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Educational Neuroscience

AT A GLANCE

Educational neuroscience is an interdisciplinary research field seeking to translate empirical findings on brain functionality into educational practice and policy making (Thomas, 2018). This field empowers educators to begin challenging education-based neuromyths by providing a different perspective on the mechanics of learning. Until recently, there has been no significant focus on the functionality of the human brain in relation to education and curriculum. However, this association is worthy of examination since the human brain is the organ most responsible for learning (Geake, 2011). As the current research suggests, educational neuroscience may help us better understand students with learning disabilities, the impacts that high levels of stress exposure may have on individuals' ability to learn, and effective methods of delivering information. An overview of the educational neuroscience field, why it is important, and a summary of recent empirical findings are provided in this research capsule.

Educational neuroscience is a moderately new, multidisciplinary field that aims to bridge brain research and effective learning (Caragea, 2017; Palghat, 2017; Tandon, 2016; Feiler, 2018; Thomas, 2018). Referred to as the *Science of Learning* (Palghat, 2017), efforts are made to translate insights about the brain and mind to enhance practices in the classroom. The field was first conceptualized in 1985 as the idea of a "neuroeducator" was posed by Jocelyn Fuller and James Glendening. These authors considered the development of an interdisciplinary field of science that would highlight the importance of good teaching by utilizing knowledge of brain structure and function (Feiler, 2018). Although the concept was introduced almost 35 years ago, the discipline has received increased attention from researchers, school administrators, and practitioners over the last ten years.

Educational neuroscience is somewhat unique in that an interdisciplinary research team is employed to translate research findings on neural mechanisms of learning into educational practice and policy and to understand the effects of education on the brain (Thomas, 2018). Scholars have defined this multidisciplinary field in which scientists (neuroscientists, psychologists, educational researchers, and others) apply the findings of neuroscience, guided by the theories and paradigms of psychology, to the goal of improving student learning (Soo-hyun Im, 2017). Essentially researchers are exploring links between education and “Brain Sciences” (Tandon, 2016). Additionally, educational neuroscience is considered a basic science that studies how education changes the brain and hopes to identify mechanisms that lead to behavioral change through education (Thomas, 2018). As Howard-Jones (2011) argued, educational neuroscience is not just a way to improve, explain, or analyze teaching. Rather, it seeks to explain how students learn and how learning changes the brain and then apply these findings to into the classroom (Feiler, 2018).

Neuroscientific knowledge has been explored in relation to education specific areas and examines how the brain works in different educational contexts (Caragea, 2017). Topics of interest have included cellular mechanisms for memory, mouse models for reinforcement learning, human brain network analysis during simple perceptual tasks, psychological discrimination tasks, social psychology in the classroom, pedagogical evaluation and recommendations, and educational policy formulation and evaluation (Palghat, 2017). Commonly discussed applications of neuroscience in the classroom include reading, language, numeracy, attention and memory, as well as the effect of emotion, stress, and sleep on neuroplasticity (Feiler, 2018).

Why Is It Important?

Knowing not only if an approach works, but why it works, can help refine instructional practice and improve outcomes. Neuroscience has always been evidence-based, whereas the field of education has just recently begun moving towards this status. However, using data to inform curriculum requires scientific literacy and the ability to critically analyze research; skills that the education field has not traditionally emphasized (Coch 2018).

Educational neuroscience provides educators with the ability to counter or support neuromyths (Coch, 2018). Neuromyths are generally defined as mistaken beliefs about learning and teaching loosely based on neuroscience findings. One example of an educational neuromyth is the belief that students learn better when they receive information in their preferred learning style (e.g. visual, auditory, or kinesthetic) (Coch, 2018). Contrary to this belief, research shows that an intact brain in the real world (ex. child in classroom) is virtually impossible to exclusively process information in a single sensory modality. In addition to this misconstrual of neuroscientific evidence, there is currently little behavioral evidence in support of the claim that matching preferred learning style with teaching style results in better learning (Coch, 2018).

There are several factors that contribute to the emergence and proliferation of neuromyths, most notably: (1) differences in the training background and professional vocabulary of education and neuroscience, (2) different levels of inquiry spanning basic science questions about individual neurons to evaluation of large-scale educational policies, (3) inaccessibility of empirical research which fosters increased reliance on media reports rather than the original research, (4) the lack of professionals and professional organizations trained to bridge the disciplinary gap between education and neuroscience, and (5) the appeal of explanations that are seemingly based on neuroscientific evidence, regardless of its legitimacy (MacDonald, 2017). Neuromyths spawn from challenges in the communication of educational neuroscience, rather than the validity of the science itself. Such communication challenges are not unique to educational neuroscience, but common to all translational or applied sciences that engage multiple disciplines (Feiler, 2018).

