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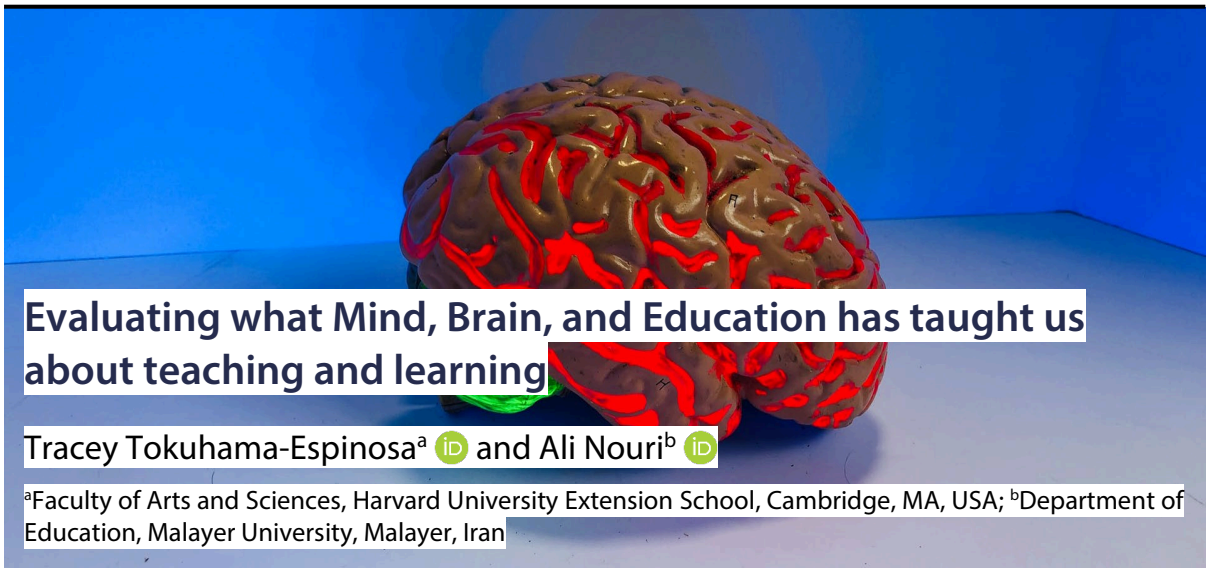

Evaluating what Mind, Brain, and Education has taught us about teaching and learning

Tracey Tokuhama-Espinosa[a] and Ali Nouri[b]

[a]Faculty of Arts and Sciences, Harvard University Extension School, Cambridge, MA, USA; [b]Department of Education, Malayer University, Malayer, Iran

(Connell, 2019)

ABSTRACT

The purpose of this study was to evaluate the current initiatives in the field of Mind, Brain, and Education (MBE) science that have potentially impacted the teaching-learning dynamic. Previous research, including a 2007-2008 International Delphi Panel on Mind, Brain, and Education, and a 2017 International Delphi Panel 10-year follow-up (Tokuhama-Espinosa) served as the primary source of review. The 2019-2020 survey sought to confirm the validity of the 2017 findings as well as to address additional components of teacher practices. Three-hundred and fifty-eight experts were invited to participate, and 112 actually completed the survey. These MBE, Educational Neuroscientists and Neuroeducators came from 30 different counties and were asked nine questions in which there was varying levels of consensus, suggesting a growing global consensus on teacher knowledge that should be incorporated into educator professional development. More research is needed on programs proclaiming to use Mind, Brain, and Education science in comparison with findings from this study in order to validate both current practice as well as explore new areas of teacher education.

KEYWORDS

Mind, Brain, and Education science; educational neuroscience; neuroeducation; teacher education; educational professional development

Introduction

This study evaluated the current initiatives in the field of Mind, Brain, and Education (MBE) science that have potentially impacted the teaching-learning dynamic. Previous research, including a 2007-2008 International Delphi Panel on Mind, Brain, and Education, and a 2017 International Delphi Panel 10-year follow-up (Tokuhama-Espinosa, 2017)[1] served as the primary source of review.[2] The 2019-2020 survey sought to confirm the validity of the 2017 findings as well as to address additional components of teacher practices. The authors hope that the results of this survey will further advance understanding of teaching and learning by determining what credible information should be shared with teachers from Mind, Brain, and Education science.

