Crossing Mind, Brain, and Education Boundaries

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By

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This book is dedicated to the memory of Kurt W. Fischer (1943-2020), transdisciplinary thinker and inspirational mentor.

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We wish to thank our colleagues around the world who participated in the 2020 survey conducted to evaluate what Mind, Brain, and Education science has taught us about teaching. They have challenged us, taught us, and helped us extend our thinking about learning sciences. This book would not be possible without the support received from several experts, most especially Professor David Daniel who contributed to the 2020 survey. We are grateful to all for their intellectual generosity.

PREFACE

WHAT YOU WILL FIND IN THIS BOOK

This book is a journey through time, looking backwards in order to move forward. Historical thinking is defined by Seixas (2006) as organizing collective experiences of the past such that they form a meaningful way to think about the present. Historical thinking allows educators a path to consciously prevent the repetition of the mistakes made in earlier renditions of problem-solving (Eisner, 1994a; Ponder, 1974). This type of thinking is crucial for all practitioners, especially teachers (Shulman, 2005) as "those who cannot remember the past are condemned to repeat it" (Santayana, 1905, 284). Like other disciplines, Mind, Brain, and Education (MBE) science has its unique history; MBE has grown out of the intersection of neuroscience, education, and psychology (see Fischer, et al., 2007; Fischer, 2010; Gardner, 2008; Tokuhama-Espinosa, 2008, 2010, 2011, 2014, 2018, 2021), with historical roots grounded in philosophy and episiotomy. These strong roots lay the foundation for research, practice, and policy in the discipline at an important moment in education in which millions are re-thinking the role of formal schooling due to revaluations during the global pandemic.

The research for this book analysed and synthesized the literature on the history of Mind, Brain, and Education as it relates to turning points in the evolution of the discipline. A scoping review which, according to Xiao and Watson (2017), aims to extract as much relevant data from each piece of literature as possible, was conducted to provide a snapshot of MBE and a complete overview of what has been done. The present research initiated with a systematic search of English language publications around the terms "mind, brain, and education [history]," "neuroscience and education history," "neuroeducation history," and "educational neuroscience history," on six databases: Google Books, Google Scholar, ISI Web of Science, PUBMED, ProQuest, and Scopus. This search led to the identification of a long list of articles and books. Because of the lack of a peer-review process or possible relevance to the research scope, many of the publications were excluded from the review as one of the goals of this work was to base all findings on solid evidence. Only five studies had investigated the history of the intersection between neuroscience, psychology, and education before this book, which builds from their excellent documentation. Through a snowball technique (Lodico et al., 2010) the citations from these five investigations were then used to identify further relevant literature. The search for additional studies stopped at the point of saturation, when each new set of citations in a publication began to repeat key references that had already been identified (Creswell, 2015). As the current lingua franca in science is English, the study was limited to this language. Key individuals mentioned repeatedly in the literature as being part of the formal construction of the International Mind, Brain, and Education Society (IMBES) from 1990 to the present were also interviewed or queried by email or teleconferencing about key events in recent history to confirm citations in the literature, and their recommendations for additional source material were included. A summary timeline of our findings is illustrated in the poster that can be accessed the hyperlink and/or QR code found in Appendix D.

In Chapter 1 we look at what can be gleaned from Ancient Civilizations to establish not only key hypotheses about how the human brain and mind work, but also to show that where we come from, why we are how we are, and how we shape or succumb to our own circumstances, have always sparked human curiosity. We then document how humans wavered between their wish to leave everything in the hands of God and their desire to be in control of their destiny. Here we look at the Middle Ages and delve into the role of religion as an impetus for learning, as well as the establishment of the first universities. During this time, drawings of the brain created by brilliant minds, such as that of DaVinci, Vesalius, and Willis lead to the first shared definitions of brain parts. We close this chapter with a look at the way the Renaissance provided the backdrop for philosophy to stream into educational thinking, thanks to the likes of Descartes, Locke, and Rousseau. This was paralleled in time, but divided by intellectual chasms, with the way medical physicians and other scientists began to be more methodological, and the scientific method was born.

