NEUROSCIENCE CONCEPTS SUPPORTING TEACHERS' ADAPTIVE EXPERTISE

KRISTIN SIMMERS
PH.D. STUDENT
NEAG SCHOOL OF EDUCATION, UNIVERSITY OF CONNECTICUT
ORCID 0009-0009-3369-2959

SAMEERA MASSEY
PH.D. STUDENT
TEXAS A&M UNIVERSITY-CORPUS CHRISTI
DEPARTMENT OF CURRICULUM, INSTRUCTION, AND LEARNING SCIENCES
ORCID 0000-0001-8838-6005

ABSTRACT

Effective, responsive teaching benefits from a foundational understanding of the cognitive and neural mechanisms that underlie student learning, which can inform teachers' instructional decisions. This article explores the potential influence of neuroscience concepts on teachers' adaptive expertise, which can empower educators to navigate unpredictable teaching scenarios with efficient flexibility. The interdisciplinary framework of Mind, Brain, and Education (MBE) is proposed as a means to enhance this adaptability. Two core MBE concepts are explored: neuroplasticity, underscoring the brain's adaptability through learning experiences, and the intertwined nature of emotion and cognition in shaping the learning process. Integrating MBE insights offers educators a holistic lens with which to better analyze and respond to classroom dynamics using research-informed approaches, thus maximizing student engagement and learning outcomes.

Keywords: Educational neuroscience, teacher education, adaptive expertise, mind brain and education.

The demands of modern education require that teachers have a deeper understanding of how students learn and the underlying brain processes of learning to best inform their decisions (Council of Chief State School Officers, 2013). Teachers are faced with the challenge of raising all students' achievement, in addition to supporting students' holistic development. Achievement can be measured in numerous ways, including nationally normed tests, teacher-created assessments, and quantified observations. While there are several factors impacting student achievement, teacher quality has been identified as a critical factor (Dudley-Marling et al., 2006; Kunter et al., 2013; Stronge et al., 2007) and some say the greatest controllable factor (Hattie, 2003). Highly effective teachers, defined as those producing at least a year's worth of growth in their students, are distinguishable from less effective teachers by their beliefs about learning, critical and adaptive thinking, and judgements (Hattie, 2023). Mastering these process skills has greater influence on teacher effectiveness than mastery of content knowledge and specific instructional methods (Hattie, 2023; Männikkö & Husu, 2019).

Teachers make a high volume of planned and in-the-moment decisions in response to the varied emotional, social, developmental, and instructional information they gather about their students (Kennedy, 2019). Responding effectively to unusual or new situations requires the ability to identify and analyze novel situations, engage in flexible problem solving, and generate innovative solutions. This flexible application of knowledge and skills in the context of new situations is at the core of adaptive expertise (Ng et al., 2022). Adaptive expertise is the ability to use deep knowledge to flexibly address new and unforeseen challenges (Carbonell et al., 2014; Hatano & Inagaki, 1986; Novick & Holyoak, 1991) and is contrasted with routine expertise, which also involves a depth of knowledge but without the ability to adapt in response to unexpected or novel situations (Carbonell et al., 2014; Hatano & Inagaki, 1986). For example, a teacher with routine expertise might be successful if everything in a lesson goes according to plan, but struggle if unexpected situations arise (as they often do in teaching!). Novel situations in teaching that require adaptive expertise could be anything that adds a layer of complexity to the teaching and learning dynamic, such as a shortened class period, a technology glitch, students' emotional states, or a teacher realizing that the students are not learning as expected. In response to these dynamics the teacher has to make decisions to adjust and adapt. Teachers' adaptive expertise is influenced by the ability to interpret events in the classroom and by their knowledge and skills (Fairbanks et al., 2010; Männikkö & Husu, 2019), and we propose this may be of particular importance if the teacher has limited practical experience to draw upon. Therefore, we propose that a broad repertoire of research-based knowledge about teaching and learning could be advantageous for adaptive decision making and support adaptive expertise, as it equips a teacher with more lenses through which to adeptly interpret classroom events and choose an effective response (Blake & Gardner, 2007).

