The Place of Neuroscience in Curriculum Thought and Practice

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Abstract: This paper presents an explanation of the potential contribution of neuroscience to curriculum theory and practice. An integrative review of the relevant literature suggests that curriculum thought and practice can benefit from neuroscience as an informative source of knowledge. Understanding the neural bases of learning and memory provide new and valuable scientific insights that can be incorporated into curriculum in a number of different areas. This study has outlined these insights into a set of broad and interrelated principles of learning and has described their important implications for curriculum theory and practice. It is concluded that, neuroscience research can be considered as a strong theoretical foundation for contemporary curriculum reform and therefore, the contribution of neuroscience in curriculum theory and practice should not be underestimated. What can neuroscience offer to curriculum theory and practice however, need to deliberately be explored and carefully be interpreted from a variety of perspectives.

Key words: Curriculum foundations · Neuroscientific foundation of curriculum · Brain research and curriculum

INTRODUCTION

Recent research on neuroscientific foundations of learning has introduced major changes in both methods and theories of learning and provided us with many notable insights and information about neural bases of learning, memory, attention, emotion, development, thinking and motivation which all of them are fundamental for education [1, 2, 3]. In light of these new insights, many educators and neuroscientists argue that linking education and neuroscience can play a major role in improving educational knowledge, policy and practice [4-12]. Additionally, some studies have revealed that there is a general consensus among educators and neuroscientist about the necessity to establish a strong link between neuroscience and education [13, 14]. This has encouraged some educators to say “those educators, who are unaware of how the brain learns, are like a cardiologist who studies veins, arteries and blood chemistry, but never learns how the heart works!” [5, p. 21]. Hart [15] also remind us that explosion of new knowledge about the brain is “an invitation to examine our practice and commit ourselves to drop what is ineffective and embrace promising new approaches that are brain compatible- compatible with the brain’s natural development and learning- rather than brain antagonistic- which can actually prevent learning” [p. xi].

There are also skeptics who have consciously warned educators against generating a number of over-simplified or over-interpreted assertions which have come to be labeled “neuromyths”. Examples of the most popular neuromyths include: 10% brain usage, brain gym, critical periods and left/right-brained students which do not have a basis in the neuroscientific and educational evidence [16, 17, 18, 12].

While this is still the case that research in neuroscience has been educationally misinterpreted and/or overgeneralized in some cases, it is fair to say that research in the neurosciences can and will be a valuable informative source to educational theory and practice in a number of different areas. The main reason why neuroscience is potentially important for educational issues is that it can identify some of the basic mechanisms of learning; once we have a good grasp of how these mechanisms work, we will be better able to offer viable knowledge for instance to those who design educational programs and those attempting to remedy specific difficulties in learning capabilities [19].

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What can neuroscience offer to educational theory and practice however, should be more carefully considered from a variety of perspectives in all subfields of educational sciences. This study addresses this issue from a curriculum studies perspective; as such, it has been represented in scholarly studies and writings in the literature. The purpose of the study was to review and synthesize brain research, particularly as it relates to curriculum in order to identify why and how neuroscience can inform curriculum theory and practice. With this intention in mind first, the necessity and possibility surrendering the contribution of neuroscience in curriculum is argued and then a set of brain compatible learning principles and their implications for curriculum thought and practice are introduced.

Why Neuroscience Can Inform Curriculum Theory and Practice?: To understand why neuroscience can inform curriculum thought and practice, we firstly need to consider what curriculum means, even though defining the concept of curriculum is perhaps a difficult task, as it has been defined in wide variety of ways [20]. In the following argument however, curriculum is conceived as “series of planned events that are intended to have educational consequences for one or more students” [21, p. 31]. These events include what students have an opportunity to learn in the school through both the explicit and implicit curriculum; and what they do not have an opportunity to learn because certain matters were included in the curriculum- what is called the null curriculum [22, 21]. Such an interpretation of curriculum implies that there will be more than one event planed, although theoretically one could have a single event or activity constituting curriculum (but that likelihood is small) [21].

