

# Applying Neuroscientific Findings to Education: The Good, the Tough, and the Hopeful

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**ABSTRACT**—Advances in neuroscience during the past century have yielded important insights into mental functioning, but their implications for the field of education have remained largely unexplored. In a bold attempt to bridge this gap, Immordino-Yang presents findings from 2 boys, Nico and Brooke, each of whom lost half of his brain. The remarkable recovery of functions in the 2 boys highlights the degree to which children's emotional and social experiences shape brain development, as well as the importance of plasticity. Immordino-Yang places emphasis on cognitive plasticity—the ability to use different strategies in solving a task—which is clearly evident in the boys' performance. It is possible, however, that neural plasticity may have occurred as well, either prior to or after surgery. Although it may not be possible to distinguish between cognitive and neural plasticity at this point, Immordino-Yang makes a crucial contribution. By placing these findings in an educational context and presenting their implications in a clear and compelling fashion, she successfully brings neuroscience and education a notch closer.

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A dialogue between neuroscientists and educators is a most difficult and yet a most needed endeavor. Advances in neuroscience during the past century have yielded important insights into mental functioning and development. Although the potential significance of these insights to education is enormous, so far this potential has proved to be difficult to realize in practice. Education and neuroscience have remained on the opposite sides of a river of difference, each afraid to wade through to the other side. In her article, "A tale of two cases:

Lessons for education from the study of two boys living with half their brains," Immordino-Yang (2007) boldly does what many others hesitate to attempt: She examines the depth of these differences and begins to chart the paths of possible passage that may eventually connect the two disciplines and enable the dialogue we so urgently need.

The approach taken by Immordino-Yang is both daring and original. The two boys she examined—Nico and Brooke, each of whom has lost half of his brain—are extremely rare. It is to her credit that she not only surmounts the difficulties in conducting psychological testing on such a rare population but also does this using highly innovative and scientifically rigorous means. She also undertakes the additional challenge of examining the most relevant but most difficult to study aspects of development: children's emotional and social experiences and their interaction with brain development.

One of the big strengths of Immordino-Yang's argument is that it underscores the importance of emotional and social factors in children's development and learning. Historically, both neuroscience and education have focused on cognitive development, often neglecting the emotional aspects of learning that are generally much more difficult to tackle. Immordino-Yang's approach has the potential to benefit both disciplines. The fact that her findings demonstrate an enormous influence of emotions on learning not only enriches our neuroscientific knowledge but also suggests one possible area of its application to education. By turning teachers' attention to emotional development, in addition to cognitive, it may be possible to modify educational practice to include a consideration of the social and emotional environments that children encounter during learning. This also suggests that it may be useful to consider possible expansions to the educational curriculum to include the acquisition of emotional skills that would enhance children's emotional intelligence (Goleman, 1995). By making a compelling argument for the

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organizing role of emotion in brain development, Immordino-Yang paves one of the first possible points of contact between neuroscience and education.

Although the lesion approach that Immordino-Yang uses is a strong and established method in neuroscience, she goes further than the localizationist conclusions that are typically drawn based on this approach to explore the effects of lesions on brain development, compensatory mechanisms, and cognitive strategy. Indeed, the question of “how” children do a particular task is of crucial importance to educators more so than “where” in the brain the process takes place. By emphasizing the importance of strategy and the existence of multiple ways to solve the same task, Immordino-Yang strikes another key point of contact between neuroscience and education that could help advance both disciplines. An appreciation of the range of strategies that one may take toward a task could greatly benefit neuroscience, where differences in recruitment of regions (e.g., between depressed and healthy subjects or between male and female subjects) are often interpreted as difference in function—although a simpler difference in the task approach that each group takes is much more likely. For example, the finding that men and women show differences in terms of brain recruitment during visual search and emotion recognition tasks (Baron-Cohen et al., 2006) has been used to support the argument that female and male brains are “wired” in fundamentally different ways—with female brains wired for empathy and male brains for understanding systems (Baron-Cohen, 2003). A much simpler explanation for these differences in brain recruitment, however, would be a difference in the strategy that women and men are likely to undertake toward the same task. Indeed, there is no reason to believe that empathy and understanding systems are two mutually exclusive abilities. Either sex is clearly capable of both, but the likelihood that a particular strategy would be employed for a given situation may differ.

Appreciating the diversity of strategies that people can undertake toward a problem could also benefit education by emphasizing the importance of teaching different strategies and helping students develop the skills necessary to be able to take different approaches to a problem. Much too often, educational practice is solution oriented, stressing the importance of reaching a solution much more so than the fact that there could be different ways of getting to it. The existence of multiple intelligences (Gardner, 1993) and diverse learning pathways (Fink, 2006; Fischer & Bidell, 2006; Fischer & Fusaro, 2007) is often ignored. This approach not only neglects important individual differences but also prevents educators from helping children expand the range of strategies available to them (e.g., a more emotional one vs. a more analytical one)—something which would be invaluable to them later in life, when the plasticity to learn different approaches is likely to be greatly diminished.

The standardization of examination methods and educational assessment is perhaps the biggest hurdle toward applying such an individualized and versatile approach to schooling. However, the vital importance of different strategies demonstrated by Immordino-Yang suggests that assessment might be one of the areas that may require the most important modifications. It suggests the necessity to include not only an assessment of the student’s ability in fields they excel in but also their relative *improvement* in fields that they may have difficulties in. A system that rewards a relative improvement in ability, as well as achieving high levels of expertise, is likely to encourage students to engage in the process of learning much more than our current education system and to expand the range of strategies available to students. Our current system, instead, encourages students to engage in the strategies which they are already good at to the detriment of their ability to solve tasks in different ways.

