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The emerging role of educational neuroscience in education reform

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ABSTRACT

In the early 90s a movement began in education called "brain-based learning" that attempted to link neuroscience and education. However, many in both science and education felt it was untenable to make this leap. While early attempts to bridge the fields sparked controversy, it can now be argued that neuroscience does have a role to play in education reform. This paper explores suggestions for the appropriate training of the Educational Neuroscientist, broad interventions based on Educational Neuroscience that could reform curriculum, and emerging ways the Educational Neuroscientist can inform professional development of educators.

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El papel emergente de la neurociencia educativa en la reforma de la educación

Palabras clave:
Neurociencia
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Aprendizaje

RESUMEN

A principios de los años 90 surgió un movimiento en educación llamado "aprendizaje basado en el cerebro" que trataba de unir neurociencia y educación. No obstante, muchas personas tanto en ciencia como en educación, pensaban que no era viable dar tal salto. Mientras que los primeros intentos por tender puentes entre estos campos suscitó controversia, puede decirse ahora que la neurociencia sí tiene un papel que jugar en la reforma de la educación. Este artículo explora propuestas para el adecuado entrenamiento del neurocientífico educativo, intervenciones amplias sustentadas en la neurociencia educativa que podrían reformar el currículum y de qué nuevas maneras podría contribuir neurocientífico educativo al desarrollo profesional de los educadores.

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It has been over 20 years since "brain-based learning" emerged, initiated by teachers to make inferences from findings in neuroscience to classroom practice. Bruer (1997) called this movement a "bridge too far" because the practitioners were lacking in scientific understanding and making untenable leaps (Fischer, Goswami, & Geake, 2010; Goswami, 2006; Pickering & Howard-Jones, 2007). Scientists began joining the movement to inform professional development, but lacked classroom teaching experience, especially K-12. The field was treated both with skepticism and with competitiveness, as educational psychologists, cognitive psychologists, educators, neurologists, and neuroscientists debated who should advise educators. Others felt that a bridge between the fields should not exist at all (James S. McDonnell Foundation, 2007). Debate and discussion ensued (Blakemore, 2005; Byrnes, 2001; Della Sala & Anderson, 2012; Fischer, 2009; Howard-Jones, 2010; Royal Society, 2007; Tokuhama-Espinosa, 2010).

As the movement gained popularity, cross-talk began emerging between disciplines. Publications and presentations by scientists to teachers informed educators in more depth, leading to more credibility, although neuromyths still persisted. Now, almost two decades after Bruer's "bridge too far", a credible bridge is being made between neuroscience and education, including Master's and PhD programs being offered in Educational Neuroscience. However, these programs are inconsistent in recruitment, qualifications, and training. School systems and universities are not

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recognizing this new field of expertise and seeking input and, instead, get information from those unqualified in either neuroscience or K-16 education. Neuroscientists lament that we know certain things about how to improve learning but the field of education is not responding. "Brain" presenters are hired for keynotes and professional development with no experience or credentials in neuroscience. Neuromyths still abound (Howard-Jones, 2014). A clearer conception of the definition and training of an Educational Neuroscientist, awareness of curriculum interventions that are well-supported by research, and examples of potential educational professional development from neuroscience that could lead to educational reform can help us strengthen and advance this bridge between education and neuroscience.

As someone with credentials and experience in both fields and who has presented to teachers at events with other teachers and scientists, I can see across both sides of this bridge. Scientists believe they are the ones qualified to speak to teachers about translating the research while teachers believe that they can better make implications for the classroom. Educational psychologists believe they are more qualified. And so the turf battle continues. However, the issue is not just what we know, but what are we going to *do*?We need perspectives from research *and* practice to reform education. Has neuroscience revealed interventions to reduce the achievement gap?Can we credibly conduct professional development on the brain and learning?As with any new field of endeavor, there is a shake-out period where initial enthusiasm may lead to overgeneralizations, but as we come to recognize this field of Educational Neuroscience as an authentic field, training will improve and information will flow both ways, such that both research and practice benefit.

What will constitute a credible and authentic field?An editorial in *Nature Neuroscience* (The science of education reform, 2006) argues that all translational efforts should be reviewed as rigorously as other basic science findings and compares translating into implications for educational practice to drug company regulatory processes involving large clinical trials. To what standard should Educational Neuroscience be held? Teaching is not as much like medicine as it is the practice of psychology. For example, if psychologists recommend the technique of "reframing" as a viable tool in the psychologists' toolbox, is this based on large clinical trials? Teaching is an art and a science. We cannot underestimate the ability of good teachers to take this information and use it wisely as part of their background knowledge and their strategy toolbox for reaching diverse and struggling learners.

Defining and Training the Educational Neuroscientist

To support this bridge, we need a specialist with a foot on each side, a hybrid (Howard-Jones, 2010), with both experience and credentials in both neuroscience and education, as one alone is not sufficient. Scientists have two inherent weaknesses. First, I have been told repeatedly by educators that scientists have difficulty speaking to teachers, although some are outstanding speakers. There is a standard method of presenting scientific information at conferences and many use that presentation style with teachers, failing to understand the teachers' perspectives and needs or the "cultural conditions and concepts of education" as Paul Howard-Jones calls it (Howard-Jones, 2014). Secondly, they have not taught unmotivated or struggling learners – earlygrades, high school, or college developmental courses. They can't make a leap into practice if they have not practiced in this field (Pickering & Howard-Jones, 2007). "Translational efforts should be guided by determining what problems teachers currently face in the classroom, and should be evaluated based in part on their experience of what works" (The science of education reform, 2006).

