Philosophical Questions and Opportunities at the Intersection of Neuroscience, Education, and Research

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Neuroscience is a popular solution to a host of social problems, perhaps constituting a "neuromania" (Legrenzi et al. 2011). Education is an especially fertile ground for neuroscientific applications, for there are many who envision finally putting education on a firm scientific footing, a vision that has not been realized up to now. Neuroscience has all the trappings for such a footing: rivalled perhaps only by genetics, it has an immense authority in the popular imaginary, with flashy presentations in the media where alluring images of brains are used to point out crucial differences in everyday behaviors and traits. Previously, discoveries about how the brain operated were limited to what could be found through brain damage studies such as lesions and localized trauma, which typically brought to light very particular disabilities, a kind of subtractive approach. These were usually interpreted as evidence for correlations between local brain areas, particular mental functions, and visible abilities. However, noninvasive techniques to study the brain in action have given us many possibilities of going beyond those earlier limitations. These techniques, which typically involve producing brain images, go by a variety of acronyms including PET, SPECT, MRI, and fMRI. Recent improvements in such techniques have made neuroscience alluring not only for the general public but also for educators. It is very tempting to assume that the noninvasive approaches to localized brain functions give us direct access to particular mental activities, including learning.

Neuroscience's popularity and authority combine to give it great cachet in its application to educational research and practice, a field that often struggles with issues of legitimacy and expertise. There are many books for the K-12 teachers by popular enthusiasts (e.g. Jensen 2008; Wolfe 2010), which spell out "brain-based" teaching methods and learning strategies, ardently suggesting that neuroscience will

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finally give educators effective teaching approaches. There are also more nuanced, scholarly books advocating neuroscience-based educational practices (e.g. Geake 2009; Sousa 2010), whose assumption, likewise, is that education ought to use evidence-based methods. Philosophers of education have noted that these approaches are typically rooted in cognitive science, and thus already interpret education as applied psychology (Smeyers 2016b). Understanding education as applied psychology can easily incorporate neuroscience and thus would have a natural propensity to view education as an application of neuroscientific discoveries. On this model, education amounts to an applied science, which might be called evidence-based learning (Carew and Magsamen 2010). Perhaps in part because of its continuation of the psychological model, neuroeducation does not typically address philosophical issues around the intersections between neuroscience and education.

This gives philosophers opportunity to develop thoughtful, incisive appraisals of neuroscience in its connection to educational research and practice. Jan Slaby has suggested that neuroscience can be doubly fascinating for philosophers, for on the one hand the brain is the zone where "matter meets mind" (subjectivity, consciousness, learning, memory, agency) while on the other the brain is one of the "last true frontiers of science" (with possibilities of novel discoveries and breakthrough technologies) (Slaby 2015). This is particularly true for educational philosophers. Certainly the topics of memory, learning and agency are central in education, and could profit from continued philosophical attention. Indeed, there is now a nascent interest by philosophers of education in the intersection of neuroscience and education (e.g. Joldersma 2016c). This chapter surveys the current work in this area by philosophers of education, and suggests directions for further research. The survey includes ongoing philosophical critique of the ways that neuroscience is positioned and applied in education, while also incorporating scholarship that asks new philosophical questions at this intersection.

Philosophy of Education's Critique of Neuroscience and Neuroeducation

Although some philosophers of education might be leery of engaging with empirical research in their scholarship, there is often something to be gained in interacting with empirical studies. There are already numerous examples of philosophers of education engaging with, and *doing*, empirical research (Wilson and Santoro 2015). This includes for example Amy Shuffelton's arguments against a certain conception of poverty and cultural interventions (Shuffelton 2013) and Walter Feinberg's research in faith-based and public schools addressing religious belief in a democracy (Feinberg 2006; Feinberg and Layton 2014). Conceptualizing the engagement with empirical research has varied, including seeing it at a *midpoint* on a continuum (Golding 2015) or a *fusion* between the philosophical and empirical investigations (Hansen et al. 2015). However, perhaps more fruitful for understanding philosophy's