Adaptive expertise requires pulling from a broad knowledge foundation as opposed to deep knowledge in one area (Grotzer et al., 2021) and a dynamic interplay between practical and theoretical knowledge (Männikkö & Husu, 2019). This allows an adaptive expert, such as a teacher, to access prior knowledge from across domains and respond flexibly rather than prescriptively, allowing for more dynamic problem-solving (Grotzer et al., 2021). A teacher's ability to adjust their approach in response to multiple variables can be thought of as adaptive instruction or adaptive teaching (Parsons et al., 2017), and

researchers have identified this ability as an essential component to effective teaching, beyond basic content knowledge (Fairbanks et al., 2010). Furthermore, choosing an effective adaptive strategy for a particular situation requires analysis of cognitive as well as emotional conditions (Tokuhama-Espinosa et al., 2023), making a holistic lens based on multiple disciplines ideal for constructing a more complete assessment of the situation.

With an incomplete or inaccurate knowledge base, adaptive expertise becomes more challenging. It benefits teachers to have a more complete conceptual framework for making research-informed judgments about why, when, and how to apply specific strategies, responses, and tools (Hohnen & Murphy, 2016; Howard-Jones et al., 2020). Researchers studying thoughtful, adaptive teachers identified these common traits: teachers know when to apply "what" and "how" knowledge, and when not to; they know why certain knowledge would be appropriate in one situation but not another; and they proactively look for multiple perspectives and pursue multiple possibilities because they recognize and respond to the complex needs of their students (Fairbanks et al., 2010).

Providing teachers with a foundational understanding of neuroscience concepts related to teaching and learning provides an opportunity to both refine and expand teachers' knowledge base, enhancing their adaptive expertise from the start of their teaching careers. While there are many terms for the area where neuroscience and education overlap (such as educational neuroscience, neuroeducation, cognitive neuroscience, and even neurocognitive pedagogy), we will generally use the term Mind, Brain, and Education (MBE), as it is most clearly aligned with our integrative view of the field. MBE is an interdisciplinary field that explores the connections between neuroscience, cognitive psychology, and education, giving all fields equal weight, with the goal of creating a scientific groundwork to support teaching and learning (Fischer, 2009). Early evidence suggests that providing teachers with knowledge from MBE can influence their planning decisions (Schwartz et al., 2019), but more evidence is needed to understand this more fully. We propose that core concepts from MBE research have the potential to enhance teachers' adaptive expertise by providing a research-informed transdisciplinary lens through which to better understand complex teaching and learning dynamics, so that teachers are best supported in making informed decisions in response to their learners.

KEY MIND, BRAIN, & EDUCATION CONCEPTS SUPPORTING ADAPTIVE EXPERTISE

Identifying foundational "key concepts" of MBE can be complex because there are numerous robust resources to choose from, each providing slightly different perspectives, all well-supported by research. However, despite this diversity, several common MBE principles consistently emerge across multiple studies, including those highlighted in a 2020 international survey conducted by Tokuhama-Espinosa and Nouri (2020), which identified 18 MBE concepts with which teachers should be familiar. We found the majority of the core concepts identified by Tokuhama-Espinosa and Nouri (2020) to be related to teachers' adaptive expertise, such as "The brain is plastic and can change as a result of learning experience" and "Affective and cognitive processes are inextricably linked" (Tokuhama-Espinosa & Nouri, 2020, pp. 67-68). We interpret most of these core concepts as falling under two domains: the concept of neuroplasticity and the link between emotion and cognition. Here we explore them further.