CONTACT Tracey Tokuhama-Espinosa tracey.tokuhama@gmail.com

Methodology

The present study employed a deductive qualitative online survey. Participants were selected using a criterion-based sampling technique. The final list of people invited to participate in the survey included 358 people[3] who were identified as influential in shaping MBE policy, practice and research. Of the 358 invitations sent, 112 people from 30 different countries completed the survey. Invitations were sent through email. Responses were gathered through SurveyMonkey© and one response was accepted per invitation. The survey had 42 questions and took an average of 22 minutes to complete. The wording of the survey questions on principles and tenets was based on the consensus of the 2017 Delphi findings.

One of the goals of this study was to determine if there was international agreement on what should be part of teacher training from a Mind, Brain, and Education science perspective. To do this, the current study sought answers to nine questions:

1. What principles of learning are supported by Mind, Brain, and Education research?
2. What tenets of learning are supported by Mind, Brain, and Education research?
3. What key concepts should be included in basic teacher knowledge?
4. What are the lasting contributions of Mind, Brain, and Education science to educational practice, policy and/or research?
5. What is the main aim of education based on Mind, Brain, and Education science?
6. What changes should be made in the current education system?
7. What should children be taught about the brain and learning?
8. How do experts distinguish the field of Mind, Brain, and Education science from Educational Neuroscience and Neuroeducation?
9. What are some possible careers for Mind, Brain, and Education science?

The first six questions are explained in this article.

Most survey responders self-identified as being from Education (23%), and the second largest group from Mind, Brain, and Education (19%). This was followed by Cognitive Neuroscience (10%), Educational Psychology (9%), Educational Neuroscience (8%), Developmental Psychology (6%), Cognitive Psychology (5%) and Neuroscience (5%). This created an imperfect, but relatively balanced input from people from in different learning sciences.

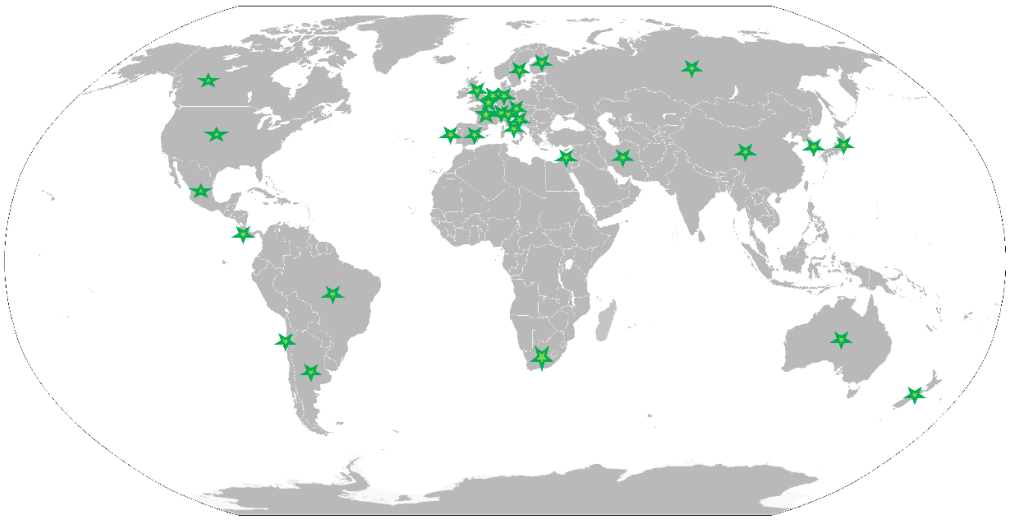

Figure 1. World Map Depicting Country Participation in the Survey.
Note: Each star depicts at least one participant.

This survey cast a broad net in hopes of gathering an international perspective on the topic. The final list of people who participated came from 30 different countries: Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Costa Rica, Finland, France, Germany, Holland, Hungarian, Iran, Israel, Italy, Japan, Mexico, New Zealand, Portugal, Russia, Slovenia, South Africa, South Korean, Spain, Sweden, Switzerland, UK, and USA.