engagement with neuroscience is Claudia Ruitenberg's suggestion that "other educational research can provide philosophy of education with phenomena—and knowledge of phenomena—to think *about*, to ask questions *about*" (2014, p. 90). This takes us beyond a mere fusion or a location on a continuum, to a particular *reason* for the engagement. Gert Biesta and Michael Peters argue that a central task of philosophy of education is to "expose and criticise often hidden assumptions and dynamics that are often presented and understood by researchers and policy makers as benign and as orientated towards the improvement of education…" (Biesta and Peters 2015, pp. 620–621). Ruitenberg's suggestion gives this task another content area for such questions, namely, phenomena outside of philosophy of education as such. These philosophical questions can bring to the foreground ways such assumptions and dynamics might play out. Philosophy of education thus has the unique task of asking *philosophical* questions about the empirical research around the nexus of neuroscience, education, and research.

Questioning Frameworks for Simplistic Claims, Neuromyths, and Commercializations

Educational philosophers are well positioned to ask philosophical questions of neuroscience, both as a science and in its so-called application to education. As a science, neuroscience's findings are illuminated through certain concepts (e.g. levels of explanation, neuron doctrine, cause-effect, appearance-reality, subjective-objective, computational model), highlighting particular dimensions while hiding others from view, thus creating potential distortions in our understandings even as it reveals other truths. This gives philosophers of education something substantive to question, highlighting problematic conceptualizations and simplistic applications, including how uncritical assumptions create problems in neuroscience's application to education. In this section I examine some of the ways in which philosophy of education has developed critiques of neuroscience, including its application to education, and I suggest directions for further work.

One area is that of misleading and simplistic claims about neuroscience for education. There is already much helpful educational literature involving warnings about this, typically tackling the misleading nature of neuromyths and the exaggerated claims of brain-based commercial products. Neuromyths are claims about the efficacy of ways of learning or teaching that are, at best, *loosely* based on neuroscientific research and evidence about the way the brain is involved (Pasquinelli 2012; Tardif et al. 2015). Although often debunked, neuromyths remain a central issue in neuroscience and education, and likely will not be going away soon; for example, a recent study showed that teachers believed in about half of the popular neuromyths (Dekker et al. 2012; see also Willis 2015). Geake (2008) lists examples, including "we use only 10% of our brains", the idea of multiple intelligences, the idea of general brain exercises; the existence of "left- and right-brain learners", that there

are "visual, auditory, kinaesthetic (VAK) learning styles", and "drinking water enhances learning", Dekker et al. list several more neuromyths, including "children are less attentive after consuming sugary drinks", "fatty acid supplements have a positive effect on academic achievement", "exercises that rehearse co-ordination of motor-perception skills can improve literary skills", "short bouts of co-ordination exercises can improve integration of left and right hemispheric brain function", "there are critical periods in childhood after which certain things can no longer be learned", "extended rehearsal of some mental processes can change the shape and structure of some parts of the brain" (2012, p. 4). Beyond neuromyths, there are also a host of commercial products that claim the attention of educators. Brain-training products and organizations such as *LearingRx*, *CogMed*, and *Lumosity* often use computer-based activities to achieve brain improvement and enhancement. They typically legitimize their claims with appeals to brain plasticity research, suggesting that their activities enhance strategic neurological pathways for cognitive functions such as attention and memory (see Hurley 2012). Some commercial curricula and teaching guides are geared specifically toward educators, including *Brain Targeted Teaching*, *Fast ForWord®*, and *MindUP* (Busso and Pollack 2015). Fortunately, there is also good scholarship showing that employing neuromyths and using these commercial products are problematic for practitioners; 'exploding' the myths and deflating the claims is good public service by educational theorists, and this work needs to continue.