Chapter 2 is devoted to homing in on specific scientific discoveries that catalysed very different theories of how the brain learns during the Industrial Revolution. On the one hand, ideas advanced by *localizationists*, or those who searched for a neat and clean division of brain functions, led to over-simplified interpretations of brain functions and to the pseudoscience of phrenology. On the other hand, some relished the new understandings of the electrical and chemical workings of the brain and ascribed to cell theory and a more micro analysis of brain functioning. The late 1800s brought with it new technologies, like better microscopes, which made the invisible visible and permitted a surge in more complex theories. We then look at the way the Second Industrial Revolution (1850–1900) brought a renewed, human-centric view to understanding learning. On the micro-level, specifically at the molecular and cellular level, neurons were better documented thanks to new technology developed by Golgi (from Italy) and used by Ramón y Cajal (in Spain) to establish the smallest unit of analysis for learning. At the macro, evolutionary level, animal observations–most notably by Darwin and Lamarck–led to hypotheses about human intellectual trait dominance, and the first intelligence tests were created. The "nature vs. nurture" debate, established back during Plato's time, was renewed with Francis Galton's ideas on eugenics, as was the postulation that some humans were naturally superior to others. The late 1800s firmly established the functioning of the nervous system and led to visions of how human learning is shaped by contact with the environment, including school settings. This is followed by a review of the remarkable consolidation of information about the workings of the human brain made possible through technology at the turn of the 20th century. A better understanding of neuroanatomy opened the door to the exploration of general cognitive functions, like memory. Modern educational practices, exemplified by the Dewey schools of the time, invited new theories based on a constructivist approach. The Third Industrial Revolution (1900–1950) was the first time the intersection of mind, brain, and behaviour was systematically studied, paving the way toward a more nuanced science of human learning focused primarily on early childhood development.

In **Chapter 3** we consider how the counter-culture movement in the 1960s united a surge of interest in how people learn to culminate in the Decade of the Brain in the 1990s. A new understanding of constructivism–how individuals build their knowledge based on prior experiences–combined with a growing understanding of how different environments influence learning created the shoulders upon which Mind, Brain, and Education could finally establish a footing. This time in history (1950–1999) was the perfect frame for three publications, which we explore in this chapter, which can be considered the foundational documents of MBE science.

The Digital Age (2000–2010), explained in **Chapter 4**, used the elements of the perfect storm between technology, neuroscience, psychology, and education to give birth to Mind, Brain, and Education science, including a formal society, an award-winning journal, and a regular conference. New academic programs in Mind, Brain, and Education science emerged around the world, and there was a flood of new publications in the discipline. This leap to formality caused concern in many, some claiming that bridging hard and social sciences was not useful, easy, possible, and/or desirable. Others urged caution due to the unchartered territory, leading to a new area of Neuroethics. The Human Connectome Project was launched, which, among other things, documented the complexity of human thinking and learning, and the influence of teaching, leading to a new appreciation of the intricacies of the human brain, closing the chapter on simplistic theories, including localizationism, and the resulting in the demise of eugenics. Along with MBE's debut and more global interest in the brain by people around the world came misinformation, however, and neuromyths flourished.

In **Chapter 5** we explore how research is being conducted in MBE. While MBE has an international society, a journal, and annual meetings, until the 2020s it could not lay claim to a specific methodology as neuroscientists, psychologists and educators have different types of ways of doing research. This chapter also looks at how MBE has evolved to include a "researcher-practitioner" model in which the ideal professional formation results in an individual who can walk the fence between neuroscience, psychology, and education in terms of basic knowledge, including teaching and researching skills. Additionally, while the critical role of technology on learning is mentioned throughout this book, the particularly interesting implications that it poses for Mind, Brain, and Education science are the focus of Chapter 5 as well. Interventions using knowledge gleaned from other learning sciences, including Artificial Intelligence, ushered in a different way to think of education spurred on by the analysis of "Big Data" and the first lab schools to monitor changes in children using measures from neuroscience, psychology and education simultaneously began a new age and established a unique methodology for MBE science. The growth of social media, online learning communities, and the collective intelligence of humanity began to corral neuromyths and counterpunch claims with evidence, elevating the general understanding of the brain. We close with a reminder that technology tends to lag behind human imagination, suggesting that interesting hypotheses about human learning may not currently have evidence or be visible with current tools, but they should be shelved rather than discarded.