Curriculum in this conception therefore, is the system within which a set of wide variety of decisions are made about what the curriculum will be and how it will be designed, developed, implemented and evaluated to engage students in events or activities that will have educational benefits for them [23, 24, 21]. However, in order to make more informed curricular decisions, curriculum practitioners ought to think more deliberatively and holistically about curricular concerns. According to Gardner [25], they “ought to be able to think about educational issues from a number of angles and they ought to have enough familiarity with other relevant disciplines so that they can at least participate meaningfully when important issues are being addressed” [p. 69]. Schwab [26] referred to this quality as “polyfocal conspectus” which is the employment of a variety of lenses and perspectives to view curricular issues. In principle, no single perspective can provide an adequate foundation for curriculum making. It is the polyfocal conspectus that asks us to recognize and master multiple theories without really doing much to compare one to another and then helps us to see how one theory can complement another. Eisner [21] has supported this position by stating that “to engage in curriculum development, one must put together much more than any of the theories can provide either individually or collectively” [p. 39]. He stated that theoretical training requires intensive study of relevant disciplines within philosophy and the social sciences and the critical analysis of one’s written work by competent critics [21].

What is needed more urgently however is increasing and continuing dialogue between theorizers at all levels, from teachers to academics, so that we can learn from our history and our diverse perspectives [20]. Indeed, the insights from the nexus of all disciplines relevant to the curriculum field provide powerful foundations for curriculum that influences thinking about curriculum deliberation, development and implementation. A basic understanding of curriculum foundations will provide the basis for determining the direction of an educational program [27]. Thus, as William Bristow [28] stated intelligently more than two decades ago “modern curriculum foundations rest on the synthesis of many disciplines. An adequate treatment of foundations therefore would be broad in scope.” [p. 221].

Philosophy, psychology and sociology have historically been viewed as the major foundations of curriculum; while it also can benefit from other areas of knowledge such as [but not limited to) historiography, anthropology, psychoanalysis and neuroscience. This article focuses specifically on the insights which neuroscience could offer to curriculum thinking and practice. This attempt is justified by the belief that neuroscience can inform curriculum theory and practice; and that this field not only has not been a major concern in curriculum studies, but also has been underestimated in the established discipline of education [29, 30, 31]. Overall, learning happens primarily in the brain and studying the neuroscientific bases of learning can therefore provide educationally relevant insights that with careful implementation and evaluation may improve schools and other learning environments for the generations to come [1]. Furthermore, as Worden, Hinton & Fischer [32] have pointed, “ignoring important findings from research in neuroscience can be just as dangerous as
uncritically embracing products or interventions that claim to be based on these findings” [p. 9]. In this way, the importance of neuroscience research as a theoretical foundation for curriculum should not be underestimated. However, it needs to move beyond neuromyths and false claims and establish a rigorous research foundation for learning and teaching in educational settings with emphasis on carefully grounded analysis of neural, genetic, cognitive and emotional components of learning [33].

It should also be mentioned that whereas neuroscience could inform curriculum by providing additional evidence in support of good practice by helping to resolve educational dilemmas or suggesting new possibilities in curriculum making; curriculum research could also inform cognitive neuroscience by providing a source of complementary behavioral data, as well as posing new worthwhile lines of investigation. Therefore, biology and cognitive science have as much to learn from education as education has to learn from them [34; 35].

How Neuroscience Can Inform Curriculum Theory and Practice?: Although there is no reputable debate over the significance of neuroscience for education, there is a little controversy over the potential possibility of linking neuroscience to education and curriculum. June Bruer is one of those who started his criticism on making any direct link between neuroscience and education from more than a decade ago and even recently has asserted that “so I remain skeptical about the implications of neuroscience for education currently and into the near future. Maybe I should say the direct implications of neuroscience for education. I do believe that eventually we will be able to bridge neuroscience at its various levels of analysis with education, but I am convinced that all of these bridges will have a least one pier on the island of psychology” [36, p. 109]. Bruer [36, 37] argued that it is too early to think about the applications of brain science for educational practice and the bridge between neuroscience and education is too far. He proposed “cognitive psychology” as a potential link which can bridges the gap between them.

There is no reputable debate over the significance of cognitive psychology for education. According to Jensen [38] cognitive psychology has provided a great deal for educators and will continue to do so. However, as Blakemore & Frith, [2] argue, there is a vast amount of brain research of direct relevance to education practice and policy and now is the time to explore the implications of brain science for education. They have pointed out that “we do not think that it is too early to think about the educational applications of many achievements of brain science” [p. 464]. Indeed, understanding the brain mechanisms that underlie learning and teaching could transform educational strategies and enable us to design educational programmes that optimize learning for people of all ages and all needs [2]. We know that the brain is the major organ of learning and neuroscience is the study of the brain. It is therefore clear that neuroscience will be important for education and may have many important implications for curriculum theory and practice [9].