There is evidence, however, that in deflating the claims about commercial products or refuting neuromyths, educational researchers often continue to tacitly accept problematic frameworks, including the idea that evidence-based practice should shape educational conversations (Carew and Magsamen 2010; Davies 1999). Philosophers of education have taken a variety of approaches in bringing further this critique, particularly around neuroscience's application to education. For example, Ansari has examined the ethics around how the current hype around neuroscience influences educators, including the neuromyths teachers might embrace in their enthusiasm for neuroscience's authority (Ansari 2015). Davis has criticized the propriety of an evidence-based model for education in the first place (Davis 2004; see also Biesta 2007). He suggests that neurophysiology does not have the requisite authority about learning, for the latter involves value-laden claims in ways that the former cannot adjudicate. Maxwell and Racine have explored the ethics of aligning moral education with cognitive psychology and neuroscience (Maxwell and Racine 2016). And Boyles argues for what he calls "neuropragmatism" to counter the "commercialism" of neuroscience's application to education precisely because it "is currently largely divorced from philosophy and history" (2016, p. 74). In his critique of commercialization, Boyles brings to light that education is more than a technical problem of 'engineering', but rather always also involves normative visions of purposes and end goals. These approaches show how philosophers of education go beyond mere critique of the excessive claims by neuroscience-based commercial products, moving the conversation philosophically, to the ethical and conceptual.

Questioning Neuroimaging Technologies and the Medicalization of Learning

But philosophical questions are also asked in areas beyond the low-hanging fruit of neuromyths, commercial products, and evidence-based practices. For example, the explosion of neuroscientific knowledge involves the development of noninvasive ways of studying the brain. Some neuroscience literature suggests that despite the clear color-coded pictures of brain scans, techniques such as fMRI give results that are at best incomplete (Zatorre et al. 2012). Philosophically, the advent of such techniques has opened up a line of questions that might be termed *technical*, focusing on the status of the claims made on the basis of these techniques, whether that be about what they claim to tell us about the brain's functioning or about the mind and human behavior (Dumit 2011; Manzotti and Moderato 2010; Poldrack 2000; Raz 2011). Smeyers has questioned the assumption of "visible proof" that brain pictures supposedly provide (Smeyers 2016a). More generally, Joldersma has argued that technical criticisms "raise important methodological questions about the scientific project of localization required to confidently draw conclusions about neural correlations between mind and brain…" (2016a, p. 162). The technical or methodological problem here is that in order to get the neural correlation thesis off the ground, the technologies for localizing brain activity need to be unambiguous. There is still debate over whether or not these technologies have yielded the required accuracy (Hanson and Bunzl 2010). Philosophically, however, the technological issues of localization have exacerbated the problem of conflating correlation and causation. Smeyers has suggested that the correlations themselves are plausible only when we gloss over the actual differences between individual brains, "which often vary greatly" (2016b, p. 40). Moreover, as Maxwell and Racine point out, a "significant portion of [this research] is also animal-based…" (2016, p. 64), which requires the assumption of basic similarity to humans for strong cross-over conclusions. Although techniques such as fMRIs are clearly useful in studying the brain, they have often led to overhasty conclusions and applications, temptations that philosophers caution ought to be resisted. Through a critique of neuroscience's technological issues, educational philosophers can rightly question the educational importance of the techniques backing the correlation claims.

Correlation claims are central in neuroscience-based diagnosis of learning deficits, the latest approach to a long history of medicalizing student behavior and abilities (Petrina 2006). By 'medicalization' I mean using the binary of normal and pathological to label students on various dimensions, where the pathological then invites interventions toward restoring normalcy. Neuroscience's standard mode of operation is finding mind-brain correlations, neural correlates as they are often called (Chalmers 2000). This is something that fits hand in glove with the medicalization of behavior (Conrad 2008) and is reflected in education (Tröhler 2015). The unstated assumption here is that differences are medical deficits in normal behavior, for example, shyness becomes an anxiety disorder, wandering attention becomes ADHD. Resistance to authority becomes ODD (oppositional defiant disorder). The

correlation of behavioral differences with brain variances then interprets the neurological distinctions as the source of the behavioral deficits. When what is assumed to be the source of the pathology is discoverable in the brain's structures and functions, it then invites possible micro-interventions at the neuronal level (Schrag 2011). One central philosophical question about the medicalization metaphor is its underlying categorial schema. In previous work I have pointed out that the labels of medicalized deficits such as ADHD and dyslexia are imported into the discovery of neurological differences, which in turn are then used as evidence-based advice for educational interventions (Joldersma 2013). In turn, this approach assumes a one-to-one correspondence between micro-level localized brain processes and macro-level global educational behavior. A philosophical critique of this schema uncovers how neuroscience continues "to categorize learners using apparent neurological differences" (Busso and Pollack 2015, p. 6) while smuggling normative valuations into those judgments through extra-scientific metaphors such as "deficits". That is, philosophy of education attends to the conceptualization of the critique by drawing attention to problematic underlying assumptions of the medical model seemingly inherent in neuroscience. This is especially important in its engagement with neuroscience because many of the current labels for different learners are couched in the authority and popularity of neuroscience.