The unification of different sources of input into MBE meant that the lines between neuroscience, psychology and education have become blurred in the past few decades. In **Chapter 6** we consider the semantics around the term "Mind, Brain, and Education" and the debate as to whether MBE is a discipline or a collection of concepts. Educational Neuroscience emerged as a formal discipline itself, increasing the need to distinguish what, if any, differences existed between the many learning sciences (neuroeducation, educational neuroscience, MBE science). Despite, or perhaps due to, the healthy debate about the borders between fields, new and exciting contributions have begun to emerge that benefit learners of all ages. In **Chapter 7** we turn to MBE's influence on has for teaching. Using data from the 2020 International

Survey to gauge changes in education stimulated by MBE, we consider the *Principles* and *Tenets* of Mind, Brain, and Education science as agreed upon in this international consensus that greatly change pedagogy, as well as the influence this may have on teacher education.

Projecting is just as much science as art; while the formula of the historical evolution of science appears to point to a clear trajectory–-toward the continued growth, popularity, use, and acceptance of MBE science–-it is unclear whether we may have hit a moment as Aristotle did in which current understandings stagnate for centuries, only to be revived when the time is ripe, or if MBE will continue to thrive and add new insights to educational practice. In **Chapter 8** we look at three possible changes in educational research that might occur as the scientific value of MBE becomes better appreciated. A significant lesson from this historical review suggests that ideas that might have once appeared siloed or separate can now be unified to tell a different story with transdisciplinary hindsight. This historical perspective of Mind, Brain, and Education science, along with its sister disciplines–Educational Neuroscience, Neuroeducation, Cognitive Developmental Neuropsychology, Neuro-Psycho-Biology–outlines a clear, albeit complex period of gestation and birth, but also a promising early childhood and future development. From a global, historical perspective, several clear patterns have emerged. Some of the more outstanding relate to scientific advancements, information access, new academic programs and interventions, and the globalization and transdisciplinary focus of science today.

This short book is meant for teachers and educators who value the history of science as a lens towards future practice. As a global overview, we acknowledge our work may not have done justice to each and every contribution towards the emergence of MBE over the past 5,000 years of history and invite further exploration on the part of the reader in other texts. *The Soul Made Flesh* (Zimmer, 2005) offers a wonderful narrative voice on the insights of human understanding about the brain. *Seven and a Half Lessons about the Brain* (Barrett, 2020) is a brief, how-to look at cognitive functions in a contemporary context. Immordino-Yang's work on *Emotions, Learning, and the Brain* (2015) is a fabulous collection of our modern understanding of the link between feelings and thinking. Bordeau and colleagues' "The Humanities in Medical Education: Ways of Knowing, Doing, Being" (2015) is an excellent reminder of how the hard and soft sciences can serve as compliments to one another. And for those interested in tracking the continually evolving refinement of teacher education, there is no better reference that Darling-Hammond and colleagues' *Educator Learning to Enact the Science of Learning and Development* (2022).

This book is different from the important contributions that have come before it in that it uses a macro-overview of multiple branches of the learning sciences – neuroscience, psychology, and education – to paint an historical overview in broad strokes to emphasize the collective contributions to our knowledge base and "ways of knowing" (Eisner, 1985) that are shaped by time, place and most importantly, culture and context. MBE is an international science, with contributions from nearly every country on earth. It is a transdisciplinary science, with contributions from nearly every learning science. And it seeks to share important messages about the human teaching-learning dynamic by translating evidence into useable knowledge. We hope the reader fills in the gaps between the broad strokes and digs deeper into the many facets of teaching and learning presented by the following pages, and that some may even use this book as a canvas for their own future work.