Moving from neuroscientific knowledge such as an image of brain activity directly to educational application however, is difficult in many cases [33]. Indeed, a long history of applied research shows that the path from research to application is never straightforward and often is very indirect [39]. It is clear that no such direct application of neuroscience research to curriculum application is possible. Therefore, curriculum strategies and guidelines need to be concluded from the principles of learning which are derived from our understanding of the learning brain. These implications serve as guides to make curriculum practice more effective and broadly supportive.

What Neuroscience Can Offer to Curriculum Theory and Practice?: In recent decades, several attempts have been made to investigate the implications of brain research for education and there are number of principles of learning supported by empirical studies which may be safely incorporated into learning and teaching [12, 9, 40]. Up to now however, no systematic attempt in this area has been devoted to derive brain compatible principles particularly in relationship to curriculum theory and practice. To this end, relevant literature is reviewed and a set of broad and interrelated principles, with a particular focus on their implications for curriculum theory and practice are drawn and introduced.

Taken together, these principles show the need for integration of insights from neuroscience with other foundations of curriculum toward making more informed decisions about curricular components. Although this review may not include all the curricular implications of research in neuroscience, it provides a useful explanation to build bridges between research in the neurosciences and research, theory and practice in curriculum. These principles and implications are briefly described below.
Each Brain Learns and Thinks in a Unique Way: The rapid development of neuroimaging techniques has provided us with methods to investigate the differences among individual brains, both in terms of their anatomy and functions. There is a body of evidence suggesting that individual differences in brain functions can be reliably assessed. Based on these studies, two human brains are never alike and therefore students never learn and think the same way. The results implied that, while there are general patterns of organization in how different people learn and which brain areas are involved, each brain is unique and uniquely organized [41, 42, 12, 5]. These differences are expectable; because people are not identical in terms of their genetic potentials and their experience through the lifespan [41, 42]. Taken together, while search for patterns and context may be universal, every brain is unique. The key message of these findings for curriculum is that while there is a universal process by which all learn by the same physiological process of neural growth, each student learns and thinks in a unique way [5].

These neuroscientific findings about the brain uniqueness are also consistent with the theory of multiple intelligences, new view of intelligence that is rapidly being incorporated in school curricula. According to multiple intelligences theory as proposed by Howard Gardner [43], human beings have at least eight relatively autonomous intellectual capacities in their learning approach and activities. For Gardner, these are not simply aptitudes or talents, but socially important ways of solving problems. Furthermore, he argues that environmental conditions have something to do with the particular kind of intelligence that is valued and practiced [as cited in 21]. According to Gardner's theory, “the ways in which intelligences combine and blend are as varied as the faces and personalities of individuals” [44, p. 34].

In short, each student has a unique combination of intelligences and it implies that curriculum activities should be presented in a variety of ways in which all students with different intelligence profiles could actively engage in the teaching- learning process. Educational implications of these findings are quite important, because they represent neuroscientific foundations of individual differences and the necessity to adopt a differentiated approach towards curriculum design and instruction. In principle, the key point here for curriculum practitioners is that prescribing a single and unified curriculum for all students and assessing them in a similar fashion regardless of their differences not only is unjust but also is not supported by scientific research.

Learning Is a Social Process: We have social brains. Although learning takes place in the independent brains, learning is highly enhanced by collaboration and social interaction. The wealth of studies has shown more clearly that the complex mammalian brain is evolved in complex social environments [9]. There is also much evidence in support of the notion that early humans have learned socially and much of their learning has been through their interactions and their social relationships [45, 46]. Recent studies in evolutionary neuroscience indicate that even young infants are predisposed to attend to people and are motivated to copy the actions they see others do. They more readily learn and reenact an event when it is produced by a person than by an inanimate device [48].

Another interesting evidence from cognitive neuroscience in support of social learning is the discovery of mirror neurons which is believed to play an important role in understanding the actions of others and hence, our ability to learn by observing and/or imitating others’ behaviors. Specifically, it appears that watching other people’s actions and inferring their emotions and implicit goals recruits some of the same neural systems involved in planning and carrying out those actions by one’s own self [1, 47]. The social nature of human learning means that learning with others is usually more effective than learning alone and that lends support to design curriculum that is personally meaningful and culturally relevant to students [9, 49, 12].

This new insights are also consistent with cognitive psychology notions and educational research findings, which have demonstrated the importance of cooperative learning strategies in students' thinking and learning. Among the most notable of these efforts, Ann Pihlgren [50] has summarized philosophical and theoretical foundations of dialogue and has shown why and how Socratic seminars can be incorporated into curriculum. In this sense, the Socratic dialogue is a way of knowing and learning that can be considered as one standard model for teaching [47].