Technological Interventions for Self-Enhancement

The medicalization issue points to an equally important matter that philosophers of education need to address. As Slaby and others have argued, the medical frame is merely one side of a discourse that has been ensnared by neuroscience. The other dimension involves what Slaby calls "technological self-optimization" (Slaby 2015, p. 20), namely, an anticipatory optimistic future that promises human life progress if not perfection. Medicalization is merely the reverse side of this visionary framework, for it sets, by means of neuroscientific expertise, the demands we as society feel authorized to place on individuals—for example, about what each of us has a duty to do with respect to brain development, maintenance and repair, if not enhancement (Joldersma 2016b). Embedded in the idea of technological self-optimization are problematic concepts of human life, salvation, and utopia. Paul Smeyers has called these theorists the "believers" for whom "the sky is the limit" (Smeyers 2016b). Emma Williams and Paul Standish point out that hidden in this optimism is a problematic fusion of neurobiological accounts of the brain with psychological accounts of the mind (Williams and Standish 2016). As the neuroscientific optimists incur greater inroads into educational practice, more of these sorts of philosophical critiques are necessary.

There are now neuroscientific technologies which no longer merely record brain events, but which are aimed at *interventions* in the brain processes. Although societies have long used neuropharmaceuticals to intervene in what was considered pathological behavior, the new interventions seem more powerful and in need of greater

philosophical scrutiny. For example, an emerging cluster of techniques is called "optogenetics", methods that combine genetics and optics to control particular events inside specific (living) cells (Pastrana 2011). In particular, the technique inserts genetic material into cells that allow it to be responsive to light stimulation, and this is used as a way to stimulate those particular cells with targeted light. According to one of its main developers, although it is presently not yet ready for application to human brains, this set of techniques will at some point have "potentially near-complete powers for mapping, recording the dynamics of, and controlling the dynamics of neural circuits" (Boyden 2015, p. 1201). Optogenetic technologies, designed to deliberately intervene in local brain events, are now being looked at to improve, for example, cognition (Kantak and Wettstein 2015). Another technique of noninvasive (or quasi-noninvasive) direct intervention in brain functioning, which has already been used with human subjects, including ones deemed nonpathological, is transcranial direct-current stimulation (tDCS). This has been put forward as "a non-invasive tool to guide neuroplasticity and modulate cortical function by tonic stimulation with weak direct currents" (Nitsche et al. 2008, p. 220). This technology intervenes in the brain's plasticity (as it interacts with the environment) by means of weak electrical currents applied to the scalp through electrodes placed in strategic locations. Depending on where on the scalp the current is delivered, the method is meant to enhance performances of a variety of cognitive tasks of particular interest to educators, including language, mathematics, attention, and memory. Indeed, this method is beginning to be thought of as a low-cost, portable way to help educators: "A major goal of educational efforts is to develop techniques for enhancement of learning and to promote better retention. tDCS has the potential to help in such efforts" (Coffman et al. 2014, p. 899).

Neurologically based intervention techniques into educational behaviors such as learning give rise to a number of philosophical issues, including particularly moral or ethical ones. Are such interventions ethically permissible? Albeit in a slightly different context, Maxwell and Racine have pointed out the ethical issues around the risks of experimental (including imaging) techniques used at the interface between neuroscience and education (Maxwell and Racine 2012), a critique that could be extended to address direct interventions. But further, such interventions give rise to questions concerning the ethical stance involved in believing that technological enhancement of learning is a moral good. What view of normalcy is involved? What is the understanding of the learner's agency and responsibility that is being harmonized with the good of interventions such as these? Philosophers of education have not yet addressed these questions directly or explicitly. But they could well build on Smeyers' skepticism that a description or explanation "in terms of neurological concepts and theories does not in itself warrant an *educational* surplus value" (Smeyers 2016b, p. 41). And they could build on Davis' analysis that there is an inherently ambiguous understanding of the taxonomies used to label learners, distinguishing normal from pathological (Davis 2008). Just changing a brain-state and effecting some behavioral change is not yet educational. To warrant calling it an educational enhancement requires going beyond the factual into the normative, beyond the technical into the realm of judgment. Philosophers of education are in a good position to evaluate the 'good news'

about the neurological enhancement of learning. Their role can be to help educators sort out the ethical stances they might take toward 'artificial' interventions in learning. And central to philosophy of education is connecting such judgments to normative visions of education.