INTRODUCTION

THE SEARCH FOR WHY AND HOW PEOPLE LEARN

Learning and teaching are complementary human activities. All animals learn, but few know how to teach, and only humans have made a science out of the teaching-learning dynamic (Battro, 2010). To teach well, one has to understand how learning occurs in brains and minds, and how this happens within and due to various contexts (National Academies of Sciences, Engineering, and Medicine, 2018). Indeed, throughout history, people have developed hypotheses about the means, mechanisms, and influences of and on human learning. The history of research on learning can be traced back to the efforts by early philosophers regarding a long debate over the place of the mind in the human body more than 5,000 years ago. Knowledge grew over time and the early illustrations of brain functions in the late Middle Ages created common starting points for speculation, discussion, and research across Europe, the Middle East, and Asia. During the Renaissance, researchers continued investigations to localize mental processes based on scientific evidence. This was intensified by the early 19th century with the establishment of the field of psychology. In the mid–19th century, the theory of evolution had a profound influence on the understanding of the effect of learned behaviour on human evolution. Brain-lateralization theory rose at the end of the 19th century, and, in the early 1930s, the evidence became available to show that neurons could communicate with each other, and that human experience changes their communication. By the 1960s, there were clear attempts to show the potential implications of brain research on education. The early 1990s coincided with both increased knowledge about the brain, but also a proliferation of misconceptions about learning, including neuromyths. In the first decade of the 21st century, many formal associations and academic programs were launched through a new discipline that emerged at the intersection of mind, brain, and education. Different labels have been used to describe such programs, such as Educational Neuroscience, Neuroeducation studies, and Mind, Brain, and Education.

There continue to be vigorous debates in academic circles, however, as to whether differences between Mind, Brain, and Education (MBE) and other labels, such as Educational Neuroscience, are simply a matter of semantics, or if there are conceptual and philosophical foundations that distinguish them, which is explored further in Chapter 6. If viewed with 20-20 hindsight, we might suggest that this process of development parallels that of a foetus growing towards early childhood, or at an even more macro level, of the moment in evolution when humans split from other apes to establish a new species. However, it is possible that like evolutionary tracks in general, clarity on this question will only emerge after more time has passed.

As authors in MBE, we work with people around the world who we would quickly identify as "Mind, Brain, and Education scientists" including the past Presidents of the International Mind, Brain, and Education Society, Kurt Fischer (2004-2008), Antonio Battro (2008-2010), Marc Schwartz (2010-2014), Daniel Ansari (2014-2016), Mary Helen Immordino-Yang (2016-2018), Nora Newcombe (2018-2022), and Bert DeSmedt (2022-2024), and others whose research reflects MBE's goals, such as Stanislas Dehaene, Michael Posner, Nienke van Attenveldt, Janet Dubinsky, Paul Howard-Jones, Daniel Willingham, David Daniel, Jay Giedd, Howard Gardner, among others. Most of these MBE thought leaders do not self-identify as MBE researchers and often prefer to use more traditional fields of affiliation ("Neuroscientist"; "Psychologist"; "Educator"). This is an important stumbling block to growth in the discipline as we will explore further in Chapter 6, as most of the historical turning points in science are associated with key figures and thought leaders, which, if absent, lead to far more extended periods of gestation of ideas than would normally occur if promoted by a strong group of advocates. The complexity of MBE, its newness, and its slowly refining focus to laser in on the teaching-learning dynamic, is at once informed by and informs a new understanding of the brain and its place in educating about how we should teach to maximize each individual's potential. The lack of societal affiliation is at once a symptom as well as a cause of its slow but steady speed of development. While the name itself is of little consequence–a rose by any other name would still smell as sweet–important opportunities to influence public policy as well as to globally improve education are likely lost without explicit identity to the discipline. After all, no discipline exists without membership and membership depends on identity.

Having said that, this historical review shows that the pace of acceptance of MBE as a new discipline is actually far faster than the norm. Whereas it took Aristotle's understanding of the role of the senses as the way we learn about our world hundreds of years to gain acceptance, MBE has grown from a concept to a reality in just two decades. Even good, solid, modern, and "obvious" ideas usually take more than a generation to take hold. For example, the need for a field like Cognitive Neuroscience seems obvious today, however, few remember that it was born conceptually in 1976 and challenged in 1998, that it debuted in university faculties in the late nineties, finally being established in textbooks in 2002, and eventually embraced by 2008. Yet practitioners, who are often deep in their research, and seldom have the time to raise their heads above their detailed silos to appreciate long-term development, may sometimes be impatient and fail to realize that new ideas in science rarely occur within a single lifetime, let alone within the span of a professional career. This makes the early abandonment of the professional affiliation with MBE much like someone playing the stock market. If you simply leave the investment alone over time, it inevitably grows, but many are spooked by reduced gains early on and pull out, thinking to cut their losses, only to find that their profits would have improved if they would have stayed in for the long haul.