NEUROPLASTICITY

Neuroplasticity is arguably one of the most impactful concepts for shaping teachers' decisions. Stated simply, "Plasticity is key to education" (Ansari et al., 2017, p. 200). Neuroplasticity is the idea that the brain is constantly changing and adapting in response to stimuli (Sousa, 2011). The term encompasses the formation and pruning of connections between neurons and how the brain continuously changes in response to experience and the environment (Ansari et al., 2017). Given its centrality to the learning process, the concept of neuroplasticity tends to be prominent in MBE research. We propose that understanding neuroplasticity can empower teachers with the knowledge that learning can shape the brain's development and thus inform adaptive decisions that foster diverse and effective teaching strategies.

In considering which aspects of MBE are most important for teachers to understand, a Delphi panel identified eighteen key concepts, many of which relate to neuroplasticity, either noting physical changes in the brain, such as "The human brain undergoes enormous development across the lifespan" or referencing the brain's malleability, such as "Intelligence is a malleable biopsychological process…" (Tokuhama-Espinosa & Nouri, 2020, pp. 67-68). This concept is also recognized in two of the six Principles of MBE established through the Delphi panel: "Neuroplasticity" and "Constant Changes in the Brain" (Tokuhama-Espinosa & Nouri, 2020, p. 65). It is also found among the "Concepts of MBE Teacher Literacy," which states "The brain is neuroplastic and can change as a result of learning experiences" (Tokuhama-Espinosa & Nouri, 2023, p.172). Several other researchers include neuroplasticity as a key MBE concept for teachers (Brick et al., 2021; Carrasco et al., 2015; Chang et al., 2021; Dubinsky et al., 2013, 2019; Schwartz et al., 2019), and some note that teachers who participate in neuroscience related professional development or interventions then report changes in their instructional decision making, such as using more student-centered practices (Brick et al., 2021; Schwartz et al., 2019), or allowing for repetition to enhance plasticity (Chang et al., 2021).

When teachers appreciate that neuroplasticity is present throughout the lifespan but is highest in early childhood, it underscores the importance of early childhood education and encourages providing children with access to a rich learning environment during this key stage of cognitive development. Understanding neuroplasticity builds teachers' knowledge base and provides support for principles such as growth mindset and for adopting a more positive perspective of student potential (Carrasco et al., 2015). Ultimately this challenges perspectives that hold intelligence as a fixed trait, and rather presents intelligence as a "malleable biopsychological potential to process information and problem solve" (Tokuhama-Espinosa & Nouri, 2020, p. 67). This recognition that intelligence is not fixed is important in education as it highlights the crucial roles that education and the environment play in helping learners to reach their full potential (Sousa, 2011) and is also identified as a core concept by the Society for Neuroscience (2008). Increased understanding of neuroplasticity can support teachers' adaptive expertise by shifting perspectives about student potential.

EMOTION AND COGNITION

The idea that emotion and cognition are inextricably linked is another prominent core MBE concept, and several researchers examine this connection in the context of education.

We maintain that recognizing the interconnectedness of emotion and cognition can enhance a teacher's adaptive expertise by informing their use of strategies that address both emotional well-being and cognitive development, thereby fostering a more holistic, responsive, and effective learning environment. Researchers have found relationships between emotion and several other aspects of learning, such as memory, attention, motivation, associative learning, and interpersonal factors in the classroom. Hamann (2001) and LaBar and Cabeza (2006) explored the role emotion plays in encoding, showing that valence (positive or negative emotion) and arousal (the intensity of the emotion) impact activity in the hippocampus and amygdala. They found that arousal, regardless of valence, can enhance memory encoding (LaBar & Cabeza, 2006). Talmi (2013) explained the neurocognitive role emotion plays in attention and long-term memory, which is essential for learning, exploring the neural mechanisms that support emotional memories being remembered more vividly and accurately. Several other researchers have explored the connection between the neuroscience of emotion and classroom practices, both directly and indirectly (Hammond, 2014; Immordino-Yang & Damasio, 2007; Li et al., 2020; Whiting et al., 2021). In what has become a seminal work in the field, Immordino-Yang and Damasio (2007) suggested that emotion is the first form of cognition and cannot be divorced from learning. They suggest that emotion steers reasoning and decision making and is key to the ability to apply learning in novel contexts. Immordino-Yang and Damasio (2007) introduced two key concepts from their findings: emotion is critical for applying learning in real-world and social situations, and culture shapes our cognition through emotion. We propose that knowledge from MBE, such as how emotion and cognition are interlinked, can support teachers in their instructional decision making, thereby increasing their adaptive expertise.