Teachers, on the other hand, can innocently make untenable and unquestioned leaps from research to practice because they are usually not reading the scientific body of literature, but are getting information second and third hand, learning from a presenter who may have learned from a presenter or read a few books written for lay audiences or basic science articles they can't understand without the broader information. Recently I was asked to co-present with another "brain research presenter" at a conference. I asked her what her training in neuroscience was and got this response:

I have been a. . . teacher for (redacted) years. I fell into presenting brain research just two years ago after becoming fascinated by the research and adding it to one of my presentations... Apparently, that part intrigued many and I have been asked to do presentations on it since.

I looked at her information, and it contained incorrect information with untenable leaps, but the audiences are enthralled with brain terms and would not know the difference. The scientifically untrained often fail to realize what research was done on animals or what studies are so limited as to be useless in translation. They can't answer questions in a credible way without a broad knowledge of the scientific body of literature and without having been exposed to scientific discourse, ways of thinking and critiquing, and limitations in design and execution of neurobiological research. Otherwise, neuromyths get perpetuated, teachers are taught strategies that are not credible, or the new information is not conveyed in a way that informs educators' understanding and practice. However, with proper education and lab experience, they would be able to do this.

What we need is a blend of all of these currently competing specialties – a person educated across disciplines (Howard-Jones, 2010). The issue is not *whether* neuroscience information can be translated, but *how* we are training people to do this translation. An overarching and consistent view of the requirements and role of the educational neuroscientist is required in order to move from research to practice in a useful and credible manner. If we are going to take this new field seriously, then a new training program must be developed that is as rigorous as the training for other specialties, and not just providing a few cross-disciplinary courses to someone trained in either education or science. For example, in some institutions the training begins with scientists who then are taught some education theory. As explained earlier, this has limitations. Two strands are necessary, recruiting both scientists and teachers in a rigorous program of cross-training.

The training of scientists must include a student teaching practicum, and not in specialized laboratory schools which are often associated with a university and high socioeconomic status students, but in the trenches of schools with poverty and struggling learners, with a teacher in the program as a guide. Alternatively, experienced classroom teachers would be put through a specialized neuroscience program, conducting research in a neuroscience lab with a scientist in the program. Many rigorous educational programs require a practicum, and so should this program. The program should include literature from both domains and discussion in groups consisting of scientists and educators to share perspectives and styles of thinking and speaking. I am guessing that both scientists and educators may balk at this rigorous program, but better to have fewer well-trained and credentialed Educational Neuroscientists than having a valuable new discipline deemed as not credible or effective. Graduates then have credentials and experience in both education and neuroscience. They can see research through the eyes of a teacher and teaching through the eyes of a researcher.

Dual perspectives and experiences would provide valuable insight into scientific and educational research design (Fischer, 2009; Fischer et al., 2010; Hinton & Fischer, 2008) as well as implementation of new insights to education reform. Research questions are limited by our perceptions and educators can help formulate the questions as well as expand the perspectives from which a problem is viewed. For example, when I was in the lab researching developmental dyslexia, I pointed out that, as a prior reading teacher, there are more difficulties with reading than phonological dyslexia and wanted to investigate subtypes, which had not been done at the time. In a small pilot study, we looked at subtypes and found some interesting differences in anatomical measurements (Zadina et al., 2006; Zadina, Corey, Cusick, Lemen, & Foundas, 2005). Recently, new research on reading subtypes is emerging and findings could lead to specific individualized strategies in the classroom. This is the advantage of having input from both science and education if we are researching learning. Experience with struggling readers and learners is essential to design meaningful scientific research on learning. A literature review of previous scientific studies is necessary but not sufficient.

Informing Curriculum Choices

Critics argue that it is too early for Educational Neuroscientists to inform curriculum, but who is making curriculum decisions now? Politicians? Money interests? I argue that it should be an Educational Neuroscientist capable of blending education, psychology, and neuroscience. What would be the best alternative? If not now, when? I argue that we have reached the tipping point.

A significant body of literature on the neuroscience of learning has developed in the last decade. Scientists moved beyond studying only what had clinical implications and began looking at the effects of bilingualism, the arts, and physiology on the normal brain and on the underlying components of learning. This research is now substantial enough to warrant curriculum reform in several areas, including the impact of language learning, exercise, the arts, and sleep on learning. This is not the forum for an extensive literature review on these topics. A few important examples are offered as evidence that we are ready to cross this bridge.

The research on language and on second language learning and the brain indicates the importance of early language learning for later language learning, improved reading skill, achievement, general cognition, and brain health. Yet most students in the United States are not exposed to a foreign language until high school, foreign language is not compulsory, and bilingual education is often terminated early.

Poverty and low socioeconomic status (SES) has been implicated as an important factor in the achievement gap, a serious educational issue. Petitto and Dunbar (2008) found, in a study of monolingual children, that the lowest SES monolingual children put into a bilingual 50/50 program outperformed the high SES who were not placed into the bilingual program. It ameliorated the typically negative low SES effects on achievement. In a related study, Petitto's lab (Petitto et al., 2012) showed that dual language exposure in infants gives them a language processing advantage that may aid language and reading development in childhood. Kuhl, Williams, Lacerda, Stevens, and Lindblom (1992) reported the importance of children hearing sounds of another language before six months of age to facilitate later learning of that language. Delaying language learning until high school may negatively impact grammatical processing in the new language (Flege & Fletcher, 1992; Neville & Bruer, 2001). Clearly, the imperative is to start second language exposure early.

