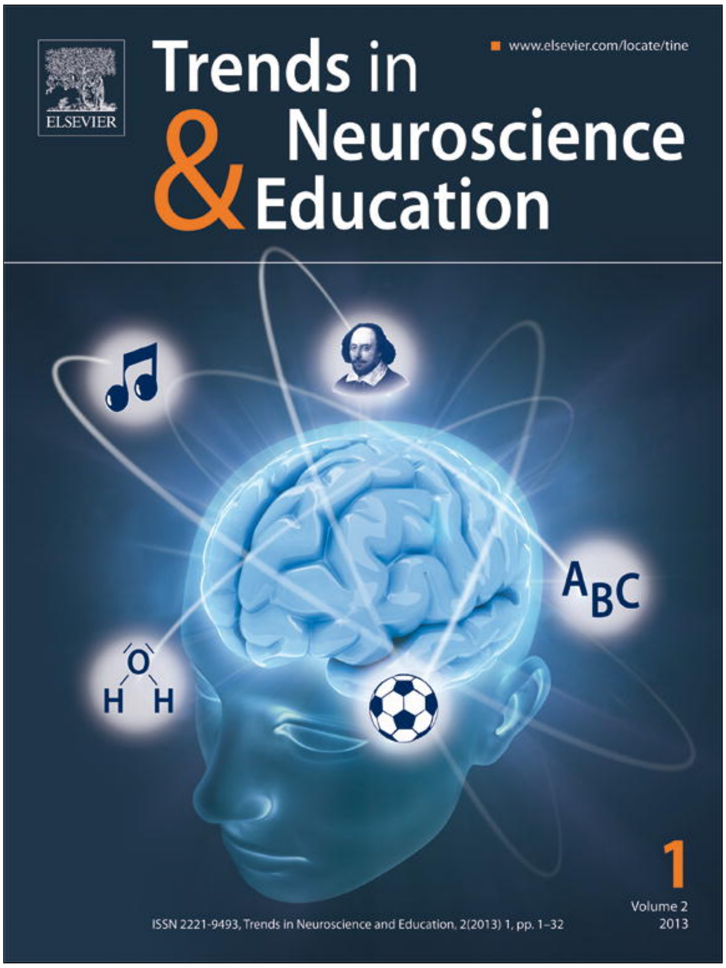
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Discussion

Educational neuroscience in the near and far future: Predictions from the analogy with the history of medicine

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ABSTRACT

Educational neuroscience is an emerging field that, proponents argue, holds great promise for the future of education. Several commentators have drawn an analogy between what neuroscience might contribute to education in the future, and what science has historically contributed to medicine. In this article, I pursue the analogy in greater detail, in order to provide a glimpse of the possible implications of the discipline for education.

1. Introduction

Educational neuroscience is an emerging field that, proponents argue, holds great promise for the future of education. Several commentators have drawn an analogy between what neuroscience might contribute to education in the future, and what science has historically contributed to medicine. For example, in 2011, The Royal Society in the UK published a policy document entitled 'Neuroscience: implications for education and lifelong learning', in which the report's authors argued that there was common ground between neuroscience and education that 'suggests a future in which educational practice can be transformed by science, just as medical practice was transformed by science about a century ago' [6], p.*v*. In the mission statement for *Trends in Neuroscience and Education*, the editors similarly draw parallels between educational neuroscience and the nineteenth century scheme instigated by von Helmholtz and others to move medicine onto a foundation of a scientific understanding of the body.[1] In the Editors' view, both education and medicine are forms of applied science.

In this article, I pursue the analogy between educational neuroscience and medicine in greater detail, in order to provide a glimpse of the possible implications of the discipline for education. What will happen to education following the application of (neuro)science? I first derive from the analogy a number of predictions about what lies in wait for educational neuroscience in the near future. I then speculate on what might lie ahead in the far future: in some cases, these speculations may be surprising and potentially uncomfortable for current educationalists.

2. The medical analogy

By the 19th Century, medicine reflected an accumulation of culture knowledge of what treatments seemed to work for what ailments. While rooted in 'folk' theories of biology, this knowledge base was in effect accumulated over generations of trial and error. In amongst those successful treatments, there was no doubt quackery, and fashionable treatments of the day with no efficacy or perhaps even harmful to the patient. These treatments were combined with a powerful placebo effect, whereby people benefitted from being treated and believing that the treatment would be successful (which provided the opportunity for quackery and health fads to perpetuate). Separately, natural scientists and anatomists were beginning to make progress on understanding how biological organisms functioned, from the cell to the organ to the whole individual. However, an understanding of mechanism had yet to influence medical practice.

Two hundred years later, we have a medical practice that is based on a vast scientific literature from multiple disciplines on the functioning of biological mechanisms, the genetic and environmental factors that lead to illness, the causes of disease, the efficacy of treatments and their potential side effects. In modern medicine, practitioners such as surgeons, diagnosticians, doctors, radiographers and nurses undergo many years of specialist training before they deploy their treatments on patients. Medical research continues, and a significant proportion of medical practitioners have contact with or involvement in research to

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further advance scientific knowledge of how to keep people healthy.