USING KEY MBE CONCEPTS IN ADAPTIVE EXPERTISE

Teachers' knowledge of MBE principles, including neuroplasticity and the interconnectedness of emotions and cognition can have a positive impact on their decision-making processes (Hohnen & Murphy, 2016; Schwartz et al., 2019). MBE's interdisciplinary approach aims to ensure teaching practices are based on robust scientific research, which should support teaching efficiency, or teachers "working smarter, not harder" (Sousa, 2011). To achieve this, teachers should have a foundational understanding of how the brain learns for adapting their instructional and interpersonal decisions to best support student learning.

For example, we can consider how the concept of neuroplasticity could help support teachers' adaptive expertise. Knowledge of neuroplasticity allows teachers to recognize that the brain is malleable and constantly changing, which can influence teachers' pedagogical practices (Gholami et al., 2022). When teachers are aware that specific brain networks (such as those responsible for planning abilities) continue to develop during adolescence and are influenced by experiences, they can adapt their instruction to provide the necessary guidance and stimulation for students' cognitive growth (Dekker & Jolles, 2015).

Studies have demonstrated that training teachers in educational neuroscience concepts, including neuroplasticity, has tangible effects on their pedagogical practices. For instance, after participating in a course that included neuroplasticity concepts, teachers' lesson

plans became more student-centered, emphasizing approaches that promote individual growth and adaptability (Schwartz et al., 2019). Additionally, instruction in educational neuroscience has been found to significantly increase teachers' mindset beliefs, further supporting their adoption of a growth mindset and the integration of neuroscientific principles into their decision-making processes (Gutshall, 2020).

Furthermore, a recent study suggests that teachers who possess knowledge about neuroplasticity tend to also have a more sophisticated epistemological belief system and are less likely to hold a fixed mindset (Gholami et al., 2022), meaning they are more likely to view intelligence and abilities as traits that can be developed through effort and practice. Teachers' mindset beliefs can also impact their decision-making processes and actions towards students (Gutshall, 2020). Researchers suggest that incorporating the concept of neuroplasticity into teacher professional development could support teachers in developing a holistic and growth-oriented approach (Gholami et al., 2022), which could positively influence their instructional strategies and interpersonal interactions.

The interconnectedness of emotion and cognition also supports adaptive expertise. Talmi (2013) suggests that emotional events, regardless of valence, result in increased involuntary attention as compared to neutral emotions when paired together. This means students pay attention to, and encode, emotionally charged information better than neutral information when presented as a seta set. A practical way teachers could use this is in deciding which texts, examples, or activities to use in the classroom. Those experiences and examples with positive or negative connotations would be encoded with less effort than neutral connotations. The adaptive teacher may apply this knowledge about the impact of emotional events in planning instruction ahead of time or as an adjustment after observing students. Furthermore, research indicates there is a delay in memory encoding when information is presented during these emotionally charged moments (Talmi, 2013). Again, this is useful for teachers' instructional planning; it suggests utilizing a delay when asking students to retrieve the information may yield better results than immediate retrieval tasks, an instructional practice known as "spaced retrieval" (Karpicke & Bauernschmidt, 2011, p.1250). The expert teacher may use this knowledge by first analyzing students' affect and making an adaptive decision about when to ask students to retrieve the information.