Increasing evidence indicates that being bilingual creates a better brain overall, including better executive function (Bialystok, 2001; Krizman, Marian, Shook, Skoe, & Kraus, 2012). Being raised bilingual may improve working memory (Blom, Kuntay, Messer, Verhagen, & Lesseman, 2014), a skill critical to achievement in reading, writing, and math. We can no longer ignore some of the important findings and the implication that dual language instruction is beneficial and necessary.

A common curriculum choice when cutting budgets is to cut arts instruction. Emerging neuroscience literature is showing the positive effects of art instruction on the brain and learning. An early and growing body of research reports the effects of musical training on both cognition and achievement. This is not to be confused with the Mozart Effect that involved listening to music, but rather training in learning to play a musical instrument. Selective attention, important for learning, has been shown to be enhanced in musicians (Schellenberg, 2005). Petitto (2008) found that students with music expertise learned a second language more proficiently and speculates that music training may confer long-term cognitive advantage. A study from Vanderbilt indicated that music training may enhance creative thinking, a skill that we can all agree is necessary for the 21st century (Gibson, Folley, & Park, 2009). The researchers also found that musicians had higher IQ scores than non-musicians, supporting other earlier studies that indicate that intensive musical training is positively associated with verbal intelligence, language, and executive function (Moreno, Friesen, & Bialystok, 2011), overall memory skills (Franklin, Moore, Yip, Jonides, & Rattray, 2008), superior skills in reading (Piro & Ortiz, 2009), and math (Wandell, Dougherty, Ben-Shachar, Deutsch, & Tsang, 2008). Increasing evidence that the ability to clearly hear sounds is linked to reading ability as shown in Nina Kraus' lab indicates that music may help the developing auditory system, thus affecting reading ability (Carr, White-Schwoch, Tierney, Strait, & Kraus, 2014). Being informed by neuroscience research would have allowed education administrators to make better choices.

Another area in which budget cuts have led to some unfortunate curriculum decisions is the area of recess and physical education. Some schools are cutting recess even at the pre-kindergarten level. Schools cut physical education time and yet there is no evidence that taking time for this negatively impacts academic performance (Trudeau & Shephard, 2008). There is evidence that exercise helps cognition, however. A study showed that 3 minutes of aerobic exercise improved both short and long term memory (Winter et al., 2007). Sibley and Etnier (2003) and Hillman, Erickson, and Framer (2008) saw a positive relationship between physical activity and school achievement, including standardized test scores. Ratey (2008), Coe, Pivarnik, Womack, Reeves, and Malina (2006), and Hillman et al. (2008) found that the better grade school children performed on physical tests, the better they scored on achievement tests, regardless of SES. This research suggests ways in which we can improve the life and learning ability of our students far more than a focus simply on academic content. As Helen Neville (2012) suggests, interventions that enhance plasticity should be determined. Exercise appears to do that.

As early as 2001, I spoke with a principal in Louisiana who changed school start times based on research that showed that adolescent sleep patterns were different and that they needed late morning sleep for better learning (Carskadon, 1981, 1990; Dewald, 2010; Hagenauer, 2009; Hansen, 2005; Mitru, 2002). This is an excellent example of basic research informing educational reform. Unfortunately, we have not seen much reform in this direction.

These findings from neuroscience could lead to top-down curriculum reform *if* administrators are made aware of the research and make changes. School officials need credible sources that can synthesize the research and argue for important changes.

Informing Professional Development and Classroom Strategies

The question remains unresolved as to whether Educational Neuroscience can address classroom practices. Critics argue that there is no direct relationship (Szucs, 2007) or that applications of research have not been rigorously reviewed (The science of education reform, 2006). I agree that we may not quite be at the point of direct implications in all cases, but that does not rule out the value that insights from neuroscience can bring. I agree that we should require rigorous studies on interventions that may be promoted by for-profit companies or required for all students. If a company is going to sell educational programs to schools then any claims made must be backed up by rigorous testing. But what about our overall understanding of best practices? What have we based our classroom practices on in the past? We have been trained to use education and psychology theory and research and our experience with learners. I argue that having an understanding of basic neuroscience research on learning and underlying components of learning is as essential as the study of child development or educational psychology or any other aspect of teacher training. Just as doctors and psychologists attend professional development workshops to stay up to date, so must educators stay up to date on what we are learning about the brain, emotions, motivation, and physiology from scientific research. This information can inform our actual practices in the classroom in the form of our understanding of students and our ability to design and execute lessons that are more effective.

However, I am still seeing neuromyths and false information presented to teachers because those who hire the “brain research presenter” are not checking credentials. Because those hiring presenters for conferences or professional development often do so on the basis of presentation skills and audience response, rather than an examination of credentials, this field continues to get a bad name and perpetuate misinformation. The person hiring and the audience are misled by the use of brain terminology and presentation skills and do not have enough knowledge of the body of scientific literature to recognize incorrect information. To stop this practice and make this a legitimate field, we need credentialing programs and those in the field of education need to know that the brain is complex and that “reading the research” is not sufficient background.

When presented by properly trained presenters, we can make this leap from research to professional development and several trends emerge. Some of the practices elucidated and supported by neuroscience have been proposed by educational theorists and by good teachers long before neuroscience validated, explained, or showed the importance of them. Teachers can feel validated and supported in continuing these practices. In other cases, we look at our practices in a new light and make appropriate modifications based on a new understanding. Educational Neuroscience can provide us with new strategies as well as indicate that perhaps some of our current strategies need to be eliminated in light of better information.