The social nature of human learning, according to Jensen [38] reminds us that we should be more active in managing the social environment of students, because students are more affected by it than we thought. In practical terms, it means that school curriculum program should provide a variety of opportunities for creating and supporting social interactions and relationships at school.
Emotions Are Fundamental to Learning and Thinking:
As a consequence of many years of study, researchers now know that emotions have critical impacts on learner's ability to think rationally and learn in a meaningful manner. While neuroscience research has shown that cognitive and emotional processes are integrated in the brain at multiple levels, educational settings often emphasize on logical reasoning skills and factual knowledge as the most direct indicators of educational success [1, 51]. As Immordino-Yang & Damasio [51] has noted, there are two problems with this approach. First, neither learning nor recall happen in a purely rational environment, divorced from emotions. Second, in teaching students to minimize the emotional aspects of their academic curriculum and function as much as possible in the rational domain, educators may be encouraging students to develop the sorts of knowledge that inherently do not transfer well to real-world situations.

Clearly then, cognition and emotion are two sides of the same coin and most of thought processes that educators care about, including learning, attention, memory, decision making and social functioning involve both cognition and emotion [1, 51, 12].

Recent studies show that stress, particularly chronic stress, disrupts the brain’s ability to shift attention [52] and undermines learning by impairing students’ ability to decision making [53]. Since emotional responses have the power to either impede or enhance learning, learning is likely to be more effective if educators help students to minimize their stress and fear at school, teach them emotional regulation strategies and provide them with a positive learning environment that is motivating [54, 4, 55]. Such an emotionally positive and supportive climate is the key to developing the optimal state of mind, what is called “relaxed alertness state of mind” [56]. The relaxed alertness is defined as a state of mind that learner feels competent and confident and has a sense of meaning or purpose. Learner in this state experiences low threat and high challenge, both of which are essential to mastering new skills and engaging the executive functions [56].

Decades of research in the cognitive neuroscience of emotion and attention have also led to the widely held view that the brain not only absorbs information of which it is directly aware, but it also learns from a context it rarely consciously attends to. Simply put, human learning involves both focused attention and peripheral perception [56, 12]. The central point here is that the context teaches and children in school are actually being profoundly influenced by the total environment [56]. This echoes the belief of many educators that the teacher’s values, beliefs and attitude to learning could be as important in the learning process as the material being taught. It is those attitudes and beliefs that are easily picked up and imitated by learners even when not intending to do so [2]. In fact, students learn a great deal from each other, from how the adults interact and from what those adult value and adapt [56].

This insight clearly confirms what is known as “hidden curriculum” or “implicit curriculum” [21] in the literature of curriculum studies. The implicit curriculum generally refers to an unwritten curriculum that students experience from the interaction with the physical and cultural structures of the school. Curricularists therefore, need to pay extensive attention to all facets of the educational context that influence students learning and thinking.

The Brain Is Plastic and Capable of Learning Throughout the Lifespan: Several studies have shown actual structural changes in various parts of the brain as a result of learning [57]. The brain is constantly changed by experiences, even the adult brain is flexible and it can grow new cells and make new connections, at least in some regions such as the hippocampus [2]. Experiences gradually modify the connections between neurons according to ‘use it or lose access to it’ rule [12]. As a result, the active connections are stabilized and strengthened, while less active ones are weakened or eliminated. Gradually, these modifications aggregate to significant changes in the brain structure and function [55]. In other words, learning experiences change and reorganize the brain's structure and physiology at the cellular and network levels [54]. In this stance, according to Koizumi [29] learning may be defined as the process of forming neuronal connections in response to external stimuli.

This process of brain's capacity to adapt continually to changing circumstances and conditions is called “neuroplasticity” [2]. The brain's ability to reorganize itself in response to new experiences is what makes it possible for us to learn throughout our life [2, 12]. Research on plasticity suggests that the brain is well set up for life-long learning and adaptation to the environment and that educational rehabilitation in adulthood is possible and well worth investment [2].

Current research in neuroscience suggests that human brain learns what it needs to learn in order to survive. This confirms what many teachers have learned
by experience: when learning is linked to real life experiences, students retain and apply information in meaningful ways [58]. The key point for curriculum practice is that students’ brains are naturally more ready to learn if curriculum is related to their personal lives and needs [58, 38].