Findings

Q. 1 What principles of learning are supported by MBE research?

In this survey, the term *principle* is referred to as a concept which is "universal" and has robust evidence for human brains independent of age, gender, or culture. Participants were asked to review six statements that are listed as the principles of learning (Tokuhama-Espinosa, 2017) (Table 1) and to answer if they agreed, disagreed or had no basis to reply. They were also invited to comment after each statement. The participants agreed with all six tenets, but to differing degrees, as seen in Table 1.

Principle	Agreement
Principle 1. **UNIQUENESS**: Human brains are as unique as human faces. While the basic structure of most humans' brains is the same (similar parts in similar regions), no two brains are identical. The genetic makeup unique to each person combines with life experiences and free will to shape neural pathways.	94.64%
Principle 2. **DIFFERENT POTENTIALS**: Each individual's brain is differently prepared to learn different tasks. Learning capacities are shaped by the context of the learning, prior learning experiences, personal choice, an individual's biology and genetic makeup, pre- and peri-natal events, and environmental exposures.	90.18%
Principle 3. **PRIOR EXPERIENCE**: New learning is influenced by prior experience. The efficiency of the brain economizes effort and energy by ensuring that external stimuli are first decoded, compared, both passively and actively, with existing memories.	84.68%
Principle 4. **CONSTANT CHANGES IN THE BRAIN**: The brain changes constantly with experience. The brain is a complex, dynamic, integrated system that is constantly changed by individual experiences. These changes occur at a molecular level either simultaneously, in parallel, or even before they are visible in behavior.	93.69%
Principle 5. **NEUROPLASTICITY**: The brain is neuro-plastic. Neuroplasticity exists throughout the lifespan though there are notable developmental differences by age.	96.40%
Principle 6. **MEMORY SYSTEMS AND ATTENTION SYSTEMS ARE NEEDED FOR LEARNING**: Learning involves multiple cognitive processes, including memory and attention. There is no new learning without some form of memory and some form of attention. Learners are not always conscious of these processes. Most school learning requires well-functioning short, working and long-term memory systems and conscious attention. However, other types of learning can occur without conscious attention (e.g., procedural memory, habituation, sensitization and even some episodic memory).	74.55%

Table 1. Mind, Brain, and Education Principles 2020 Results.
Note: If a Principle had less than 75% agreement it was modified in wording to reflect participants' comments. The evidence supporting the principles supplied by the 2017 Delphi panel and updated by the authors in 2020 can be found here.

Q. 2 What tenets of learning are supported by MBE research?

In this survey, the term *tenet* is a concept that is true for all people but with a large degree of human variation either due to culture, genetics, or prior experiences. Participants were asked to review 21 statements that are listed as the tenets of learning and to answer if they agreed, disagreed or had no basis to reply. The participants agreed with all 21 tenets, but to differing degrees, as seen in Table 2.

Tenet	Agreement
Tenet 1. **MOTIVATION** influences learning. However, what motivates one person and how may not motivate another in the same way.	97.72%
Tenet 2. **EMOTIONS AND COGNITION** are mutually influential. Not all stimuli result in the same affective state for all people.	98.18%
Tenet 3. **STRESS** influences learning. However, what stresses one person and how may not stress another in the same way.	95.45%
Tenet 4. **ANXIETY** influences learning. However, what causes anxiety in one person may not cause anxiety in another.	97.25%
Tenet 5. **DEPRESSION** influences learning. However, what causes depression in one person may not cause depression in another.	93.64%
Tenet 6. Learning is influenced by both **CHALLENGE AND THREAT** as perceived by the learner. What a person finds challenging or threatening is highly individualized as are their reactions to the stimuli.	88.99%
Tenet 7. Reactions to **FACIAL EXPRESSIONS** are both universal in that there are six or seven emotional states recognized by all humans, as well as highly individualized in that a person's culture as well as their own past life experiences condition responses to faces.	74.55%
Tenet 8. The brain interprets **HUMAN VOICES** unconsciously and almost immediately. The perception of tones and inflections of human voices are both universal in that basic emotional states, such as anger, are recognized by all humans, as well as highly individualized in that a person's culture as well as their own past life experiences condition responses.	73.39%
Tenet 9. **SOCIAL INTERACTIONS** influence learning. Humans are social beings who learn from and with each other. Different amounts of social interactions around learning are desired by different people.	96.36%
Tenet 10. **ATTENTION** is a complex phenomenon comprised of multiple systems supporting functions such as metacognition, self-reflection, mindfulness, states of high alertness, selective attention and focused attention. These systems work to different degrees in different people. These systems also have different relationships with one another in different people.	88.99%
Tenet 11. Most **LEARNING IS CYCLICAL** and advances and recedes based on stages of growth, reflection, consolidation, and the amount of repetition to which one is exposed.	86.24%
Tenet 12. Learning involves **CONSCIOUS AND UNCONSCIOUS PROCESSES**, which may differ by individuals based on their training and other individual experiences. Learning is also described as implicit (passive or unaware processes) and explicit (active or aware processes).	92.66%
Tenet 13. Learning is **DEVELOPMENTAL** (nature and nurture) as well as **EXPERIENTIAL** (nurture). A person's age, cognitive stage of development, and past experiences all contribute to learning and do so differently for each person.	89.81%