The impact of educational neuroscience is not merely in discoveries made, but in its potential to increase teaching effectiveness. In this respect, it has often been called a translational science (Feiler, 2018) and has provided further evidence to support issues such as social justice and equity (Coch, 2018). Integrating multiple perspectives informs a deeper understanding of the complexities of child development and learning in context and can highlight underlying causes of inequity such as poverty (Coch, 2018). For example, cognitive impairment among the socioeconomically underprivileged children who have problems adjusting to the educational environment can be identified and appropriately addressed through knowledge gained from brain research (Tandon, 2016).

Research Findings

Although educational neuroscience is a relatively new discipline, there has been a considerable amount of discussion regarding its potential benefits. Examples of recent empirical findings are provided below.

Research has shown that learning disabilities may be impacted by the use of educational neuroscience. (Dresler, 2018). Despite conventional instruction, adequate intelligence and sociocultural opportunity, a few children fail to achieve age-appropriate reading skills. This is defined as developmental dyslexia and is known to occur due to structural or functional disruption of the reading network in the brain. However, if detected early, children with dyslexia can be provided systematic personalized instruction that can help them cope with reading (Tandon, 2016).

Heissel, Levy, and Adam (2017) reviewed the literature on stress, illustrating how stress exposure results in changes in multiple biological systems. Importantly, stress exposure can impact hypothalamic-pituitary-adrenal activity and sleep quality. These can all significantly affect cognitive functioning and test performance. Furthermore, stress exposure and the resulting biological changes are differentially affected as a function of socioeconomic status and race/ethnicity, which has important educational implications in that those factors might contribute to the persistent racial-ethnic and socioeconomic achievement gap. In particular, stress exposure—which is more prevalent in low-income and minority populations—has detrimental effects on learning as well as the way that students respond to stressful situations, such as high-stakes testing.

Brockington (2018) found a positive correlation between the prefrontal cortex of a teacher and that of a child during an educational interaction. Since learning is a bidirectional transfer of knowledge, this finding may emphasize the importance of a teacher's role in delivering information to students at the right moment.

Educational neuroscience studies have identified the neural correlates of academic subjects such as reading and mathematics, clarified the causes of developmental learning disabilities such as dyslexia and dyscalculia, and documented the effects of interventions targeting these developmental disabilities and the level of brain structure and function (Soo-hyun Im 2017).

Al Dahhan, Kirby, and Munoz (2016) focused on the development of reading skills, as well as the difficulties to acquire those skills. They illustrated how neuroscience and cognitive psychology could play an important role in the early assessment of risk factors by integrating neuroimaging techniques, eye tracking, and behavioral assessments, as well as in revealing the potential mechanisms by which educational remediation approaches might be successful.

Kim and Cameron's (2016) study of atypical development can be especially helpful to obtain a better understanding of mathematics development and the underlying cognitive and brain mechanisms. To illustrate their point, they focused on two neurodevelopmental disorders—namely, autism spectrum disorder and Williams syndrome. They showed that individuals with autism spectrum disorder and Williams syndrome display distinct cognitive profiles, differentially affecting domain-general processes, and how they contribute to deficits in mathematical learning. As such, the focus on those disorders can reveal potential difficulties and/or developmental limitations in the acquisition of mathematical skills, which can in turn facilitate the development of interventions or strategies to help children with specific mathematical learning difficulties.

Libertus et al. (2017) investigated whether and how action video games that are thought to improve attentional brain networks might also affect mathematical skills. Based on their results, the authors suggested that this pattern could be taken as further evidence that interventions that successfully improve attentional control might have the potential to improve other cognitive functions that rely on those functions. The action video game training group did demonstrate some generalizing effects in standardized mathematics assessments requiring complex mathematical computations, which suggests that playing action video games might not be detrimental for performance in school-related tasks; but may actually support the development of complex mathematical skills.

Mangels, Rodriguez, Ochakovskaya, and GuerraCarrillo (2017) used neuroscience methods as a tool for assessing the impact of a small-scale intervention. They investigated how task instructions emphasizing the importance of mastery or performance goals to complete a challenging test might influence the neural response to negative feedback. Additionally, researchers also observed participants' task engagement and their ability to use this learning feedback to improve their performance in a delayed surprise test. Overall, the results showed that task goal framing did not affect the neural response to feedback processing

Tandom (2016) discussed two main streams of knowledge which link neuroscience to education: (1) brain structures responsible for various educational processes like reading, attention, memory, calculation, language acquisition etc., and (2) the manner in which educational processes affect brain structure and function. An example of the integration of these streams include learning to read. In order to read, children need to learn to associate sounds with letters, forming neural circuits between brain structures, originally specialized for seeing and hearing (Tandon, 2016).

Promoting interdisciplinary studies between neuroscience and education enables educators to ask neuroscientific questions and enables neuroscientists to ask educationally-relevant questions (Felier, 2018). Carew and Magsamen (2010) noted that new technologies and new innovations can lead to better learning. A prime example of successful interdisciplinary collaboration is a study conducted by Neville et al. (2013). Researchers utilized principles of neuroplasticity to design a family-based training program for at-risk preschool students that helps them to develop skills in attention both in the classroom and at home (Felier, 2018).