The analogy between educational neuroscience and medicine proposes that the teachers of today are the healers of yesteryear, with current teaching shaped by an accumulation of cultural knowledge of what practices seem to work; and the neuroscientists of today are the natural scientists and anatomists of the 19th century. In the future, the analogy implies, teaching will have been transformed and underpinned by a foundation of scientific understanding on the nature of biological learning mechanisms.

3. Three predictions for the influence of neuroscience on education in the near future

While the analogy may have shortcomings (and the characterisation of the history of medicine is no doubt simplistic), I believe it is sufficient to provide us with a glimpse of how educational neuroscience may influence educational practices in the future. Here are three implications that follow from the analogy.

Natural scientists and anatomists initially set about understanding how the body works and why it shows the ailments that it does. The novel medical treatments we now have stemmed from the scientific understanding of biological mechanism. The first prediction is that most of the initial contributions of neuroscience (and psychology) to education will be about understanding *why the educational methods that work do indeed work*. The contribution will be to understand the mechanisms at play. The initial contributions are, therefore, unlikely to tell teachers that everything they have been doing is wrong. It is reasonable to think that educational methods do, on the whole, reflect an accumulation of knowledge about what works. Only later would one expect neuroscience to tell educators '*and here's what else might work*'—that is, to predict new or optimised teaching methods based on an understanding of mechanism. In the more distant future, it is possible that these new methods will lead to a stark improvement in educational outcomes, in the same way that historically modern medicine has transformed public health outcomes. That part is still uncertain. If correct, the consequence of this first implication is that teachers should have little to fear from educational neuroscience. In the immediate future, the discipline is not there to prove teachers wrong but to show why they are right.

Of course, educational neuroscience may straight away offer some suggestions of novel methods. The second prediction of the medical analogy is that neuroscience is likely to offer rather few 'magic bullet' insights of methods that suddenly revolutionise education. If one looks at the history of medicine, one can identify some such bullets: the discovery of penicillin, the discovery of germs as the pathway of disease transmission, the discovery of the method of vaccination. But on the whole, the contribution of science to public health has been about the contribution of many small effects to improving health. This is sometimes called the *medical risk model*—many factors are at play in determining health outcomes. The improvements that neuroscience will offer to education are also likely to be many and of small size. One may hear of cutting edge educational techniques emerging from educational neuroscience—the benefits of training working memory or training executive function, the benefits of spaced learning or reward-based learning, the importance of sleep to consolidate memories, or of diet or aerobic exercise. I predict, however, that none of these techniques will be magic bullet solutions to *revolutionise* education across the lifespan; rather, they will represent an accumulation of small effects that can combine to optimise learning.

The third prediction of the medical analogy is that the first findings from neuroscience that will exert a significant influence on education are likely to be broad, rather than specific to topics within the curriculum. In the same way that anatomy and natural science made extensive use of animal and plant models to discover principles that hold across living organisms, I expect that the first findings about mechanisms of learning to influence education will be factors that can be observed across a range of species—primates, mammals, or even simpler species. For example, influences on brain plasticity, learning and cognition may include general factors such as diet and exercise, circadian rhythms, vigilance and stress, emotions, and social hierarchy effects.

4. Three predictions for the influence of neuroscience on education in the far future

The above seem to me reasonable predictions to make about the future of educational neuroscience in the near future. The medical analogy does prompt some more speculative predictions for the more distant future, and some of these are more controversial. Again, here are three.

First, within medicine, the *placebo effect* has made the evaluation of treatments much more complicated: knowledge of the fact of being treated influences the outcome for the patient. Even today, there exist alongside modern medicine 'complementary' techniques, such as homoeopathy or crystal healing, that are at odds with a mechanistic understanding of biological systems. Scientific medicine argues that such techniques rely on the placebo effect, and maintains that they do not survive the gold standard of randomised double-blind control trials. The key question here is, *will there turn out to be a placebo effect in education*? Will knowledge of being in an educational intervention or subject to a special teaching technique produce improved educational outcomes independent of the causal mechanisms thought to be at play? There are some suggestions that it could: social scientists have identified the 'Hawthorne effect', whereby in field experiments, the participants' knowledge that they are in an experiment modifies their behaviour from what it would have been without the knowledge [1]. If there is an educational placebo effect, it will complicate the evaluation of new educational techniques, and therefore slow down the rate at which neuroscience can contribute to education, even if the causal claims that neuroscience makes about learning mechanisms are correct. And as with medicine, one would predict the survival of educational techniques that do not have a causal basis, instead relying on the educational version of the placebo effect for their success. Indeed, ironically, it is possible that these 'complementary' educational techniques will include terminology drawn from neuroscience itself (see discussion of 'neuromyths'; [3,5,6]).

