findings in neuroscience and educational practice while others have developed models and frameworks for applying the findings to everyday teaching practice (Brookman-Byrne & Commissar, 2019; Leithwood, Sun & Schumacker, 2020).

**FIGURE 1**  
**THE EMERGENCE OF NEUROEDUCATION SOURCE: INTERPRETATION OF TOKUHAMA-ESPINOSA'S**



Transdisciplinary Field by Nakagawa, (2008), Redrawn By Bramwell 2010.

Teaching is a complex matter and the way it is done cannot easily be incorporated into norms, due to the complexity of the brain and the growing number of tools available to teachers and students. However, the most important tool in achieving learning is the learner's brain. Furthermore, given that the achievement of the desired learning outcomes is not significantly affected by the quality of teachers (Leithwood, Sun & Schumacker, 2020), there is good reason to claim that the training of the latter in educational neuroscience can comprise an extremely important component of their knowledge. In this way, teachers will be enabled to evaluate traditional teaching practices, allowing them to remove some from their educational kit and include new ones, thus offering strategies and models, which according to educational neuroscience research contribute to learning. In addition, they may find that teaching and learning practices they already use are validated by educational neuroscience. However, the ultimate gain from training teachers in educational neuroscience is the transformation of their knowledge which will eventually result in improving student knowledge and learning.

In addition, research shows that teachers' effectiveness and belief that they have the ability to influence student learning is strongly linked to their knowledge of how the brain works (JohnBull, Hardiman & Rinne, 2013). According to Whitman and Kelleher (2016), the more colleagues know about the way the brain learns, the more differentiated their educational practice becomes as they recognize multiple teaching and learning paths and at the same time reject the one-suits-all educational model. Conversely, they choose precise and documented practices and do not just carry out practice. In this context, teacher training programs have been developed that contribute to the implementation of research results in educational practice (Hardiman, 2012).

In the next section, based on research findings, an attempt will be made to identify strategies and actions that can enhance ERT, but also the needs of distance education as a whole. In this way, teachers who want to implement strategies based on research in educational neuroscience can transform their practices, assess the impact of what they are trying to modify, and eventually be led to sustainable long-term solutions that can be used in the classical frameworks. The aforementioned approach is crucial as the educational process is all the more required to strengthen critical thinking and problem-solving skills, network collaboration, flexibility and adaptability, initiative and entrepreneurship, effective oral and written communication, access to and analysis of information, curiosity and imagination (Wagner, 2010).

## EDUCATIONAL NEUROSCIENCE AND EMERGENCY REMOTE TEACHING

Research in neuroscience has provided evidence that can alter our understanding of learning. One of the key concepts in learning enhancement is the plasticity of the brain and the acceptance that learning ability is not a stable and predetermined condition (Rees, Booth & Jones, 2016). In other words, all people are on a journey of development, through the experiences they come across and the learning they gain. Plasticity describes how experiences reorganize neural pathways in the brain. In this way, when someone learns new things or memorizes new information, long-term functional changes take place in the brain. Similarly, in addition to genetic factors, a person's brain is shaped by the characteristics of the environment and its actions. Based on this data, one cannot but reconsider the view that some people are able to achieve an expected learning outcome while others are not. Thus, if learners do not achieve the expected learning outcomes, it is not due to their brain, but to other factors that will be identified in the following paragraphs. As a result, people need to be trained so that when they come across a difficult subject, they make a conscious effort to strengthen the brain areas needed in order to persist more on the subject rather than to decide that they are not capable of dealing with it (Darling-Hammond et al., 2020). After all, no one is born with a brain that is suitable for one particular subject. On the contrary, everyone can and should develop the neural pathways they need. Besides, accepting the idea that a person's brain is not capable of handling a subject is destructive both to the individual and society.