Intervention techniques, medicalizations, and correlation claims call forth philosophical concerns about the *model of learning* that often is assumed. Philosophically, the concept of learning in neuroscience is typically reduced to a brain process associated with, at best, a narrow understanding of knowledge acquisition, including skills such as word decoding or number manipulation. Kraft turns this into a more general question about the propriety of neuroscience's domination over education, suggesting that it reveals a deficit in educational theorizing itself (Kraft 2012). Standish, similarly, uses Wittgenstein to uncover hidden but problematic assumptions about the relations between mind and body (Standish 2012). When asking questions about neuroscience's research on learning, philosophers of education can go beyond the typical criticism that neuroscience narrows or reduces learning, to questioning the validity of framing educative learning as primarily a brain activity. By asking philosophical questions about neuroscience's view of learning, philosophers of education are in a good position to connect this to a critique of the "learning culture" of current schooling more generally, what Biesta (2009) calls "learnification". And this does not yet address the critique that "learning is not education" (Burbules 2013), something that brings into focus the larger philosophical, normative question of the purpose of education.

Problematic Concepts of Science

Issues around interventions and localization technologies also lead to a set of philosophical questions concerning neuroscience's concept of *science*. There is a strong sense that, at least in its practice, neuroscience centrally involves using cellular and molecular neuroscience to explain psychological behavior (Bickle 2003b, 2013). This practice has strong affinities to a long-standing positivist interpretation of science (Misawa 2013; Phillips and Burbules 2000). Philosophers of education have begun to ask what this interpretation imports into its application to education. Schwandt has opened this conversation by outlining possible "deleterious consequences" of science-based educational research (Schwandt 2005). More recently, Smeyers has questioned the model of research in which basic neurofacts are taken to have straightforward applications to teaching methods. He argues that this approach has never really departed from logical empiricism "characterized by the invariance of perception, meaning, and methodology" (Smeyers 2016b, p. 34). This scholarship is a promising start, but indicates that more work can be done in identifying problematic positivist understandings in neuroscience, especially as read by educators. In this regard, philosophers can open up interpretive space by helping education understand the scientific character of neuroscience as a hermeneutic activity, importing framing metaphors and concepts into its conclusions (Hartmann 2011).

This philosophical questioning begins to create elbow room to engage with the scientific character of neuroeducational research and practice. For example, Williams and Standish suggest that the metonymic language used in neuroscience concerning the brain "is made to stand for the whole in some *reified sense*" (2016, p. 20). They argue that the metaphors in neuroscience are so deeply embedded that we often no longer recognize their metaphorical character. Understanding neuroscience's model of science as deeply hermeneutical creates room for broader questions about the status of its empirical research, precisely for the sake of education. This is an important service that philosophy of education provides, for a critical voice about science itself is nowhere more necessary than in neuroscience research, especially as it is employed toward the improvement of education. Neuroscience as a *science* is itself not without its own tacit assumptions, which deserve to be scrutinized. It has smuggled into its account concepts that come from elsewhere but seem to arise from neuroscience itself, including metaphors such as "information", "computation", "plasticity", and "representation" (see also Borck 2011). The authority and popularity of neuroscience subsequently gives added authority to those imported notions, shielding them from further scrutiny. This means not only questioning particular problematic hidden assumptions in the research itself, but also exposing its preconceptions of what constitutes educational improvement, including what is meant by the term 'education'. Asking questions about the assumptions of what counts as educational improvement draws attention to the way knowledge and concepts of neuroscience circulate, including how they are translated into education and, in turn, how these new ideas in education are legitimated. Central to philosophy of education's role with respect to neuroscience is to reveal the way its concepts circulate—with an eye particularly to their translations into education and legitimations for the its practice. By problematizing neuroscience in this manner, it will help enable the re-democratization of the discussion of what is good education, one that cannot be answered by scientific discoveries (Biesta 2010).