An educational neuroscientist with actual teaching background may see classroom strategies suggested by even basic research. For example, neuroscience research seems to indicate that using one’s fingers to learn to count may be an important developmental step (Goswami, 2006). The brain may be mentally using finger representation in the brain as a child does when learning math. Noel (2005) found that being able to tell which fingers were being touched (finger gnosis) was a strong predictor of mathematical ability in children and adults. Kaufmann et al. (2008) suggested not discouraging use of fingers when learning or struggling with math and developed an intervention for children and adults with mathematical difficulty based on this knowledge. Does this intervention need rigorous testing or is it another tool in our toolbox? If we say that all students must be taught in this manner, then we must defend that. But if neuroscience indicates potential alternatives for addressing struggling learners, then we have one more option. Something like this also prevents us from telling a child that he or she is too old to use their fingers because we realize they may be working through a developmental stage in which they are behind. This simple example is offered to illustrate that this type of information can add to our understanding of students and to our toolbox of strategies, even if it is not an “intervention” or a widespread policy derived from neuroscience. When teachers understand more about developmental stages and learning differences illuminated through neuroimaging studies, this can affect their attitudes and their practices and potentially lead to better outcomes for students (Hornstra, 2010; Howard-Jones, 2014).

Deeper and broader implications can be derived from substantial bodies of literature on processes underlying thinking and learning that are invisible to classroom teachers. Understanding these processes can help educators explore alternative or targeted interventions. Previously, for example, if a student couldn’t do arithmetic, teachers might just “drill and kill,” hoping that enough repetition and practice would break through the barrier and the child would finally “get it.” Teachers lament the student who can pronounce every word, but fails to comprehend a paragraph. Recent brain imaging studies have shown that several mental processes underlie these tasks.

For example, some issues that appear to be math or reading comprehension problems are actually working memory problems. Mazzocco, Feigenson, and Halberda (2011) investigated the role of working memory in mathematical performance and discovered that some students quickly forget verbal information or can’t hold information long enough in working memory to complete a math problem. The same holds true for long sentences or passages in reading. Rather than teachers simply drilling on the skill itself with students who do not make progress, they can also address a potential underlying source – poor working memory capacity. Training that improves working memory capacity would be more effective than having students only practicing the mathematical problems that they could not execute due to a deficit not directly related to math concepts *per se*. Jaeggi’s lab (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008) found that “fluid intelligence can be improved by rehearsing a working memory task.”

Research using functional magnetic resonance imaging (fMRI) shows more demand on working memory when students are initially learning, when the cognitive load is higher, than later in the learning process (Chein & Schneider, 2005). Teachers understanding cognitive load theory can teach differently, allocating more time early in the process than later and designing lessons in ways that address the effects of cognitive load and working memory limitations.

Working memory is closely related to a second underlying process, that of attention. Giuliano and Neville (2011) reported that working memory capacity was predicted by the ability to control attention, suggesting the importance of attention training to improve memory functions related to achievement. Evidence suggests the value of classroom strategies aimed at improving attention. Helen Neville’s lab (Stevens et al., 2011) gave preschool children attention training daily and IQ measures went up and measures of attention improved significantly. Education research has long shown a positive correlation between socioeconomic status (SES) and achievement (Sirin, 2005). Neville (2012) found that after attention training, low SES students looked like high SES students in achievement. She draws the implication for education that investing in preschool attention training gives a better return on investment dollars than remediation later in the education process. Posner’s lab (Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005) also found that attention training generalized to improvement on intelligence tests. Attention training may lead to improvement in classroom behavior by enabling children to improve in conflict resolution (Rothbart & Posner, 2005; Tang et al., 2007). Mindfulness meditation (Jha, Krompinger, & Baime, 2007;

Leeuwen, Singer, & Melloni, 2012) has been effective in improving attention mechanisms and may be a beneficial classroom strategy.

An understanding of the biology of threat, of how anxiety and stress impact learning, and the nature of our traumatized students can help educators understand why a method that appears to work can actually inhibit learning and they can learn strategies that create the right amount of positive stress while eliminating the negative stress that can impact cognitive function (Goswami, 2004; McEwen & Sapolsky, 1995). Because students often have serious anxiety or stress-related issues, it behooves educators to be aware of the impact of this on learning. While much of the research has focused on Post Traumatic Stress Disorder (PTSD) in soldiers, more current research has looked at PTSD in populations suffering from natural disaster (Karakaya, 2004), violence (Fitzpatrick, 1993), poverty (Nikulina, 2011), migration/immigration (Silove, Sinnerbrink, Field, Manicavasagar, & Steel, 1997), and sexual (McLeer, 1988), domestic (Twamley, 2009), or child abuse (Pederson et al., 2004), and we have these populations in our classrooms. It is important for school populations suffering from trauma such as school violence or disasters to understand the impact and adjust school curriculum in the presence or aftermath of this trauma (Zadina, 2012). In addition, educators confront math and reading anxiety in the classroom. LeDoux (1996) suggests that this anxiety may impair students' ability to pay attention by disrupting attentional mechanisms. Posner's lab (Tang et al., 2007) found a positive correlation between the trait of mindfulness and anxiety and aggression, which suggests mindfulness as a possible intervention for both anxiety and behavior problems. Mindfulness has also been shown to be effective with PTSD (Lang et al., 2012) and could be a valuable non-pharmacological intervention with students experiencing trauma.

Sometimes neuroscience reveals theory or practices that need to be eliminated from education conversations and practices. Learning styles theory and testing students for learning style is an example of an educational theory and practice that has taken class time, may have misdirected students' efforts, and is not supported by neuroscience research (Coffield, 2004). Neuroimaging studies have revealed the complexity of the interactions of brain regions and revealed multiple pathways involved in learning (Majjar, 1998; Zadina, 2014). An Educational Neuroscientist can advise educators against amateur diagnosis and guide them toward designing lessons with multiple pathways for understanding and practice that offer options for diverse and struggling learners.