To establish a true understanding of the learning sciences would require a deft and complete review of what we know about human learning from multiple disciplines, ranging from the medical science to social sciences, with contributions from technology as well as from philosophy, morals, and ethics. There already exist a handful of excellent books that do this. Fischer, Hmelo-Silver, Goldman and Reimann's *International Handbook: The Learning Sciences* (2018), the National Academies of Sciences, Engineering and Medicine of the United States' consensus study report of *How People Learn II: Learners, Contexts, and Cultures* (2018), and Sawyer's *The Cambridge Handbook of the Learning Sciences* (2022) are gold star-references in this arena. Readers are encouraged to see these books for a more thorough understanding of our current knowledge of the complex phenomenon of learning. The goal of this humble book is slightly different and uses the learning sciences as an historical roadmap through humanity's quest to know itself better. With a better understanding of from whence we came, we can more easily navigate towards more complex goals in human learning broadly speaking, and in education as a science in particular.

Broadly speaking, the literature suggests human learning serves multiple goals. At its most basic level, the brain learns to ensure the body's survival (Kempermann et al., 2010). At its most complex level, the brain learns to create and innovate (Yang et al., 2018). The human brain is the seat of all learning (Chang, 2014), and it is the focus of many of the main findings highlighted in this book. The brain bas been said to be "the last and grandest biological frontier, the most complex thing we have yet discovered in our universe" (Gordon and Koroshetz, 2021, para. 1) and "the most complex organ in the body—and perhaps the most complex object in the universe" (Ackerman, 1992, iii), which is only just beginning to be understood (Tokuhama-Espinosa, 2015). This means that what is shared here should be taken in historical context and with a mind open to continued development.

In looking at the history of the learning sciences, we are guided by an overarching question: What useable knowledge for teaching comes from MBE and the learning sciences? Lessons from the original How People Learn (Bransford, Brown and Cocking, 2000) hint at key answers to this question. First, all learning hinges on knowledge (dates, facts, formulas, names, theories, concepts), skills (the ability to use the knowledge), and attitudes (value premises). Knowledge–such as the memorization of certain facts or formulas–is vital to learning but can be found on any Smartphone. This suggests that teaching should not only be focused on content alone. Skills can now be rehearsed based on personal needs using digital tools. This suggests that differentiation can be facilitated by technology. However, unlike knowledge and skills, attitudes, values and belief systems, require guided instruction from another human being. Deeper learning, not just the transmission of content, requires guidance from quality teachers (Darling-Hammond and Oakes, 2021).

Furthermore, one could argue that learning is a design problem. Leveraging prior knowledge (Witherby and Carpenter, 2021), giving time for reflection (Chen et al., 2017), and constructing learning contexts (García-Martínez et al., 2018) all help learning, and are only possible in the skilled hands of learning design specialists who are normally well-trained teachers (Darling-Hammond, 2017). The purposeful planning of classroom events (Stender et al., 2017), the balance of synchronous to asynchronous learning activities (Anderson, 2015), and the artful management of complex personalities in classrooms (Brophy, 2006) are all part of good instructional design. Finally, the most effective instructors know why their interventions work (Dome et al., 2005). That is, a better understanding of *why* leveraging prior knowledge (e.g., Witherby and Carpenter, 2021), time for reflection (e.g., Hodgkinson, 2021), and the design of learning contexts (e.g., Mandl, et al., 2005) work must be a part of every instructor's preparation. This necessarily requires knowledge of how the human brain learns best (Tokuhama-Espinosa, 2018). These ideas were reaffirmed by Tokuhama-Espinosa, Nouri and Daniels, 20 years after *How People Learn* was published, in an international panel to survey what teachers should be taught about the brain (2020). The consensus of 121 experts in the learning sciences from 29 different countries was that there are six principles in learning, –concepts that are evidence-based for *all* human brains, in *all* cultures, and *all* ages–which should be recognized as "basic" knowledge in the learning sciences. Experts also identified 21 tenets, which explain human learning, but which have to be considered within the broad range of human variability as no two people will leverage them identically. The tenets include things like motivation, which is a vital component for learning, but which is triggered by different stimuli for different people at different times in the learning process. This uniqueness exists because all new learning passes through the filter of prior knowledge, and no two people have identical life experiences.