A compounding philosophical issue in the science of neuroscience is the question of *reductionism*. For neuroscience, especially cognitive neuroscience, its stock method of analysis typically leads to some form or other of reductionism (Bickle 2003a, 2006; Soom 2011). There are of course many ways to parse out reductionism. Conventionally, in philosophy of science, it has meant the reduction of a theory in one domain to a theory in another—say, a theory in chemistry reduced to a more fundamental one, in physics. The assumption in the reduction is that the 'higher' theory is explained, with no remainder, by the 'lower' theory. Reduction typically is framed with a levels conceptualization, where a lower level provides simultaneously an explanatory (epistemological) and a causal (ontological) account of the higher level, without remainder. This opens the door for mapping manifest (observed, experienced) phenomena onto unobserved (theoretical, scientific) constructs. This form of reduction is prevalent in the neuroeducation field, often using the language of neural correlates (Aziz-Zadeh et al. 2013; Dehaene et al. 2010; Hruby and Goswami 2011; Kobayashi et al. 2007). In general, the idea is that mental states, construed as mental representations, are correlated with equivalent physical (neural) states.

This then allows physical properties of brains to be taken as both causing and explaining mental representations, reducing the latter to the former.

A central philosophical question arises: Is 'levels' the right metaphor? There are, as noted earlier, a number of theorists who use this metaphor in thinking about neuroscience, mind, and education (Bruer 1997; Gazzaniga 2010; Willingham and Lloyd 2007). The 'level' metaphor has some strengths, for it helps avoid particular errors. If, for example, mental representations exist on one level (the mind, say), but not the level below it (the brain, say, or the neuron), then it is a mistake of levels to insist that mental representations are in the brain, or that they can be observed via brain imaging. As noted earlier, Williams and Standish argue that neuroscience has pulled us into a category mistake with respect to learning: learning is not a neuronal activity of the brain, but a cognitive human activity—that we shouldn't talk about what the brain does when we mean something a person does—a version of the mereological fallacy (2016, p. 19). They argue that the reason for this confusion is because neuroscientists and neuroeducators draw on a historical reductionist conception of consciousness. Similarly, Maxwell and Racine tease apart levels of evidence, suggesting that philosophically, some applications of neuroscience to educational practices such as child-rearing have not respected the difference of levels of evidence (2016, p. 62). These are helpful philosophical analyses of reductionism via the idea of levels. However, more philosophical work developing critiques of the idea of levels itself remains to be done. This includes examining the almost inevitable hierarchical implications, the conceptual problem of isolating levels, the reification of entities indexed to levels, and the simplification of causal structures into linear (bottom up) ones.

Political Questions

A final set of philosophical questions might be clustered around what can be called the *political*. Importantly, philosophy of education's critique of neuroscience, especially in the area of education, can show the limits of conceptualizing the student as an autonomous, liberal subject, and of taking the purpose of education to be about developing individual autonomy. Thompson takes up this challenge, arguing that a future direction of philosophy of education is understanding the limits of the concept of subjectivity. Attending to one such limit, what she calls "normalization in education", reveals how "[t]he figure of the autonomous pupil is layered with various power constellations: the promise of an autonomous learning process, the perspective of a successful future, the hope of a successful school experience etc." (2015, p. 657). This limit reveals that the subjectification of the self involves not merely normalizing students with respect to a problematic autonomy but instead more questionably with respect to an enterprising self. Joldersma (2016b) extends this critique, suggesting that neuroscience can be and has been coopted by neoliberalism's interpretation of an ethic of self-responsibility. These political questions of neuroeducation deserve further exploration by philosophers of education.