While learning styles theory drew a distinction between learning visually, auditorially, or kinesthetically, neuroscience research revealed the importance of vision in learning (Nelson, Reed, & Walling, 1976). Thus, we can guide educators to make lessons more visual while reminding them that all components of a lesson use brain resources and increase cognitive load, so the images must be meaningful and make a contribution. This is the kind of synthesis of the scientific literature created by an understanding of both the body of literature and the types of learning opportunities that educators create that can enhance lesson design.

Conclusion

While brain research may not yet tell us *how* to teach *per se*, it does *inform* teaching, learning, and school reform. We are at the beginning of a new vision in which scientists, educators, and the hybrid Educational Neuroscientist can all work together toward school reform. As with many initially disparate fields, where shared efforts seem to be a "bridge too far", nurturing the cross-fertilization of ideas and paradigms and refining our vision of the Educational Neuroscientist can lead to change in both fields and the emergence of ideas that can revolutionize education. It's not a bridge too far if it is built by properly trained "engineers."

Resumen ampliado

A principios de los 90 surgió en el mundo de la educación un movimiento llamado "aprendizaje basado en el cerebro", cuya pretensión era unir la neurociencia y la educación. Sin embargo, tanto desde la neurociencia como desde la educación, surgieron muchas voces advirtiendo de la imposibilidad de llevar a cabo ese salto. No obstante, y aunque los primeros intentos de unir ambos campos fueron objeto de enconadas controversias, actualmente sí se puede decir que la neurociencia tiene un papel verdaderamente importante que jugar en las reformas educativas. Este artículo explora diferentes posibilidades al respecto. Por un lado, se harán sugerencias sobre cuál sería la formación apropiada para el neurocientífico educativo. Por otro, se enumerarán una serie de intervenciones generales que se podrían hacer para reformar el currículum basándose en la Neurociencia Educativa. Por último, también se proporcionarán sugerencias respecto a de qué nuevas maneras podría contribuir el neurocientífico educativo al desarrollo profesional de los educadores.

Mi planteamiento inicial es que ya ha llegado el momento en el que la Neurociencia Educativa puede reformar el currículum educativo y proporcionar a los educadores una serie de estrategias basadas en la neurociencia *si* la persona que realiza el traspaso de conocimiento ha sido convenientemente formada tanto en ciencia como en educación –una situación que por lo que sé se da en muy pocos casos. Para poder tender puentes entre la neurociencia y la educación necesitamos profesionales con un pie en cada lado, con una formación híbrida y experiencia tanto en educación como en neurociencia, pues uno sólo de estos aspectos resulta insuficiente. Los científicos tienen dos puntos débiles inherentes. Por un lado, se me ha dicho repetidamente desde la educación que los científicos tienen dificultades a la hora de hablar con los docentes. Por otro, no han enseñado jamás a alumnos desmotivados y con problemas –edades tempranas, alumnos de instituto, etc. No pueden poner en práctica un salto cualitativo en la enseñanza si nunca han practicado en este campo. Los docentes, por otra parte, pueden inocentemente poner en práctica algunos avances científicos de manera inviable y sin haber escuchado posibles críticas, pues quizá normalmente no lean la literatura científica al respecto, habiendo obtenido su información de segunda o tercera mano. Este tipo de circunstancias perpetúa numerosos *neuromitos*, a los docentes se les enseña estrategias que no son creíbles, o los nuevos avances no son convenientemente canalizados como para ser informativos para la práctica y la comprensión de los educadores.

En definitiva, la cuestión no es si la información neurocientífica puede ser trasladada a la educación, sino cómo estamos formando a los futuros profesionales para realizar convenientemente dicho traspaso. Si queremos tomarnos este campo en serio, debemos desarrollar nuevas aproximaciones en la formación de los profesionales. La formación de los científicos debe incluir unas prácticas de enseñanza, pero no en los laboratorios especializados de escuelas universitarias normalmente asociados a estudiantes universitarios y de alto nivel socioeconómico, sino en verdaderas escuelas con alumnos en situaciones de pobreza o problemáticas, con un docente en el programa que sirva de guía. De esta manera conseguirían ver la investigación desde el punto de vista de un docente y la docencia desde el punto de vista de un investigador. Las hipótesis y objetivos de una investigación están limitados por nuestras percepciones y los educadores pueden ayudar a formular preguntas así como a ampliar las perspectivas desde las que se aborda un problema.

Por otra parte, hay muchos críticos que argumentan que es todavía muy pronto para que los neurocientíficos educativos puedan hacer aportaciones válidas a la hora de diseñar un currículum. Pero ¿quién toma las decisiones en este momento?, ¿los políticos?, ¿los intereses financieros? Yo propongo que tiene que ser un neurocientífico educativo capaz de entremezclar educación, psicología y neurociencia. ¿Cuál sería la mejor alternativa? Si no se hace ahora, ¿cuándo? Creo que ya hemos llegado al punto crítico.