Guidelines about how humans learn best can be built upon these foundational consensus-driven ideas. This is no small feat. The history of the learning sciences reached this important level of understanding after more than 1,000 years of development, international cooperation, compromises in language, negotiation of communication media, and great advances in technology. To better appreciate the "shoulders of giants" upon which the learning sciences currently sit, this book will review some of those historical highlights which presently permit the use of the principles and tenets as evidence-based guidelines for teaching and learning practice.

The information chosen for this book comes from all major branches of the learning sciences, including philosophy and history, and more modern constructs such as cognitive psychology and neuroscience. This book closes with the idea that the ultimate goal of the learning sciences is to improve teaching. Knowing that all animals learn, but only humans have made a science of teaching reminds all learning scientists, including teachers, trainers, coaches, and parents, that they can and should play a role in advancing knowledge through actions. Some readers will contribute by developing educational technology. Others will reach out to colleagues internationally. Some will improve their thinking processes through transdisciplinary insight. Readers may be inspired to move out of their comfort zones and learn the new language of learning for research. And others may have the imagination to create the next big insights into the human meaning-making and teaching exchange. All, hopefully, will commit to the rigour of being true to the learning sciences by using evidence-based information.

I.

THE HISTORY OF MIND, BRAIN, AND EDUCATION SCIENCE

CHAPTER 1

EARLY CONTRIBUTIONS TO MIND, BRAIN AND EDUCATION SCIENCE

The history of the learning sciences spans back to the earliest records in civilization. The ancient Egyptians, Chinese, Greeks and Roman separately at first, and then later collectively through translation, used basic observation of behaviour to hypothesize the origins of complex thinking. This means the historical relationship between brain sciences, mind sciences, and educational sciences is not particularly new. Indeed, knowing how the brain acquires new information and how these learning processes are affected by age, emotion, and context are questions that have long fascinated scientists (Blakemore and Frith, 2001).

Ancient Civilizations (3000 BCE–300 CE): Brain vs. Heart Hypothesis

The roots of humankind's complex understanding about thinking can be traced back in written form from the Egyptians in Africa, the Chinese in Asia, and the Greek, and Romans in Europe, and in oral traditions and pictographs from the Mayans in the Americas. Some of the primary debates in these earlier times shared by all of these cultures were about whether mental processes are located in the brain or the heart (Newby-Watson, 1988), what drives will, motivation, and learning, and how this influences the teaching-learning dynamic (Tokuhama-Espinosa, 2014). Perhaps one of the most interesting contributions from this early time is the transdisciplinary vision with which the major actors considered philosophy, religion, medicine, neuroscience, and education to develop their theories.

The first record of the neurobiological symptoms of brain injury was found in the Edwin Smith Papyrus reports written around 1700 BCE, nearly 4000 years ago, in which the first documented record of the word "brain" was mentioned. It is believed to be a copy of a much older treatise dating back to about 3000 BCE written by Imhotep, the famous Egyptian polymath and architect. It contrasts with most ancient subsequent medical writing which placed the heart, not the brain, as the seat of the mind and the centre of intellectual activity (Gross, 1987). Intellect and well-being, while complementary, were considered to be embodied in different physical structures of the body. Approximately 1,000 years after the Egyptian's first mention of the brain, the great Chinese philosopher, Confucius (552–479BC), contributed to what is now known as the Confucian theory of mind. His ideas influenced both theories about the nature of the human mind and methods of education, especially moral education. For Confucius, the mind was viewed as a mental substance that reflects, thinks, evaluates, and chooses. Confucius' ideas exist today in modern neuroscience, though limitations in technology still hide the precise neural correlates for these basic functions. Mencius (371–289 BC) and Xun Zi (298–238 BC) followed Confucius to develop a better understanding of the mind from the moral point of view, emphasizing the mind as a mental substance of both moral and cognitive functions (Chen, 2016). These ideas are fundamental to modern developmental theories 2300 years later.