Moreover, there are many evidences indicating that humans develop concepts through an active process of adaptation to new and challenging experiences. In other words, authentic learning situations increase the brain’s ability to make connections and retain new information in a meaningful manner and this is due to the fact that motivation tends to be higher if facts and skills are embedded in natural contexts [12]. Hence, designing curriculum and instruction around problems/projects is an appropriate tool for improving students' learning and thinking that not only engages them individually, but also encourages them to learn from each other. It also calls for the students to formulate solution strategies and to continually re-evaluate their approach in response to outcomes of their efforts [59].

The Search for Meaning Is Innate and it Occurs Through Patterning: Humans are natural meaning-seeking organisms. The human brain is constantly searching for meaning and seeking patterns and connections and resists against any meaningless information imposed on it [56, 58]. Studies strongly support the notion that the brain connects and organizes new knowledge on the basis of previous experiences and the meaning that are developed from those experiences [12, 11]. It means that our brains are biologically designed and intrinsically motivated to learn conceptually as a survival function [62]. Geake [63] argues that, if thinking requires the concerted effort of numerous modules located in different parts of the brain across both hemispheres, we should promote integrative thinking.

Based on this principle, it is argued here that educational programs could be designed based on the big ideas or themes such as concepts, authentic problems and projects, what is called “thematic curriculum”. Thematic curriculum is an integrated approach to curriculum design focused on a broad theme as an integration canon for enhancing meaningful learning. This approach is strongly supported by current neuroscience and cognitive science research [64, 65, 49].

As educators have long known, concepts are one of the most useful tools for integrating curriculum contents and student's learning experiences. Edward De Bono's works on lateral thinking remind us that concepts constitute a very important part of thinking, especially creative thinking in particular. He points out that “concepts are the brain's way of simplifying the world and actions in the world” [66, p. 254]. Caine & Caine [67] have also argued that a concept is “an idea that organizes and makes sense of facts. It pulls facts together and can be used to sift through information. It is a way of thinking and makes it possible for us to generate explanations for ourselves” [p. 161]. They emphasize that teaching for understanding requires teaching in a way that “students get the underlying concepts” [67].

There Are Multiple Ways of Knowing and Representation: We now know that the brain is a parallel processor that performs many tasks simultaneously. There is no single place in the brain where meaning occur, but a variety of related interconnected neural networks coordinates their activity to produce a united mental concept [38, 60]. Neuroscientific studies also indicate that different types of memories are stored in slightly different areas of the brain. It means that the same information received through various sensory channels are processed in different neural pathways [12, 8].

In brief, ‘parallelity’ means that the elementary functions which make up complex functions are performed simultaneously in different areas of the brain and not one after another in serial fashion [8, 10]. Moreover, as neuroimaging studies have shown, the more student are engaged in a learning activity using multiple sensory modalities, the more parts of their brain are actively stimulated [61]. Such findings support the idea that the school curriculum need to provide opportunities to benefit from advantages of parallel processing. In a broader sense, it means that children demonstrate multiple modes of knowing and learning and represent their knowledge in multiple ways [21, 62].

This principle is also supported by cognitive pluralism orientation to curriculum which is heavily represented in the works of Eliot Eisner and Howard Gardner [21]. The main message of cognitive pluralism is that understanding is secured and experienced in different ways. Looking at multiple perspectives rather than only one right way, allows more energy to be concentrated upon the problem and its solution [20]. In short, the key message of this principle is that school curriculum program should provide a variety of challenging and interesting ways to encourage and engage all students in solving problems and producing new results.
Conceptual understanding creates a synergy between the lower (factual) and higher (conceptual) levels of thinking. In a thinking classroom, facts become tools to develop concepts and make generalizations as building blocks for conceptual understanding [64]. Students must have a rich foundation of factual knowledge; understand facts and ideas in the context of a conceptual framework; and organize knowledge in a way that facilitates its retrieval and application [68]. Clearly then, students need to develop an in-depth understanding of concepts in order to be able to use what they have learned in school in the real world and allow them to apply their learning in new situation [64].

Sleep Has a Positive Impact on Student's Memory:
Circadian rhythms, in particular the sleep-wake cycle, modulate most, if not all aspects of physiology and behavior. Their impact on education has recently begun to be understood, including a clear positive relationship between sleep and learning [69]. Recent studies show that sleep is important for declarative memory consolidation or the explicit learning that takes place in school (though other types of memory such as emotional memories can be achieved without sleep) [12].