Durante la última década se ha desarrollado un cuerpo de conocimientos muy significativo desde la neurociencia del aprendizaje. Los científicos han explorado otros muchos campos más allá de los relativos al ámbito clínico y han comenzado a explorar los efectos del bilingüismo, el arte y la fisiología en el cerebro normal y en los mecanismos subyacentes al aprendizaje. Estas aportaciones científicas son ahora lo suficientemente sustanciales como para poder garantizar una reforma del currículum en diversas áreas, incluyendo el impacto que el aprendizaje de lenguas, el ejercicio, la expresión artística o el sueño ejercen sobre el aprendizaje. Por ejemplo, las investigaciones sobre el lenguaje y sobre el aprendizaje de una segunda lengua han puesto de manifiesto no sólo la importancia del aprendizaje temprano de una lengua para su aprendizaje posterior, sino sus beneficios sobre la capacidad lectora, los logros académicos, la cognición en general y la salud cerebral. Exponerse tempranamente a un segundo idioma puede incluso ayudar a que niños de bajo nivel socioeconómico obtengan puntuaciones académicas similares a las de los de estatus superiores. Cada vez hay más evidencias de que ser bilingüe conlleva en general tener un mejor cerebro, incluyendo unas mejores funciones ejecutivas. Crecer como bilingüe puede incrementar la capacidad de memoria operativa o de trabajo y una habilidad crítica para la adquisición de la lectura, la escritura y las matemáticas.

Otro ejemplo lo encontramos en la enseñanza artística. A la hora de reducir presupuestos, una decisión bastante común es la de prescindir de la formación artística. Sin embargo hay muchas pruebas que contradicen esta actitud. Así, se ha visto que la atención selectiva, un factor relevante en el aprendizaje, mejora notablemente en músicos. Otros estudios han encontrado que los estudiantes con experiencia musical son capaces de aprender una segunda lengua con mayor eficiencia y se especula con la posibilidad de que la formación musical pueda conferir ventajas cognitivas a largo plazo. La formación musical también puede potenciar el pensamiento creativo, una habilidad en la que todos estaremos de acuerdo que es muy necesaria en el siglo XXI. Otra área que es víctima frecuente de los recortes presupuestarios vinculados a las decisiones sobre el currículum es la educación física y el tiempo libre o la actividad en los recreos. Sin embargo, hay abundante evidencia de que el ejercicio favorece a la cognición. En un estudio se comprobó, por ejemplo, que 3 minutos de ejercicio aeróbico potenciaban tanto la memoria a corto plazo como la a largo plazo. Se ha comprobado igualmente que existe una estrecha relación entre la actividad física y el logro escolar, incluso en pruebas estandarizadas.

En conclusión, las investigaciones neurocientíficas proporcionan ideas y estrategias que nos permiten mejorar la vida y las habilidades de aprendizaje de nuestros estudiantes, mucho más que centrándonos exclusivamente en el contenido académico. Aunque las investigaciones sobre el cerebro no puedan aún decirnos cómo enseñar en sí, sí son bastante informativas para la docencia, el aprendizaje y, por tanto, para la elaboración de reformas educativas.

Conflict of Interest

The author of this article declares no conflict of interest.

References

Bialystok, E. (2001). *Bilingualism in Development: Language, Literacy, and Cognition*. New York: Cambridge University Press.

Blakemore, S. J. (2005). *The Learning Brain*. Blackwell.

Blom, E., Kuntay, A. C., Messer, M., Verhagen, J., & Lesseman, P. (2014). The benefits of being bilingual: Working memory in bilingual Turkish-Dutch children. *Journal of Experimental Child Psychology*, *128*, 105–119.

Bruer, J. (1997). Education and the brain: A bridge too far. *Educational Researcher*, *26*, 4–16.

Byrnes, J. P. (2001). *Minds, Brains, and Learning*. New York: The Guildford Press.

Carr, K. W., White-Schwoch, T., Tierney, A. T., Strait, D. L., & Kraus, N. (2014). Beat synchronization predicts neural speech encoding and reading readiness in preschoolers. *Proceedings of the National Academy of Sciences*, *111*, 14559–14564.

Carskadon, M. A. (1981). Sleep loss in young adolescents. *Sleep*, *4*, 299–312.

Carskadon, M. A. (1990). Patterns of sleep and sleepiness in adolescents. *Pediatrician*, *17*, 5–12.

Chein, J., & Schneider, W. (2005). Neuroimaging studies of practice-related change: fMRI and meta-analytic evidence of a domain- general control network for learning. *Cognitive Brain Research*, *25*, 607–623.

Coe, D. P., Pivarnik, J. M., Womack, C. J., Reeves, M. J., & Malina, R. M. (2006). Effect of physical education and activity levels on academic achievement in children. *Medicine and Science in Sports and Exercise*, *38*, 1515–1519.

Coffield, F. M. (2004). Learning styles and pedagogy in post-16 learning: a systematic and critical review. *Learning and Skills Research Centre*.

Dewald, J. F. (2010). The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: A meta-analytic revue. *Sleep Medicine Reviews*, *14*, 179–189.

Della Sala, S., & Anderson, M. (2012). *Neuroscience in Education: the good, the bad and the ugly*. Oxford: Oxford University Press.

Fischer, K. W. (2009). Building a scientific groundwork for learning and teaching. *Mind, Brain, and Education*, *3*, 2–15.

Fischer, K. W., Goswami, U., & Geake, J. (2010). Task Force on the Future of Educational Neuroscience The future of educational neuroscience. *Mind, Brain and Education*, *4*, 68–80.

Fitzpatrick, K. M. (1993). The prevalence and consequences of exposure to violence among African-American youth. *Journal of the American Academy of Child & Adolescent Psychiatry*, *32*, 424–430.

Flege, J. E., & Fletcher, K. L. (1992). Talker and listener effects on degree of perceived foreign accent. *Journal of the Acoustical Society of America*, *91*, 370–389.

Franklin, M. S., Moore, K. S., Yip, C.-Y., Jonides, J., & Rattray, K. (2008). The effects of musical training on verbal memory. *Psychology of Music*, *36*, 353–365.