Gotlieb's (2017) evidence suggested that the brain's executive attention network (EAN) which undergirds the skills commonly measured for IQ-based determination of giftedness, is functionally distinct from the brain's default mode network (DMN), which supports many social-emotional, imaginative, and creative processes and divergent thoughts. Appreciating the skills supported by the DMN may help improve the way in which students are selected for gifted and talented education by expanding admissions criteria to include additional important capacities.

David A. Sousa's and Carol Ann Tomlinson's latest edition of *Differentiation and the Brain (2018)* provides updated strategies and classroom-tested examples, as well as specific guidance on implementing the various components of differentiated instruction. They also emphasize that the student population continues to become more academically and culturally diverse, making it more important than ever before to shift away from a one-size-fits-all approach to teaching and learning. Teachers need to find ways to use this brain research to develop strategies that will allow students to succeed in classrooms that contain a diverse mix of abilities, cultures, and languages (Globe Newswire).

Although Rivera et al's study (2005) was conducted several years ago, it is none-the-less considered pivotal work within this field. Their study determined that younger students utilize different brain regions to learn arithmetic compared to older students. Specifically, younger students require additional working memory and attention areas to attain the same level of arithmetic competence as older students. Because older students lack activation in regions used by younger students, it is suggested that as children grow, they depend less on working memory and attention when solving math problems. However, the conclusions drawn from this study can be applied into the classroom strategically if teachers provide skills training for younger students to help them improve working memory and attention, in parallel to (or prior to) lessons on arithmetic (Felier, 2018).

Field Critiques

As with any discipline, conflict between scholars exists and the idea that neuroscience could influence teaching practice in the classroom is sometimes controversial. A common critique of educational neuroscience is that it is a 'bridge too far'. Several scholars believe that neuroscience cannot be applied to the classroom because teachers and students are unable to transfer neuroscience directly into useful educational practices (Feiler, 2018). Scholars emphasize that a direct link between neuroscience findings and application in the classroom practice "from brain scan to lesson plan" may be an unworkable fallacy as much neuroscience research is descriptive rather than prescriptive (Coch, 2018; Howard-Jones, 2011, Murray, 2000; Ansari, Coach & De Smedt, 2011; Coch & Ansari, 2012).

Additionally, the complexity of learning in the brain and the state of current scientific knowledge means that there is a risk of premature translation before a foundation is established (Thomas, 2018). No classroom-ready knowledge from neuroscience is very likely to exist. This is true regardless of prior familiarity with educational topics, attitudes toward psychology, and knowledge of neuroscience. Therein lies the danger of untrained translation of the data, resulting in the promotion of neuromyths.

Another commonly reported critique of this field involves analytical differences in how the two fields are researched. The levels of analysis for teachers and neuroscientists may be different. Scientists want to understand how a student processes complex information compared to a teacher that wants to understand how formal instruction can best utilitze and develop these cognitive abilities in pursuit of specific educational accomplishments (Coch, 2018). Additionally, many key issues such as politics of eduational inequality are not directly addressable though nureosciene (Fusarelli and Bass, 2015). Neuroscience is primarily concerned with understanding how the brain works, whereas education attempts to change the brain regardless of its working (Rosenberg-Lee 2018). Additionally, neuroscience is by nature observational with the goal of understanding how the brain works; whereas education is fundamentally interventional and may suggest specific, systemic changes (Roseberg-Lee, 2018). Due to these differences, some scholars argue that most educational neuroscience research has yet to yield practical information useful in the classroom (Rosenberg-Lee, 2018).

Conclusion

As the research suggests, educational neuroscience is a field that holds great promise in contributing to effective learning opportunities. However, caution must be used when interpreting neuroscience findings to ensure accurate information is translated into practice. The use of a multidisciplinary team is highly recommended in order to effectively apply results into the classroom. Educational neuroscience should be considered as another tool for increasing student and teacher performance, especially when addressing students with disabilities and individuals representing lower socio-economic backgrounds. Current and future research continues to shed light on how the brain functions effectively during the learning process. These results will in turn enable educators to be more efficient in providing lessons and effective learning opportunities for students.

If interested in reading further about how to translate research regarding child neuroscience into practice in education, any of the articles referenced in this research capsule would provide a good overview of the field and where it is moving. Additionally, two resources that were recently published include Sally Featherstone's book titled, *Applying Neuroscience to Early Learning* and David A. Sousa's and Carol Ann Tomlinson's 2018 edition of *Differentiation and the Brain*. Featherstone's book covers the current thinking in educational research and neuroscience, how some of the findings have been misinterpreted by 'early adopters' or 'over-enthusiastic promoters', and how new information can help practitioners to be more effective in their work with young children. Sousa's and Tomlinson's book provides new references and findings from the cognitive psychology, neuroscience, and pedagogy fields.

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