Ancient Greek scientists also speculated about the anatomical seat of cognitive, motor, and sensory functions, and the origin of neural diseases (Crivellato and Ribatti, 2007). Around the same time as Confucius, Alcmaeion (500 BCE) was the first to identify the brain as a source of human consciousness and subscribed to what is now called "the brain hypothesis" or "encephalocentrism theory" (Stavros, 2014). Empedocles, another Greek, (490–430 BCE), located mental processes in the heart and subscribed to what is now called ‘‘the heart hypothesis" or "cardiocentrism theory" (Crivellato and Ribatti, 2007; Kolb and Whishaw, 2008; Newby-Watson, 1988). Empedocles explained that the blood around the heart is the most important vehicle of life and therefore, the source of human thoughts (Crivellato and Ribatti, 2007). Slightly after Empedocles, the more well-known Hippocrates (460–370 BCE) recognized the role of the brain in human consciousness and argued for the brain hypothesis (Ferrari and McBride, 2011). According to Hippocrates's view, there were four humours (blood, yellow bile, black bile, and phlegm) responsible for the states of health and illness, and mental insanity is a process of brain corruption induced by bile. The link between physical and mental wellbeing still exists today. For Hippocrates, the brain was not only considered the seat of intelligence, sensory perception, and motor control but it was also regarded as the source of pleasure and pain, the origin of emotions, and the font of moral judgment and artistic experiences (Crivellato and Ribatti, 2007), extending the physical and the mental to the ethical and aesthetical.

Plato (427–347 BCE) proposed the concept of a tripartite soul (nutritive, perceptual, and rational) and placed its rational part in the brain because that was the part of the body closest to the heavens (Crivellato and Ribatti, 2007; Kolb and Whishaw, 2008). To Plato, the brain was a "mental wax" that becomes grooved as we learn and recall information over the same pathways and becomes a smooth surface once again as we forget the information. He also contributed to the distinctions between nature and nurture and attributed individual human differences to nature (Newby-Watson, 1988). In opposition to Plato's opinion, Aristotle (384–322 BCE) recognized the heart as the source of mental processes because it is warm and active. The brain, which was cold and inert as Aristotle observed, served as a radiator to cool the blood. He also observed that, of all animals, humans had the largest brain relative to body size (which was later proven wrong; dolphins have the largest brain-to-body ratio of mammals) and interpreted this as evidence that our blood is richer and hotter than that of other animals and so requires a larger cooling system (Kolb and Whishaw, 2008). According to Aristotle, sensory input was the foundation of all knowledge (Newby-Watson, 1988). Just a half-century later, Aristotle's belief about the heart was proven wrong while his beliefs about the senses were confirmed. Alexandrian physicians, Herophilus (335–280 BCE) and Erasistratus (310–250 BCE) provided a remarkable contribution to the development of neuroscience with a modern approach to the dissection of the nervous system, the clear description of many neuroanatomical structures, the identification of cranial and spinal nerves, and the fundamental distinction between sensory and motor nerves (Sherrington, 1897).

After the turn of the century, early Roman physicians, such as Galen (129–216 CE), devoted much experimental and theoretical work to the study of brain functions and argued strongly for the brain hypothesis (Crivellato and Ribatti, 2007; Kolb and Wishaw, 2008). Galen identified the cerebellum as the area involved in motor functions and the cerebrum as the area involved in sensory processing and was proven partially right centuries later (Voogd and De Zeeuw, 2020). Galen went to great pains to refute Aristotle, pointing out that pressure on the brain causes cessation of movement and even death, whereas pressure on the heart causes pain but does not arrest voluntary behaviour (Kolb and Whishaw, 2008). Despite Galen's heroic efforts, the controversy between encephalocentrists (brain) and cardiocentrists (heart) continued well into the Renaissance and beyond (Newby-Watson, 1988).

This first significant stage in the historical foundations of Mind, Brain, and Education science from ancient civilization can be referred to as foundational and purely functional. On the one hand, the physiological structure of the human body in the West, and, on the other hand, the exploration of inner consciousness in the East joined to form the core knowledge base upon which MBE stands today. The Middle Ages, channelled by religious zeal, moved attention away from the physical body and personal reflection towards the intangible soul, however, and as an extension, the beginning of the understanding of how humans learn and believe things about their world.