Neuroscience's Possible Impact on Philosophy of Education

Engagement with neuroscience also has the potential for transforming philosophy of education itself. Despite rich critical lenses employed by most philosophers of education, the not-unexpected relative insularity of its disciplinary conversations means that these might harbor unexamined and sedimented 'commonsense' concepts and ways of understanding. A standing danger with philosophy of education—and indeed, any discipline—is that it tends to preserve large swaths of its own preferred language and concepts as it goes about its business. It is thus never bad for philosophy of education to have its familiar ideas and patterns disturbed and opened up for examination, "disrupting the complacent belief that one understands one's own thoughts and the language in which one formulates one's thoughts" (Ruitenberg 2009, p. 426). Ruitenberg calls this *translation*, and argues that it can be used as a "philosophical method", one that dislocates the native language through a process of defamiliarization, a distancing which "deliberately and noticeably insinuates itself between the reader and the text, in order to disrupt the apparent familiarity of that text" (2009, p. 433). I am suggesting that engagement with the neuroscience literature can fruitfully be thought of as one such realm of translation, allowing the 'foreign language' of neuroscience to insinuate itself between philosophers of education and their familiar concepts and understandings. This process of distancing and defamiliarization from certain conceptions of (say) mind, consciousness, cognition, emotion, or embodiment could lead to novel understandings of these philosophical concepts. This dimension of the intersection of neuroscience and philosophy of education reveals the possibility of going beyond the critical, toward a mutual interaction in which philosophy of education itself shifts ground.

Cultural Differences, Plasticity

One example involves discussions around educating students to appreciate cultural difference (Warnick 2012; Yacek 2014), including aesthetic judgment in globally cross-cultural contexts to do so (Nakamura 2009; White 2015). Dhillon has argued that neuroscience can help in understanding a new way into making judgments about artworks that belong to an unfamiliar culture, precisely "when we cannot rely on learned conventions to help engage these artworks" (2016, p. 130). She suggests that neuroscience can help make explicit the cognitive structures all humans share, which helps her answer questions about aesthetic properties and aesthetic judgments. In particular, she offers that neuroscience can help us answer the question of the relation between aesthetic properties of an artwork and its underlying (constituent) non-aesthetic properties of (say) line, shape, and color. Her philosophical purpose is to theorize how the presentation of "artworks of unfamiliar cultures should create aesthetic possibilities for educating students towards the global democratic ethos that is required of us today" (2016, p. 131). What neuroscience offers, she

suggests, is a novel understanding of how visual neuro-processing are shared across cultural differences, something that opens up space for appreciating culturally unfamiliar pieces as works of art. Although this is not a substitution of science for philosophy, Dhillon uses neuroscience to open up new philosophical paths.

Another way that philosophers of education have used neuroscience to unsettle the familiar is by borrowing from its conceptualizations. For example, a central discovery in neuroscience is that the brain's plasticity is not limited to early childhood, but endures (Huttenlocher 2009). In this, neuroscience takes plasticity as the brain's ability to change in response to its interactions with its surroundings throughout the course of our life spans. Malabou has made conceptual use of this idea but pushes it philosophically beyond the conventional idea of mere flexibility toward a more radical philosophical meaning (Malabou 2009, 2012). She argues for a notion of plasticity that is not merely an adaptation to our existing surroundings, but more radically, that plasticity involves the freedom to intervene in our circumstances. Bojesen, acknowledging Dewey's use of the term plasticity, uses Malabou to argue that philosophers of education need develop ideas of "educational plasticity" and "the plastic subject" to develop new lines of educational philosophy (Bojesen 2015). Ulmer does just that by taking Malabou's concept to be a "new materialist methodology", using it to reconceptualize policy discourses, including how educational policies are formed and altered (Ulmer 2015). Lewis takes this a step further, using Malabou's idea of plasticity to interrupt the ideas of flexibility, adaptation, and efficiency with the notions of ruptures, events, and explosions. He suggests that this will allow us to more explicitly recognize "the fragility and precariousness of educational life", an indeterminacy that "holds open a promise" in which "an alternative notion of the self can burst into presence without warning" (Lewis 2016, p. 153). This, he offers, takes us beyond Dewey's progressivist understanding of plasticity as a condition for the continuity of growth, by emphasizing contingency, rupture, and risk in educationally formative experiences.