One of the most challenging goals Immordino-Yang sets out to achieve is to distinguish between neural and cognitive plasticity. Do the boys compensate for their extensive damage by adapting their remaining hemisphere to take over functions normally associated with the missing hemisphere, or do they instead transform the nature of the processing problem to suit the existing strengths of their remaining hemisphere?

This is an intriguing question. Unfortunately, the history of epilepsy in the two boys makes it difficult to provide a definitive answer. Because of the history of epilepsy, we cannot be confident that the hemisphere that was removed in each boy was normally functioning prior to surgery. Epilepsy is a devastating condition that can have a detrimental effect on the brain areas affected by seizures. Indeed, Immordino-Yang hints at that when she points out the potential for individual differences in the boys’ presurgery neurological profiles. Because for both boys, brain seizures were localized in the hemisphere that was subsequently removed, it is possible that the removed hemisphere’s functioning was impaired prior to surgery and that the remaining hemisphere had already assumed some of the functions that ordinarily would have been performed by the other hemisphere. Indeed, Brooke lost his left hemisphere at age 11 but was able to recover his ability to produce and understand speech in the months following the surgery—despite predictions that he would never be able to speak again. This suggests that his right hemisphere must have assumed important language functions prior to the surgery.

The remarkably successful performance of the boys on various linguistic tests, therefore, may be at least partially due to the fact that the hemisphere they were left with had already assumed some of the functions of the other hemisphere prior to the surgery. Immordino-Yang provides compelling evidence that Nico and Brooke capitalize on the important strategy of adapting tasks to suite the strengths of their remaining hemisphere. However, we cannot exclude the

possibility that in addition to this cognitive adaptation, the boys have also adapted their remaining hemisphere to take over, at least partially, some of the functions normally associated with the missing hemisphere. Indeed, it would seem that together the two kinds of adaptation—the cognitive and the neural—would produce a better outcome and more successful performance than either one in isolation. The strength of Immordino-Yang's argument is that it emphasizes cognitive adaptation, which is often neglected—although it is of greater relevance to educators. Ultimately, however, it may be difficult to draw a sharp contrast between the two kinds of adaptation: a change in cognitive strategy, if consistently employed, may well lead to neural changes in the long run.

Immordino-Yang's greatest achievement is in doing the most important thing that a neuroscientist can do to facilitate the application of neuroscience findings to education: getting involved in the dissemination of her results to an audience of educators and outlining the specific implications that these results have for the process of learning. If a dialogue between neuroscience and education is to be successful, it is indeed the neuroscientists who will have to take the initial steps of, first, formulating their results and theories so that they are accessible to the educators and, second, thinking about and communicating what they believe are the implications of these findings and theories to education. It is the neuroscientists who will need to make suggestions of possible changes in educational practice so that these suggestions can be discussed, tested, and if appropriate, considered for application.

Educators, on the other hand, will have the enormously difficult task of familiarizing themselves with these findings, theories, and implications. This is a much more challenging task than it may seem at first. Individual people and sometimes the public as a whole seem to easily become trapped into one of the two extreme attitudes toward neuroscience. On one extreme is the immense fascination with anything brain related. Magazines and newspapers are publicizing an ever-increasing array of functional MRI (fMRI) images, and some of them are making extravagant claims for their significance—such as being able to read the minds of potential voters (Iacoboni, Freedman, & Kaplan, 2007), pinpointing where love is localized (Carey, 2006), and detecting criminals (BBCNews, 2005). On the other extreme, the public, and sometimes scientists themselves, may dismiss neuroscientific findings altogether, viewing them as too reductionist and unable to explain psychological functioning (e.g., Geertz, 2000). The allure of both extremes is hidden in their simplicity: those who assume either position spare themselves the challenge of following the multitude of neuroscientific findings generated by scientists, identifying the relevant ones, and critically examining them to decide for themselves upon their credibility.

For a successful dialogue between neuroscience and education to occur, educators will need to remain in the more

difficult middle ground between these two extremes. While maintaining their interest in neuroscience, educators will need to keep in mind the potential allure of brain images and their tendency to increase people's acceptance of scientific arguments—even when those arguments are not valid (McCabe & Castel, 2007). We are all attracted to the idea of the brain itself (Carey, 2006), possibly because of the concrete physical representations of cognitive processes it offers in contrast to the more abstract representations offered by means of text, tables, or bar graphs (Weisberg, Keil, Goodstein, Rawson, & Gray, 2007). Because of this allure, the media and the general public have shown a tendency to oversimplify and misinterpret conclusions from brain imaging studies (Racine, Bar-Ilan, & Illes, 2005). Many neuroscientists are concerned about how the data from fMRI studies are presented by the media (e.g., Aron et al., 2007), and a number of scientists in the newly emerging field of neuroethics have argued that cognitive neuroscientists should become more involved in the dissemination of their data in an effort to enhance the understanding of techniques such as fMRI and reduce the misrepresentation of these data (Beaulieu, 2002; Illes, 2005; Illes, DeVries, Cho, & Schraedley-Desmond, 2006). In short, understanding neuroscientific findings is a complex process that has already presented multiple challenges to both neuroscientists and education practitioners and will undoubtedly continue to do so.

With these many challenges, the process of applying neuroscientific findings to educational practice is sure to be a difficult one. With her article, Immordino-Yang makes a decisive step toward crossing the divide. It remains to all of us, neuroscientists and educators, to face the difficulties and continue to explore the connections—and above all, to remain hopeful about our eventual success.

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