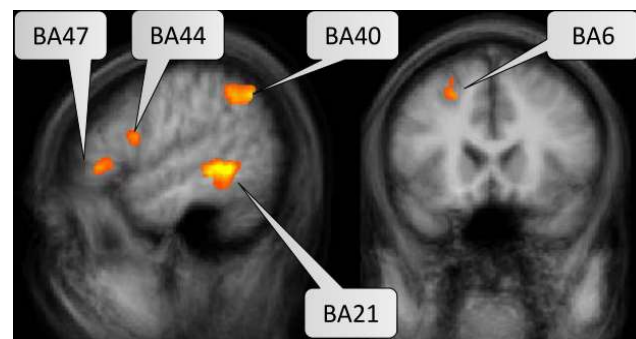
Therefore, when we learn something, we develop the brain in one of the following ways: a) by creating a new pathway, which is initially subtle, but is fortified the more we delve into the concept under study, b) by further strengthening an existing pathway, and c) by forming a new connection between two previously disconnected pathways. In addition, when these pathways are no longer needed, they gradually disappear (Anderson, Boaler & Dieckmann, 2018). Therefore, the structure of our brain changes with each different activity we perform, as circuits are adjusted. In the context of distance learning, the integration of multiple and different activities is necessary to enhance learning. In addition, due to the multiple tools, such as private chat, group chat, teamwork opportunities, optional digital tools, shared whiteboard, etc., available in distance learning, the development of neural pathways and connections can be enhanced and, as a result, opportunities for the learner to gain experience and acquire new learning are unlimited. In this context, the educator needs to focus on activities that include “Think”, “Practice”, “Interpret”, “Apply”, “Evaluate” and “Create” activities in collaborative and suitable communication environments (Doukakis & Papalaskari, 2019).

Exploring how learning can be enhanced due to the plasticity of the brain, it has been shown that assessment can play a key role in determining a person's knowledge, as well as in shaping this knowledge (Hwang & Chang, 2011). Providing frequent and non-threatening assessment (diagnostic, formative, summative), along with feedback on the understanding of an idea or concept, plays a key role in memory consolidation. It is important for this assessment to explore both prior knowledge and pre-requisite (possibly informal) knowledge, as these two types will be a suitable tool for the storage of important, new information in the student's memory during the educational process. In the context of distance education, digital environments include a variety of tools that can enhance memory consolidation (creating online assignments, quizzes, gamification of activities etc.) (Hwang & Chang, 2011). Finally, it is important to have formative assessment during remote teaching so that the student can see what he or she knows while the teacher can assess whether any expected learning outcome has been achieved and, in turn, help the student but also adjust his/her teaching.

In the context of assessment, the exploitation of mistakes plays a crucial role. People make mistakes in their everyday lives and sometimes react instinctively by blaming themselves and feeling bad since in an educational context mistakes have been associated with such consequences as punishment or grade reduction. From an educational perspective though, mistakes are valuable as they provide opportunities for brain development. In particular, dealing with obstacles and correcting mistakes in the learning process enhances neural connections, thus speeding up and enriching the learning experience. Research from both neuroscience and human behavioral studies highlights the positive effects of error utilization, as it enhances the transformation of one's knowledge (Moser, 2011). To achieve the above learning conditions, it is

necessary to design courses that will not adhere to the traditional rules of lesson design that ask trivial and unchallenged questions, which aim at score attainment. Besides, posing questions that can take more than one correct answer will motivate students. In digital distance learning environments, the tools provided allow students to experiment, deal with obstacles, and highlight and reduce mistakes in order to develop the brain. With the ability to instantly find many different resources, students can work in groups creatively. Error detection activities, progressive error reduction strategies, and practices that will encourage experimentation without being associated with negative consequences in the event of an error can lead to an ideal learning experience (Nottingham, 2017). In addition, the ability for everyone to answer a question without being able to see other students' answers greatly enhances learning in distance environments (personal chat, etc.).

**FIGURE 2**  
**OBSERVED ACTIVATION PATTERN FOR PROGRAM COMPREHENSION**



(Siegmund et al. 2014).

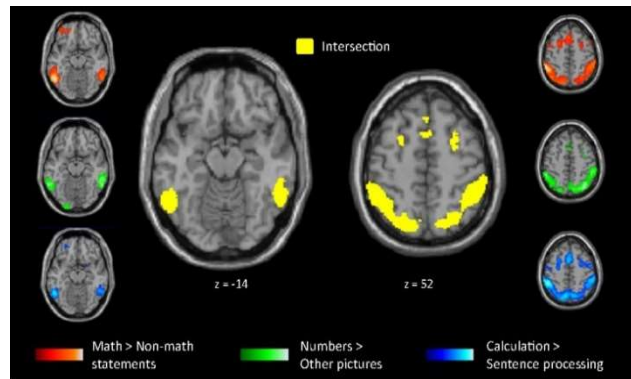
It is useful to approach the issues discussed above with a positive mind, knowing that a) they lead to success and b) success is not far away. At the same time, in addition to the right mentality and positive attitude, it is critical for the teacher to offer multiple opportunities for the development and reorganization of these neural pathways in the brain. Therefore, neural pathways and learning are optimized when the learner has the opportunity to consider a concept or idea using a multidimensional approach.