Gibson, C., Folley, B. S., & Park, S. (2009). Enhanced divergent thinking and creativity in musicians: A behavioral and near-infrared spectroscopy study. *Brain and Cognition*, *69*, 162–169.

Giuliano, R. J., & Neville, H. J. (2011). Novel evidence for a domain-general attentional control mechanism predicting individual differences in working memory capacity. Presentation at the Society for Neuroscience. Washington, D.C.

Goswami, U. (2004). Neuroscience and education. *British Journal of Educational Psychology*, *74*, 1–14.

Goswami, U. (2006). Neuroscience and education: From research to practice. *Nature Reviews Neuroscience*, *7*, 2–7.

Hagenauer, M. H. (2009). Adolescent changes in the homeostatic and circadian regulation of sleep. *Developmental Neuroscience*, *31*, 276–284.

Hansen, M. J. (2005). The impact of school daily schedule on adolescent sleep. *Pediatrics*, *115*, 1555–1561.

Hillman, C. H., Erickson, K. I., & Framer, A. F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature Reviews Neuroscience*, *9*, 58–65.

Hinton, C., & Fischer, K. W. (2008). Research schools: Grounding research in educational practice. *Mind, Brain, and Education*, *2*, 157–160.

Howard-Jones, P. A. (2010). *Introducing Neuroeducational Research: Neuroscience, education and the brain from contexts to practice*. New York: Routledge.

Howard-Jones, P. A. (2014). Neuroscience and education: myths and messages. *Nature Reviews Neuroscience*, *15*, 817–824.

Hornstra, L. D. (2010). Teacher attitudes toward dyslexia: effects on teacher expectations and the academic achievement of students with dyslexia. *Journal of Learning Disabilities*, *43*, 515–529.

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Perrig, W. J. (2008). Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences*, *105*, 6829–6833.

James S. McDonnell Foundation (2007). *The Santiago Declaration*. https.//www.jsmf.org/santiagodeclaration/.

Jha, A. P., Krompinger, J., & Baime, M. J. (2007). Mindfulness training modifies subsystems of attention. *Cognitive, Affective, & Behavioral Neuroscience*, *7*, 109–119.

Karakaya, L. A. (2004). Three and a half years after the Marmara earthquake in adolescents with PTSD, depression and anxiety symptoms. *Turkish Journal of Psychiatry*, *15*, 257–263.

Kaufmann, L. V. S. E., Wood, G., Kremser, C., Schocke, M., Zimmerhackl, L. B., & Koten, J. W. (2008). A developmental fMRI study of nonsymbolic numerical and spatial processing. *Cortex*, *44*, 376–385.

Krizman, J. M., Marian, V., Shook, A., Skoe, E., & Kraus, N. (2012). Subcortical encoding of sound is enhanced in bilinguals and relates to executive function advantages. *Proceedings of the National Academy of Sciences*, *109*, 7877–7881.

Kuhl, P. K., Williams, K. A., Lacerda, F., Stevens, K. N., & Lindblom, B. (1992). Linguistic experience alters phonetic perception in infants by 6 months of age. *Science*, *255*, 606–608.

Lang, A. J., Strauss, J. L., Bomyea, J., Bormann, J. E., Hickman, S. D., Good, R. C., & Essex, M. (2012). The theoretical and empirical basis for meditation as an intervention for PTSD. *Behavior Modification*, *36*, 759–786.

LeDoux, J. E. (1996). *The Emotional Brain*. New York: Simon & Schuster.

Majjar, L. J. (1998). Principles of educational multimedia user interface design. *Human Factors*, *40*, 311–323.

Mazzocco, M. M., Feigenson, L., & Halberda, J. (2011). Impaired acuity of the approximate number system underlies mathematical learning disability (dyscalculia). *Child Development*, *82*, 1224–1237.

McEwen, B. S., & Sapolsky, R. M. (1995). Stress and cognitive function. *Current Opinions in Neurobiology*, *5*, 205–216.

McLeer, S. V. (1988). Post-traumatic stress disorder in sexually abused children. *Journal of the American Academy of Child & Adolescent Psychiatry*, *27*, 650–654.

Mitru, G. M. (2002). The impact of sleep on learning and behavior in adolescents. *Teachers College Record*, *104*, 704–726.

Moreno, S., Friesen, D., & Bialystok, E. (2011). Effect of music training on promoting preliteracy skills: Preliminary causal evidence. *Music Perception: An Interdisciplinary Journal*, *29*, 165–172.

Nelson, D. L., Reed, V. S., & Walling, J. R. (1976). Pictorial superiority effect. *Journal of Experimental Psychology:Human Learning and Memory*, *2*, 523–528.

Neville, H. J. (2012). Training Brains:Improving behavior, cognition and neural mechanisms of attention in lower SES children. In *Conference presentation"Learning and the Brain"*. Boston, MA.

Neville, H. J., & Bruer, J. T. (2001). Language processing: How experience affects brain organization. In D. B. Bailey, J. T. Bruer, F. J. Symons, & W. Lichtman (Eds.), *Critical Thinking about Critical Periods* (p. 151-172). Baltimore: Paul H. Brookes.

Nikulina, V. W. (2011). The role of childhood neglect and childhood poverty in predicting mental health, academic achievement and crime in adulthood. *American Journal of Community Psychology*, *48*, 309–321.

Noel, M. P. (2005). Finger gnosia: a predictor of numerical abilities in children? *Child Neuropsychology*, *11*, 413–430.