Other researchers have found that positive and negative emotions affect memory, attention, and higher-order thinking (Hardiman, 2012; LaBar & Cabeza, 2006; Li et al., 2020; Zadina, 2014) - a concept that can inform instructional planning. Li et al. (2020) provided a framework for understanding how positive emotions impact learning. Their study positioned social interactions at the center of developing positive emotions to strengthen learning. Mentalizing and mirroring systems in the brain help students process cues from social interactions which become essential in productive cooperation (Li et al., 2020). In essence, the evidence of mirrored and synchronized neural activity when participants are engaged with each other provides scientific credence to cooperative practices, and provides insight into nuances about what effective collaboration looks like (Dikker et al., 2017). In the classroom, knowledge of these processes translates to designing learning opportunities and interactions that improve communication and collaboration. Incorporation of dialogue and communication opportunities in the classroom that cultivate positive interactions is a key feature of utilizing this framework (Sousa, 2011). A teacher with adaptive expertise could use this information to adapt their

decisions based on their observations and analysis of student behaviors during instruction and collaboration.

Further, Li et al. (2020) pointed out the contagious nature of emotion in social situations. Negative emotions in one person spread to others, and the converse is likewise true. Because of mentalizing and mirroring functions in the brain, teachers' awareness of this phenomenon and how it functions can be useful in responding to students experiencing negative emotions or crises as well as provide the rationale for creating intentional opportunities to cultivate positive emotions. Stress and anxiety can positively or negatively impact student performance depending on the degree of arousal (Zadina, 2014), which relates to a common phenomenon among students today: test anxiety (Von der Embse et al., 2018). High levels of anxiety can negatively affect higher-level cognitive functions, including critical thinking and metacognition – skills a student needs to utilize in many educational tasks (Zadina, 2014), whereas milder arousal, such as perceiving a difficult task as a challenge rather than a threat, can improve student performance (Travis et al., 2020).

Yerkes and Dodson (1908) recognized this relationship between arousal and performance over 100 years ago in what became known as the "Yerkes-Dodson Law," which states moderate arousal is generally better for performance, whereas arousal levels that are too high or too low generally impede performance. This finding relates to testing anxiety because it suggests students who experience high anxiety during testing situations may be likely to have lower achievement on those tests because they are less able to perform optimally in these contexts (Richardson, Abraham & Bond, 2012). The observant and adaptive teacher may engage in more nuanced and deliberate observation of students prior to and during testing and be willing to find flexible solutions that allow students to do their best, such as providing more frequent, low-stakes testing that invokes a modest stress level in these students.

Teachers' understanding of the interconnectedness of emotion and cognition can have a profound impact on their decision-making processes, as emotions play a crucial role in learning and cognitive processes (Immordino-Yang & Damasio, 2007). When teachers recognize the interconnectedness of emotion and cognition, they can use this knowledge to improve learning opportunities for their students. Research emphasizes the importance of creating a positive emotional climate in the classroom as emotions shape attention, memory, and motivation (Hammond, 2014; Hardiman, 2012; Immordino-Yang & Damasio, 2007; Li et al., 2020; Whiting et al., 2021). Teachers who are aware of this connection can intentionally promote a sense of belonging among their students, foster meaningful connections between the content and students' personal experiences, and respond more flexibly to students' needs. By doing so, teachers can create an environment that supports cognitive engagement and deeper learning.

CONCLUSION

MBE principles can deepen teachers' understanding of how students learn and expand teachers' knowledge bases, providing greater potential to respond adaptively to the unique students and circumstances in their classroom. MBE concepts equip teachers with a foundational understanding of the cognitive and neural mechanisms that support learning, which can enhance teachers' adaptive expertise and enable them to make

research-informed decisions more flexibly and efficiently to optimize student learning outcomes. Key concepts in this area include neuroplasticity and the interconnectedness of emotion and cognition. Understanding MBE concepts more fully can inform teachers' pedagogical practices and promote adaptive expertise. The authors agree with previous recommendations that MBE principles be integrated into teacher training curricula. We propose this integration would support teachers with a holistic approach to education and empower teachers to more effectively meet the diverse learning needs of their students through broadened and research-informed adaptive expertise.

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