Tenet 14. Learning engages the **BODY AND BRAIN**, which is sometimes called embodied cognition.	78.70%
Tenet 15. **SLEEP AND DREAMING** influence learning in different ways. Sufficient sleep allows the brain pay attention during wakeful states and both sleep and dreaming (normally rapid eye movement [REM]) sleep contributes to memory consolidation. The amount of sleep and dreaming individuals need can vary based on cultural norms and habits, circumstances, motivation, genetics, and rehearsed sleep hygiene practices.	72.22%
Tenet 16. **NUTRITION** influences learning. Basic nutritional needs are common to all humans, however, the frequency of food intake, the gut-brain axis and microbiome balance, and some dietary needs vary by individual. Children cannot learn well when they are hungry in the moment, or systematically malnourished.	90.74%
Tenet 17. **PHYSICAL ACTIVITY** influences learning. However, different individuals need different amounts of physical activity to perform optimally. Interspersing physical and cognitive activity may improve learning.	87.16%
Tenet 18. **USE IT OR LOSE IT**. Brains that remain cognitively active help development and can also stave off cognitive decline during aging. Individual variations, including experiences and genetic predispositions, influence the final outcomes of interventions, however.	83.49%
Tenet 19. **FEEDBACK** about learning progress influences learning outcomes. Feedback itself can be a source of learning. The type, frequency and use of feedback can influence learning outcomes, which varies by individual. Different tasks require different types of feedback, and the degree to which it is attended to, perceived, and interpreted correctly depends on the context.	96.26%
Tenet 20. It is easier to retrieve memories when facts and skills are embedded in individually **RELEVANT AND MEANINGFUL CONTEXTS**.	92.59%
Tenet 21. Brains detect **NOVELTY** and seek out **PATTERNS**. However, what is novel to or recognized as a pattern by one individual may not be novel or may not be recognized as a pattern by another.	93.52%

Table 2. Mind, Brain, and Education Tenets 2020 Results.
Note: Those with less than 75% agreement were modified in wording to reflect participant comments. The evidence supporting the tenets supplied by the 2017 Delphi panel and updated by the authors in 2020 can be found here.

Q. 3 What key concepts should be included in basic teacher knowledge?

Participants were queried about what teachers should know about Mind, Brain, and Education topics. The participants were shown 11 areas of conceptual knowledge identified by members of the 2017 International Delphi Panel and were asked if they are important for teachers to know or not. They were invited to add additional concepts they thought necessary. Finally, participants were also asked an open-ended question: *"What do you wish all teachers knew about the brain?"* The resulting list may be considered the key conceptual knowledge to design effective teacher professional development on Mind, Brain, and Education.

1. The brain is plastic and can change as a result of learning experience.
2. Intelligence is a malleable biopsychological potential to process information and problem solve.
3. The brains' attention networks can improve as a result of training.
4. Neuromyths and their origins should be understood and they should then subsequently be debunked.
5. Cognition is embodied due to the interaction of the mind, body, and environment.