The second more speculative prediction is that some findings may emerge from educational neuroscience that are not entirely palatable for current neuroscientists and educators. Here are four possible findings:

a. *The better that teachers do their job, the more different their students will become*. The field of behavioural genetics tells us that when the environment is as good as it can be, then the differences that remain will be those that are intrinsic to the individual. As teaching gets better, the genetic differences in potential between children will come to the fore. This does not sit well with the intuition held by some that teaching should bring all pupils up to the same level of excellence. Of course, for others, education is about maximising the potential in each individual. From this perspective, one role of teachers should be to encourage gene–environment correlations, which exaggerate the differences between children. In an educational gene–environment correlation, individuals select the environment to which their genotype is best suited. Children with a talent for maths choose maths classes; those with a talent for languages choose language classes. The children become more different as they maximise their potential. Whether one advocates bringing individuals up to the same level of excellence or maximising each individual's potential, the key point is that when teaching methods have been optimised, everyone will be doing better—that is, the mean of the population will have risen.

b. *Optimal teaching will require the full genotyping of children*, in order that teaching techniques can be tailored to the individual. Research on training of working memory has already demonstrated that individuals with some variants of genes affecting neurotransmitter function are more responsive to training than others (e.g., [2,7]). Society's discomfort with individual genotyping is already evident within medicine, where there is resistance to the idea of genotyping for personalised drug treatment. Society may have excellent historical reasons for harbouring a reluctance to categorise individuals according to their genotype. But this, nevertheless, may be the way to optimise teaching.

c. *Interventions may have side effects*. Because the human body is a complex system with many interacting parts, it has often proved difficult to alter one system without affecting others. The idea of side effects is familiar within modern medicine. Perhaps we will find a comparable situation in educational neuroscience. The brain has a similar level of complexity. For example, neurotransmitters such as dopamine play different roles in different brain systems. It may be that techniques benefit some skills at the expense of others. For example, an enhanced working memory may be helpful in performing tasks involving manipulating information, but impede the acquisition of abstract principles—if you can keep lots of information in mind, why would you need to extract the general principles of how a problem domain works? If side effects do emerge, learners would need to make a cost–benefit analysis before choosing to undergo a given technique, in the same way individuals weigh the benefits and risks of taking particular medicines. The contribution of educational neuroscience would be to guarantee that the intervention is effective and to allow the learner (or their guardians) to make an informed choice about its use.

d. *Not all aspects of children's abilities may be as manipulable as educators hoped*. To take two examples, motivation and self-perceived ability are held to be important in children's educational outcomes. Teachers strive to alter children's motivation and self-esteem in order to enhance their future learning. However, some initial findings from behaviour genetics suggest that while motivation and self-perceived ability are indeed important predictors of educational achievement, they are also substantially heritable [8]. For example, Tucker-Drob and Harden [9] recently presented evidence that the greater heritability of school achievement observed in children living in higher socio-economic status homes could be traced to a genetic link between learning motivation and maths achievement. As they argue, 'high quality environments [may] enable children to expose themselves more selectively, and attend more acutely, to learning experiences that are consistent with their genetically influenced motivations to learn ([9], p. 44). Similarly, Greven et al. [4] found that children's self-perception of their abilities also predicted their subsequent school achievement. Yet while many believe variations in self-perceived ability are environmental in origin, Greven et al. found substantial genetic influences on individual differences in self-perceived ability. If motivation and self-perceived ability turn out to be highly heritable, this would imply that they are not particularly responsive to the intervention of teachers—at least, not based on the methods teachers are currently using to alter them.

The third long-range prediction based on the medical analogy is that the main practical consequence of neuroscience placing education on a scientific foundation will be in the *training of teachers*. Consider the training today of doctors, nurses, and health visitors. A good proportion of their training comprises understanding how the body works. For these three, read the future head teacher, the future classroom teacher, and the future classroom assistant. Today's educational neuroscientists sometimes canvas today's teachers on what aspects of brain function they would like to know in order to help them teach. This may be an important exercise in propelling the convergence of the fields of education and neuroscience. But the main impact of educational neuroscience will be in the training of the teachers of tomorrow. If you were given the choice right now of visiting a doctor who had memorised a list of symptoms and their linked treatments, or a doctor who understood the reasons why diseases produce the symptoms they do and why treatments work, which one would you choose? Likewise, you may in the future have a choice about the teacher you choose for yourself or your children when it comes to educational techniques and educational outcomes.

5. Limitations of the medical analogy

I have offered six predictions for the future of educational neuroscience based on an analogy to the way that science transformed medical practice from the 19th Century onwards. It is important to remember that analogies break down. Educational neuroscience may differ from medical practice in important ways. Education is intrinsically a social, classroom-based phenomenon, compared to the dyadic phenomenon of the doctor–patient relationship. The child or adult's understanding of their own identity in relation to the teacher and their classmates may be an important factor in their educational achievement. Ethical issues surrounding educational interventions may be more complex than those surrounding medicine. A drug serves to treat a disease; but education serves to advance social mobility and alleviate poverty. And an understanding of the mechanisms of learning cannot tell us what should be taught in our classrooms—these are issues for society to decide. Nevertheless, the analogy we have followed here produces interesting implications. Some are comforting for educators: there will be no overnight revolution as neuroscience filters into education. Others point to the possibility of a brave new world.

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