Achieving both a change of mindset and a multidimensional approach can be attempted through a different approach to teaching. According to the literature, the change in the system plays a decisive role in trying to persuade students to work so that they can see first and then highlight their potential (Niiya, Brook & Crocker, 2010). To do this, teachers need to design teachings that allow students to try new strategies and seek information, highlighting activities that allow for exploration of open-ended topics or multiple ways to reach the same one answer.

From the field of neuroscience, the above approach is necessary, since the results from the research show that different areas of the brain are activated depending on the activity one engages in.

For example, five brain regions associated with working memory (BA6, BA40), attention (BA6) and language processing (BA21, BA44, BA47) are connected with whether someone has understood a computer program or not (see Fig. 2). Similarly, in mathematics, specific areas of the brain are activated when calculating a simple mental operation (see Fig. 3).

**FIGURE 3**  
**OBSERVED ACTIVATION PATTERN FOR CALCULATION AND SIMPLE**  
**NUMBER PROCESSING**



(Brain Mapping, An Encyclopedic Reference, London: Academic, 2015, 597–611)

Therefore, in the context of distance learning, students need to work on activities that can be approached in different ways, instead of being assigned identical or similar questions / exercises. For example, it is interesting to try to work on a problem by solving it a) with operations, b) diagrammatically, c) algorithmically (coding) and, in addition, to write a story about this problem or create an image or an object. Approaching content in a multidimensional way is important in all subjects (Boaler, 2006). This opportunity for multimodal thinking enhances communication between pathways and brain development (Ferguson, Anderson & Spreng, 2017). At the same time, students, working through a multidimensional approach on a problem or issue, develop the ability to learn and overcome fears and obstacles. What is more, they see the problems through a new perspective, gaining confidence in their own abilities.

The above framework inevitably leads to two more issues. The first is the exploration of the value of speed in relation to creativity and flexibility and the second is collaboration. According to current research, there is a need to overcome the idea that speed of thought is an important component of learning in comparison to flexible and deep thinking. More specifically, it is shown that learning is optimized when students approach concepts and ideas with creativity and flexibility (Novick et al., 2019). In contrast, when people work under pressure, their working memory is impaired and, as a result, a) they become anxious and b) they feel that "their mind has stopped" (Beilock, 2011). According to the above, when people learn something quickly, they are likely to enhance existing neural pathways as well as create new neural pathways, which, however, can be easily lost. For this reason, in distance education, working time needs to be granted without a request for information reproduction or speed of action since the development of neural pathways and synapses is a slow process.

In closing the presentation of good practices in distance learning, the importance of working with other people to strengthen neural pathways and learning cannot be overestimated (Decety et al., 2004). This last dimension comes to highlight the value of the sociocultural approach to learning (Wertsch, 1995) and the need to provide students with such opportunities in multiple ways (teamwork, project undertaking, collaborations, etc.).

## CONCLUSIONS

In this article, an attempt has been made to highlight that educational neuroscience with its principles and existing research findings can significantly improve online learning. In this context, four areas can play a key role and enhance learning.

Initially, emphasis was placed on the plasticity of the brain and its ability to grow through synapses and neural circuits. In this context, the involvement of learners in the learning process plays a key role in brain development. The value of the diagnostic, formative and summative assessment was then determined.

Through these types of assessment, educators have the opportunity to a) evaluate for learning purposes and b) assess learning. In addition, the importance of exploiting the obstacles that learners encounter was highlighted. Dealing with obstacles and correcting mistakes in the learning process enhances neural connections, thus speeding up and enriching the learning experience. The fourth area is the multidimensional approach of concepts using appropriate activities. This approach allows learners to engage with different representational models and enhance different areas of the brain, which work together to enhance brain connectivity.

In addition, two critical factors were identified for activating the four areas: speed and collaboration. More specifically, it was found that in the context of online learning, working time should be provided without emphasis on information reproduction or speed of action, as the development of synapses and neural circuits is a slow process. In addition, collaboration is a complex task and plays a crucial role in learning, achieving goals and developing the brain. Finally, it seems that important findings in neuroscience research require appropriate teacher training. In this context, the development of training programs on learning sciences using the Technological Pedagogical Content Knowledge framework can help prepare educators to teach in online learning environments according to the principles of educational neuroscience.

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