Pederson, C. L., Maurer, S. H., Kaminski, P. L., Zander, K. A., Peters, C. M., Stokes-Crowe, L. A., & Osborn, R. E. (2004). Hippocampal volume and memory performance in a community-based sample of women with posttraumatic stress disorder secondary to child abuse. *Journal of Traumatic Stress*, *17*, 37–40.

Petitto, L. A. (2008). Arts education, the brain, and language. In, M. Gazzaniga (Org.), *The Arts and Cognition Monograph: The Dana Consortium Report on Arts and Cognition* (pp. 93-104). New York: Dana Press.

Petitto, L. A., Berens, M. S., Kovelman, I., Dubins, M. H., Jasinska, K., & Shalinsky, M. (2012). The "Perceptual Wedge Hypothesis" as the basis for bilingual babies' phonetic processing advantage: new insights from fNIRS brain imaging. *Brain & Language*, *121*, 130–143.

Petitto, L. A., & Dunbar, K. (2008). New findings from educational neuroscience on bilingual brains, scientific brains, and the educated mind. In K. Fischer, & T. Katzir (Eds.), *Building Usable Knowledge in Mind, Brain, and Education*. Cambridge: Cambridge University Press.

Pickering, S. J., & Howard-Jones, P. (2007). Educators' views on the role of neuroscience in education: Findings from a study of UK and international perspectives. *Mind, Brain, and Education*, *1*, 109–113.

Piro, J. M., & Ortiz, C. (2009). The effect of piano lessons on the vocabulary and verbal sequencing skills of primary grade students. *Psychology of Music*, *37*, 325–347.

Ratey, J. J. (2008). *Spark: the Revolutionary New Science of Exercise and the Brain*. New York: Little, Brown.

Rothbart, M. K., & Posner, M. I. (2005). Genes and experience in the development of executive attention and effortful control. *New Directions for Child and Adolescent Development*, *2005*, 101–108.

Royal Society (2007). *Brain waves Module 2: Neuroscience: implications for education and lifelong learning.* Royal Society.

Rueda, M. R., Rothbart, M. K., McCandliss, B. D., Saccomanno, L., & Posner, M. I. (2005). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences*, *102*, 14931–14936.

Schellenberg, E. G. (2005). Music and cognitive abilities. *Current Directions in Psychological Science*, *14*, 317–320.

Sibley, B. A., & Etnier, J. L. (2003). The relationship between physical activity and cognition in children: A meta-analysis. *Pediatric Exercise Science*, *15*, 243–256.

Silove, D. S., Sinnerbrink, I., Field, A., Manicavasagar, V., & Steel, Z. (1997). Anxiety, depression and PTSD in asylum-seekers: associations with pre-migration trauma and post-migration stressors. *British Journal of Psychiatry*, *170*, 351–357.

Sirin, S. R. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of Educational Research*, *75*, 417–453.

Stevens, C., Harn, B., Chard, D., Currin, J., Parisi, D., & Neville, H. (2011). Examining the role of attention and instruction in at-risk kindergarteners: Electrophysiological measures of selective auditory attention before and after an early literacy intervention. *Journal of Learning Disabilities*, *46*, 73–86.

Szucs, D. A. (2007). Educational neuroscience: Defining a new discipline for the study of mental representations. *Mind, Brain, and Education*, *1*, 114–127.

Tang, Y. Y., Ma, Y., Wang, J., Fan, Y., Feng, S., Lu, Q., . . . Posner, M. I. (2007). Short-term meditation training improves attention and self-regulation. *Proceedings of the National Academy of Sciences*, *104*, 17152–17156.

The science of education reform (2006). Editorial. *Nature Neuroscience, 9*, 1345.

Tokuhama-Espinosa, T. (2010). *The New Science of Teaching and Learning: Using the best of mind, brain, and education science in the classroom*. New York: Teachers College Press.

Trudeau, F., & Shephard, R. J. (2008). Physical education, school physical activity, school sports and academic performance. *International Journal of Behavioral Nutrition and Physical Activity*, *5*(10), 1–12.

Twamley, E. W. (2009). Cognitive impairment and functioning in PTSD related to intimate partner violence. *Journal of the International Neuropsychological Society*, *15*, 879–887.

van Leeuwen, S., Singer, W.,& Melloni, L. (2012). Meditation increases the depth of information processing and improves the allocation of attention in space. *Frontiers in Human Neuroscience, 6*(133). doi: 10.3389/fnhum.2012.00133.

Wandell, B., Dougherty, R.F., Ben-Shachar, M., Deutsch, G.K.,& Tsang, J. (2008). *Training in the arts, reading, and brain imaging*. The Dana Foundation Publications. www.dana.org.

Winter, B., Breitenstein, C., Mooren, F. C., Voelker, K., Fobke, M., Lechtermann, A., & Knecht, S. (2007). High impact running improves learning. *Neurobiology of Learning and Memory*, *87*, 597–609.

Zadina, J. N. (2012). *Teaching in the presence and aftermath of trauma*. Presentation at the Symposium "Learning and The Brain". New York, NY.

Zadina, J. (2014). *Multiple Pathways to the Student Brain*. San Francisco, CA: Jossey-Bass.

Zadina, J. N., Corey, D. M., Casbergue, R. M., Lemen, L. C., Rouse, J. C., Knaus, T. A., & Foundas, A. L. (2006). Lobarasymmetries in subtypes of dyslexic and control subjects. *Journal of Child Neurology*, *21*, 922–931.

Zadina, J. N., Corey, D. M., Cusick, C. G., Lemen, L. C., & Foundas, A. L. (2005). *Corpus callosum and dyslexia: Reduced genu volume and impaired reading (Poster)*. Washington, D.C.: Society for Neuroscience.