Recently, research has shown that the brain regions involved in learning the day before are reactivated during sleep [2]. During sleep, particularly during the rapid eye movement (REM) stage, our brains are relieved from processing the continual input of information that occurs during waking [54]. Sleep deprivation also has a negative impact on memory. Without a good night sleep, the more recent memories are not fully consolidated and therefore the information that they studied never get into long-term memory [12].

Melatonin is a hormone that is associated with regulating the sleep schedule. Melatonin is a chemical released from the pineal gland, which is located in the forebrain and is activated by biological clock. Young children, naturally go to sleep early and wake up early. Adolescents’ bodies, due to hormonal chemicals, are programmed to go to sleep later and wake up later. Most secondary schools begin their day around 7:30 a.m., but adolescents are generally not completely alert until closer to 9:00 a.m. Consequently, these students will not pay full attention during lessons and may even fall asleep in class [70, 6, 4].

Bio-cognitive Cycles undergoes a deep developmental modulation that can be studied in physiological or behavioral terms, as defined by “chronotypes” [69]. Chronotypes are the temporal preferences which characterize individuals as diurnal or “larks” and nocturnal or “owls”. According to this chronotype classification, it is clear that adolescents tend to be “phase delayed” with respect to their social activities, resulting in a putative desynchronization between their endogenous circadian rhythms and the imposed temporal structure of the schools. In fact, sleep deprivation, common to adolescents throughout the world, has a deep effect on academic performance and this fact is often increased by inadequate school schedules [69].

The understanding of such processes has a deep impact on not only the scientific research but also the quality of life and academic performance of students. The key message of these findings for curriculum researchers is that the concepts of time and timing—deeply controlled by the brain—need to be incorporated into any general view of educational processes. This research clearly has implications for managing the time between teaching and learning phases [2, 69].

In light of the above mentioned discussion, neuroscience has important implications for curriculum theory and practice. Overall, the potential implications of neuroscience for curriculum are indeed enormous and are not limited to the above list. For example, neuroscience findings support the idea that there are “sensitive periods” in brain development in which certain skills are learned with greater ease [12, 2, 10]. However, these periods are not rigid and inflexible, rather, there are subtle changes in the brain’s ability to be shaped and changed by experiences that occur over a lifespan [2, 10]. Sensitive periods in brain development may inform curriculum planners by indicating the appropriate age at which academic skills are taught [71]. However, as Tokuhama-Espinosa [12] has argued “though this seems logical, it is not yet well established because the definitions of its terms and scope (academic fields versus senses only) need further refinement” [p. 46]. Currently, the one main implication of the research findings on sensitive periods is that we identify and, if possible, treat children’s sensory problems, such as visual and hearing difficulties, so that even belatedly they can regain normal function [2].

Concluding Remarks: The ongoing understanding of brain function and development and its contribution into curriculum thinking and practice holds the significant promise for improving the education of students. Curriculum thought and practice therefore may benefit
from neuroscience as an informative source of knowledge. Neuroscience provides us with much valuable information about brain's natural learning system which would allow us to make more informed decisions and create more effective educational programs. What can neuroscience offer to curriculum theory and practice however, need to be explored from a variety of perspectives and should be interpreted carefully.

It should also be said that curricularists have long been aware of many of these brain compatible principles and strategies and have used them in making their curriculum. What neuroscience research findings now offer to curriculum researchers however is confirming or disconfirming those principles and strategies by recruiting neuroscience-based evidence. The new research therefore is not prescribing a particular method or theory, but offers educators an unparalleled opportunity for building a scientific foundation for educational practice and advising them to be cautious in the practice of teaching because some methods may risk contradicting neuroscientific evidences and fail [47, 72].

Taken as a whole, the contribution of neuroscience in curriculum theory and practice should not be underestimated. What is needed now however, is finding ways to promote more dialogue and collaboration between researchers in curriculum and neuroscience. This collaboration must be guided by the goal of fostering interprofessional interactions that enhance the practice of each discipline. Furthermore, such collaboration should be based on mutual understanding and respect for the actual and potential contributions of two disciplines. Without such collaborations, the neuroscience research maybe relevant to learning broadly, but is unlikely to address specific educational issues [73].

It is concluded that curricular phenomena need to be viewed through multiple lenses. It implies that a better understanding of curricular issues and designing the optimal curriculum requires the authentic integration of neuroscientific foundations of curriculum with its other foundations such as (but not limited to) philosophy, psychology, sociology, anthropology, theory of knowledge and historiography.

REFERENCES