Middle Ages (400–1300s): The First Universities and Illustrations of Human Brain Anatomy

In the Middle Ages, which lasted for about 1000 years (from 400 to 1300 CE), scientific investigations were almost always ignored except for a handful of theories proposed by clergy members who were, along with the rich and elite, the few educated people in society. During this period, philosophy and arts served to praise God and were used to stabilize the power of the Church (Foster-Deffenbaugh, 1996). God, rather than man, was the central force and the sole determinant of behaviour. As education was limited there was little reflection on pedagogical practices which were limited to oral traditions and direct instruction. The few universities that existed at the time looked very much like church congregations with an instructor up on high and the congregation below. The human body was assumed holy, and researchers had to steal the corpses from cemeteries to perform autopsies, which made research a dangerous and costly task (Hergenhahn and Olson, 2005).

While not very advanced in other areas of human learning, Medieval thinkers did accept Galen and Herophilus postulations on ventricular localization of mental faculties (Scatliff and Clark, 1992). In the 4th and 5th centuries, a theory that became known as the “cell doctrine of brain function” proposed by early church fathers such as St. Augustine (354–430 CE), suggested that the faculties of the mind were contained within the ventricular system of the brain (Lanska, 2021). At the time, it was thought that there were three (rather than the current knowledge of four) ventricles in the brain. The lateral ventricles were thought to be one cavity or the first cell. This cell received information from the special senses (i.e., vision, hearing, balance, taste, and smell) and was known as the cavity of “common sense”. Images and ideas moved from this cell went to the second cell (third ventricle) where they were incorporated into “reasoning”. The third cell (or fourth ventricle) was attributed to “memory” functions (Scatliff and Clark, 1992). While there was little hands-on learning at the time, thought leaders showed an extraordinary amount of imagination and reflection on the little physical evidence they had as they united the body with their theories of intangible thought.

The early illustrations of brain function formed in the late Middle Ages used what was known of the physical body to explain brain functioning. In this context, though later proven imprecise, Jehan Yperman (1295–1351) identified three functional areas of the brain including the front, responsible for discrimination of visual, gustatory, and olfactory senses, the middle, dedicated to intelligence and hearing, and the posterior, devoted to memory (Clarke et al., 1996). To try and localize mental functions, John of Arderne (1307–1399) depicted the cranial cavity as being divided into anterior, middle, and posterior parts and Magnus Hundt (1449–1519) published anatomical illustrations depicting the brain as covering special senses and ventricular systems (Newby-Watson, 1988). Leonardo da Vinci's (1452-1519) sketches of a centenarian brain and Andreas Vesalius's (1514–1564) anatomical work not only created detailed visual records but also led to the consistent naming of specific brain areas, creating common terms of reference and vocabulary (Tokuhama-Espinosa, 2008; 2011). For the first time in the history of humanity, there was a consensus building process to try and share knowledge about the brain's function. Among the most complete early versions of the brain were Christopher Wren's engravings for Thomas Willis' (1664) *Cerebri Anatome* (*The Anatomy of the Brain*) (Tokuhama-Espinosa, 2008, 2019), which provided an architecturally precise and proportional view of the brain. Later, it was shown that despite their accuracy, no two brain renderings were identical, which was not due to the inaccuracies of drawing quality, but rather because there are no two identical brains.

The Medieval Age in Western Europe coincided with the Islamic Renaissance (7th–13th centuries) when Middle Eastern thinkers made great historical contributions about human learning (Clarke et al., 1996). In Persia, or modern-day Iran, prominent scholars such as Avicenna, Rhazes, and Jorjani established a new kind of medical practice based on observational data. Ali ibn Abbas Majusi Ahvazi, also known as Haly Abbas in the West, was a renowned Persian scientist of this era who wrote a large medical encyclopaedia entitled *The Perfect Book of the Art of Medicine*. The book was comprised of 20 chapters, including one on neurology, each of which began with anatomical discussions and provided not only the description of diseases and treatments but also offered detailed explanations of bodily structures, including that of cranial nerves and sutures. Al-Haytham (Latinized as Alhazen), (965–1039 CE), was an Iraqi mathematician, psychologist, and physicist of the Islamic Golden Age. Biographers call him "the first scientist" and the "inventor of the scientific method" who established that learning is generated by our sensory perceptions of the world (Ghassemi, 2020). In this process, our senses feed