6. Affective and cognitive processes are inextricably linked.
7. Teaching environments need to meet the physical, moral, social, emotional, spiritual, and aesthetic needs and interests of the whole child.
8. Active memory retrieval (as experienced through frequent, low-stakes testing) can actually improve memory and boost learning.
9. Neurotechnology tools have yielded important insights into learning and development.
10. There is a reciprocal interaction between nature and nurture during development.
11. Neuroscience, Psychology, Education and Cognitive Science have come together to form the foundations of MBE.
12. The human brain undergoes enormous development across the lifespan.
13. Human variance and individual differences should be respected through the use of differentiated instructional strategies.
14. Executive functions can improve by integrating and teaching these skills as part of the curriculum.
15. Cognition develops within social and cultural contexts of learning.
16. There are multiple memory and attention systems which process information in different ways.
17. Neurodevelopmental disorders are impairments of brain function that can affect learning.
18. Neurobiological bases of domain specific learning (e.g., school subject matters mathematics, language, literacy and arts) should inform effective pedagogies.

Table 3. Key concepts in basic teacher knowledge related to the learning sciences.
Note: Multiple comments were synthesized into these single statements. Participants were given the chance to review and critique before this publication.

Q. 4 What are the lasting contributions of Mind, Brain, and Education science to educational practice, policy and/or research?

In an open-ended question, participants were asked: *"Globally, what would you say have been the lasting contributions of Mind, Brain, and Education science/Educational Neuroscience/Neuroeducation to educational practice, policy and/or research?"*

Globally, what would you say have been the lasting contributions of Mind, Brain, and Education science/Educational Neuroscience/Neuroeducation to educational practice, policy and/or research?
1. Enhanced understanding and value for transdisciplinary thinking
2. Increased knowledge and insights about the learning and developing brain
3. Awareness and debunking of neuromyths
4. Improvement in evidence-based educational practices

Table 4. What are the lasting contributions of Mind, Brain, and Education science?
Note: Multiple comments were synthesized into these single statements. Participants were given the chance to review and critique before this publication.

Q. 5 What is the main aim of education based on Mind, Brain, and Education science?

Participants were asked an open-ended question: *"What is the main aim of education based on Mind, Brain, and Education science?"*

What is the main aim of education based on Mind, Brain, and Education science?
1. To develop translational and transdisciplinary approaches to research
2. To ground education in scientific research
3. To offer a more comprehensive view on education to education practitioners, researchers and policy makers
4. To enhance teacher expertise
5. To better understand the mind-brain connection
6. To maximize the potential of every learner

Table 5. The main aims of Mind, Brain, and Education science.
Note: Multiple comments were synthesized into these single statements. Participants were given the chance to review and critique before this publication.

Q. 6 What changes are needed in education from a Mind, Brain, and Education perspective?

This was an open-ended question: *"From an MBE perspective and in your opinion, what changes should be made in the current education system?"*

From an MBE perspective and in your opinion, what changes should be made in the current education system?
1. Change the focus from teacher-centered learning to learner-centered pedagogies.
2. Change the focus of teaching based on intuition to evidence-based teaching.
3. Change the curriculum from fixed, predetermined, age-based objectives and evaluation to more flexible mastery-based assessments.
4. Integrate MBE courses in educational sciences curricula and teachers' professional programs.
5. Inform schools about neuromyths.
6. Focus on socio-emotional domain of learning as well as cognitive aspects.
7. Consider physiological influences on learning in policy design.
8. Design education around the basic general cognitive functions of attention, memory and executive functions.
9. Establish interdisciplinary and collaborative partnerships between educational researchers, practitioners and policy makers.

Table 6. Changes Needed in Education from a Mind, Brain, and Education Perspective.
Note: Multiple comments were synthesized into these single statements. Participants were given the chance to review and critique before this publication.

Discussion

This survey sought to better understand if there were elements of teacher education that could and should be incorporated consistently in teacher education. Findings indicate a growing, though not universal, consensus of what should be included in teachers' basic pedagogical knowledge as related to contributions from MBE.

As this study began, it was interesting to note that some questioned the need for more research on teacher knowledge related to Mind, Brain, and Education science. A few participants actually said that this seems a little "ridiculous" as "everyone already knows" this information. While we agree there is robust evidence, as seen in the more than 4,200+ documents which are embedded in the

descriptions of the principle, tenets and guidelines in this report, it is precisely because this information is *not yet common knowledge for teachers* that we decided to embark on this study.