Dynamic Open Systems

A third example is how the model of dynamic open systems can help educational philosophers situate their engagement with neuroscience. The word 'system' connotes both a model (say, a mathematical construct) and a collection of elements that relate to each other in a way that allows them to stand out in a stable fashion as a kind of whole distinct from its surrounding environment—for example, a lake ecosystem. The words 'open' and 'dynamic' indicate that the system does not remain static, but has much internal movement and environmental exchanges as it maintains its overall stability—for example, water enters and also leaves the lake, but it remains more or less stable in water volume and chemical composition. These changes are often described as nonlinear, indicating that when internal changes occur, the result (the whole) is not directly proportional to sum of what went into the process (the elements); rather something novel emerges. The main take-away is that

the system's behavior is neither merely random nor predictable. Rather, the changing behavior of the system seems at once to be unstable and yet something overall is enduring, a form of "metastability" (E. Thompson 2010, p. 40). Metastability is the endurance of a novel pattern of overall behavior that remains stable even though the internal dynamics that constitute it continuously change. Thompson suggests that metastability is necessary "for self-organization and adaptive behavior" (2010, p. 40). This model is a positive alternative to the reductionism of conventional neuroscience, and thus provides a way forward from the search for neural correlates, suggesting that not only the brain, but also the embodied organism's interaction with its environment, might be modeled as a dynamic open system. Philosophers of education are beginning to make philosophical use of this model.

For example, Gallagher uses the dynamic systems model to argue against what he calls "neural hermeneutics", the idea that we can identify brain mechanisms to "understand one another" socially (2016, p. 177), something that he says is associated with "theory of mind" approaches of social cognition. For his alternative he draws on the conclusions of a variety of neuroscience studies that show "cultural variations in brain mechanisms" (2016, p. 181) including perceptual experiences, emotional responses, face processing. This empirical evidence does philosophical work, allowing him to conclude that it undermines the theory of mind approaches, because it shows that social cognition is not "entirely in the brain or inside the head" (2016, p. 181). For his positive alternative Gallagher draws on enactivism, something that "understands the brain as an integrated part of a larger dynamic system that includes body and (both physical and social) environment" (2016, p. 182). Out of this dynamic systems model develops what he calls enactive hermeneutics, an understanding of the face-to-face interactions in terms of "participatory sense making", something that he believes is constitutive of education (2016, p. 188), and "natural pedagogy", an idea that "certain interactive aspects of communicative practices lead to conceptual learning" (2016, p. 185). Gallagher's enactivist approach is informed by the neuroscience which situates the brain in a larger explanatory unit. His conclusion is that, contrary to the theory of mind claims of neural hermeneutics, large-scale patterns of educational behavior cannot be predicted from the neural elements from which they arise. He can draw this conclusion effectively because it is informed by neuroscience, namely, those theorists who model the brain-body-environment as an open dynamic system.

Another example of using open dynamic systems for a "disruption of complacent beliefs" revolves around the implications of neuroscience for agency, free will, and moral development (Bayne and Pacherie 2015; Levy 2015). As Murphy and Brown (2009) smartly ask: did our neurons make us do it? Sankey and Kim provide an example of taking up this task, engaging the question "how free is conscious free will" (2016, p. 114). They employ a dynamic systems model of neuroscience, which allows them to question the hard determinism of conventional neuroscience while using the neuroscientific idea of self-organization to ground moral values in new ways, namely, in our embodiment. In particular, they argue that "moral development is emergent and self-organizing"; they see this as "a potentially new paradigm in moral education", challenging the Kohlbergian tradition of moral development

(2016, p. 117). This is a good example of using insights of neuroscience to disrupt certain "received views" of moral development and what it means to be a responsible self, to argue for another way that our moral values emerge, given our embodiment (see also Fenwick 2009). This example suggests that conceptual models such as dynamic systems can unsettle traditional ways of understanding moral values and selves for educational settings. More generally, neuroscience has the possibility for unsettling familiar language in philosophy of education, opening up new lines of thought and research.

Conclusion

The area of neuroscience is a fairly recent area of scholarship for philosophy of education. However, as this chapter shows, there are already many lines of inquiry that have opened up as philosophers of education turn to neuroscience. One broad line is a set of philosophical critiques, ranging from simplistic applications to examining the science itself. Another broad line is a set of philosophical inspirations, ranging from drawing on novel understandings of neural plasticity to philosophical appropriations of dynamic open systems. What these lines also show is that much more can be done. Addressing neuroscience, especially in its application to education, will fruitfully involve philosophers of education for some time to come.

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