Several initiatives are underway right now that promote the conscientious understanding, research and application of evidence-based practices about human learning, including knowledge about the brain and body in classroom settings and beyond. However, there remain close to a hundred neuromyths that are commonly sprinkled throughout teacher professional development, which are promoted by unknowing or unscrupulous teacher trainers. We hope that the information here will serve as a broad, internationally accepted parameter to guide educators' professional development.

There were four important themes which were echoed throughout participant comments.

The first is that most experts in the fields of Mind, Brain, and Education science know many, or even most, of the ideas presented in this report. While knowledgeable, however, most have not spent a lot of time considering the classroom applications of this information in real student-teacher learning dynamics. That is, *the researcher-practitioner model remains relatively rare*. Few teachers research well; few researchers teach well. This suggests more work is needed to nurture a new type of professional at the crossroads not only of mind (psychology), brain (neuroscience) and education, but also at the intersection of research and teacher practice.

Second, some participants in this study either *over- or underestimate the impact of certain scientific findings on learning*. It was not uncommon to find a participant acknowledge something as being true, but then label it as "unimportant in education". For example, one scientist said that it was true that facial expressions conveyed emotions, but then commented that it was unclear how this had any role in education. Similar comments were made about the ways that sleep and dreaming, physical activity, and challenges and threat are related to learning. Such comments suggest many people remain unaware of how the teaching-learning dynamic can potentially be shaped by this information.

Third, several participants commented on the need to *balance attention for the unique aspects of human learning with the globally similar aspects of human learning*. This means that teachers should be taught both that humans as a species are remarkably similar in how we learn to read or do math problems, while at the same time appreciate how and why we also differ in learning these skills. Both the similarities of human minds and brains, as well as the differences, should play a role in teacher education. Indeed, most of the remarkable imaging research over the past decade calls attention to how amazingly similar neural pathways are for estimating non-symbolic magnitude, common nutritional needs to fuel thinking, or learning how to read, for example. Similar does not mean identical, however. This means that while the differences between human brains must be acknowledged to tailor learning experience to the individual, so should teachers be taught about the ways brains are the same so that they can take advantage of "typical" learning trajectories.

Fourth, there was a sincere concern by many that *short, abbreviated statements can never capture the complexity of the science behind them*. Several people agreed that helping teachers have better access to information was important, but that this should not be done through "edible science," as one put it. One neuroscientist suggested that writing for a general audience always puts the integrity of the science at risk. Several initiatives can help here, including more and better researcher-practitioners in the field, improved scientific literacy by all teachers, and a change in attitude that embraces complexity over quick fixes in teacher education. This places a very important role on the translators and teacher trainers that use this information, who must do so responsibly and based solely on the evidence.

Mind, Brain, and Education science, along with Educational Neuroscience and Neuroeducation, are growing up and into their own potentials. As with any emerging entity, there are many rough edges to refine, and many traits to define. The authors hope that this report contributes to the

discussions, debates, and decisions about who we hope to become as learning scientists in these exciting times.

Notes

1. The 2017 International Delphi Panel on Mind, Brain, and Education can be found here.
2. This 100-page summary is meant to identify the highlights of the report. The full compiled report and raw data are available from the authors. Contact tracey.tokuhama@gmail.com.
3. The list of invitees can be found here.

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The authors worked independently and did into receive funding from any external sources. The authors declare there are no conflicts of interest.

Notes on contributors

Tracey Tokuhama-Espinosa, Ph.D. is an alumna of the Harvard Graduate School of Education, and currently a professor at the Harvard University Extension School in a course called *Neuroscience of Learning: An Introduction to Mind, Brain, Health and Education*. She serves as Associate Editor of the Nature Partner Journal *Science of Learning*.

Ali Nouri, Ph.D. is a curriculum specialist and educational neuroscientist who studies the neurocognitive bases of learning and cognition, and their implications for curriculum design and development. He works as associate professor in the department of educational studies at Malayer University, Iran.

ORCID

Tracey Tokuhama-Espinosa https://orcid.org/0000-0002-0661-4586

Ali Nouri https://orcid.org/0000-0002-4851-265X

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