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Neuroscience for Educators: What Are They Seeking, and What Are They Finding?

Cayce J. Hook
University of Pennsylvania

Martha J. Farah
University of Pennsylvania, mfarah@psych.upenn.edu

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Abstract

What can neuroscience offer to educators? Much of the debate has focused on whether basic research on the brain can translate into direct applications within the classroom. Accompanying ethical concern has centered on whether neuroeducation has made empty promises to educators. Relatively little investigation has been made into educators' expectations regarding neuroscience research and how they might find it professionally useful. In order to address this question, we conducted semi-structured interviews with 13 educators who were repeat attendees of the Learning & the Brain conferences. Responses suggest that 'brain based' pedagogical strategies are not all that is sought; indeed, respondents were more often drawn to the conference out of curiosity about the brain than a desire to gain new teaching methods. Of those who reported that research had influenced their classroom practice, most did not distinguish between neuroscience and cognitive psychology. Responses indicated that learning about neuroscience can help educators maintain patience, optimism and professionalism with their students, increase their credibility with colleagues and parents, and renew their sense of professional purpose. While not necessarily representative of the entire population, these themes indicate that current research in neuroscience can have real relevance to educators' work. Future ethical discussions of neuroeducation should take into account this broader range of motivations and benefits.

Keywords

educational neuroscience, neuroeducation, classroom instruction

Disciplines

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NeuroEthics

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Corresponding Author:	Cayce Hook, B.A. University of Pennsylvania Philadelphia, PA UNITED STATES
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	University of Pennsylvania
Corresponding Author's Secondary Institution:	
First Author:	Cayce Hook, B.A.
First Author Secondary Information:	
Order of Authors:	Cayce Hook, B.A.
	Martha J. Farah, PhD
Order of Authors Secondary Information:	
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Response to Reviewers:	Reviewer #1: "...I was concerned by some of the questions on page 4 - why, for example, should we expect that teachers are "misinformed about what neuroscience has to offer?", or that "they are simply gullible or confused?". Without any evidence to say so, I think that the authors should avoid this kind of negative depiction (even if it is hypothetical). Parts of the section (like this one) could be written more positively. We should expect these kinds of interviews with educators and educationalists to inform the future work of neuroscientists and neuroeducational theorists - maybe this could be emphasised more."

	- Updated the phrasing of this passage to clarify: "...what is the appeal for teachers? Are they misinformed or confused about what neuroscience has to offer, as some authors have implied? Alternatively, do educators understand what neuroscience can and cannot offer..." - Added: "Educators' motivations, beliefs, and pedagogical practices have a critical role to play in improving future work in, and discussions about, neuroeducation. Our goal was thus to learn what working educators look for in neuroscience and what they have found useful." "...I would suggest, however, that some indication of which comments come from which participants (using numbers, or pseudonyms) would be useful, so that the reader is able to see what responses come from which people. It would be useful to know which responses are from classroom teachers, which from special-ed teachers, and so on. This is important because at the moment, the reader can't tell if the data referred to in the results section are representative of the 13 participants as a whole, or if some participants were more interesting (to the authors) than others." - True enough. We have identified each quote by pseudonym initials and profession. "...The main conclusion is that the educators interviewed are good judges of the merits of research, and are not overly susceptible to misinformation and 'neuromyth'. These educators are also found to avoid 'pigeonholing' of scientific disciplines - they do not show strong boundaries between evidence from neuroscience and evidence from cognitive psychology, for example. This is a very positive finding - which could perhaps have been made more of in the paper. Many researchers in the field would say that if neuroscience is to have value in educational contexts, then an interdisciplinary approach is needed - which necessarily involves working across traditional disciplinary boundaries." - Good point. Under "Distinction between neuroscience and other relevant disciplines", the word "misconception" was replaced by "blurring of disciplines." - Added to conclusion: "Numerous authors have commented that interdisciplinary collaboration is critical to the future success of neuroeducation (e.g., Szűcs & Goswami, 2007; Bruer, 2008; Hardiman et al., 2010). That the educators in this study cited a wide range of cognitive research suggests just such a crossing of traditional disciplinary boundaries." "...On page 1, the quotation from Hardiman et al. should be referenced with a page number. On page 2, my feeling is that the 3 book title mentioned should be referenced." - Corrected. Thank you!

table
Click here to download table: Table_-_Interview_script.docx

Topic	**Questions**
Background information	How long have you been teaching? What grade or subject do you teach? When did you attend a Learning and the Brain conference? What were the specific topic(s) covered?
General impressions	Can you tell us about the experience? What are a few things you learned that stayed with you or that you found especially interesting?
Motivations	What were your original motivations for attending? What did you expect to gain from the conference? Which of those things did you get?
Effects	Do you feel that knowledge of neuroscience has changed the way you teach? If yes, how? If no, were you expecting that it would, or would not, and why? Has knowledge of neuroscience changed your view of teaching? If yes, how and why? If no, were you expecting that it would, or would not, and why? Do you think that neuroscience could be more useful, in practical ways, for teachers teaching certain other subjects, ages or types of students than for you? If so, please elaborate. Does knowledge of neuroscience affect the way you think about your students' differences in ability or behavior? To what degree does neuroscience research challenge or confirm beliefs you already hold about educational practice? Are there any other ways learning about neuroscience has affected you?
School support	Do you receive any kind of professional development credit for attending the conference? Does your school pay for you to attend the conference, or do you pay your own way? How do your colleagues perceive this research? Are they as interested as you are? Are they receptive to hearing about what you have learned at the conference?
Response to criticism	Some neuroscientists have claimed that we currently do not know enough about brain development and neural function to link that understanding meaningfully to educational and instructional practice. How would you respond to this criticism?

Table 1: General interview script.

author(s) details

Cayce J. Hook & Martha J. Farah

Center for Neuroscience & Society
University of Pennsylvania
Philadelphia, PA

Email: hook@sas.upenn.edu

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What can neuroscience offer to educators? Much of the debate has focused on whether basic research on the brain can translate into direct applications within the classroom. Accompanying ethical concern has centered on whether neuroeducation has made empty promises to educators. Relatively little investigation has been made into educators' expectations regarding neuroscience research and how they might find it professionally useful. In order to address this question, we conducted semi-structured interviews with 13 educators who were repeat attendees of the Learning & the Brain conferences. Responses suggest that 'brain based' pedagogical strategies are not all that is sought; indeed, respondents were more often drawn to the conference out of curiosity about the brain than a desire to gain new teaching methods. Of those who reported that research had influenced their classroom practice, most did not distinguish between neuroscience and cognitive psychology. Responses indicated that learning about neuroscience can help educators maintain patience, optimism and professionalism with their students, increase their credibility with colleagues and parents, and renew their sense of professional purpose. While not necessarily representative of the entire population, these themes indicate that current research in neuroscience can have real relevance to educators' work. Future ethical discussions of neuroeducation should take into account this broader range of motivations and benefits.

Introduction

Among the ethical issues raised in connection with the field of neuroeducation is teachers' vulnerability to misinformation concerning neuroscience and its relevance to classroom practice. Educators are eager for innovative methods to improve student learning, but they may lack the scientific training needed to critically assess the methods of neuroeducation. As many authors have pointed out (Ansari, De Smedt & Grabner, 2010; Society for Neuroscience, 2009; Devonshire & Dommett, 2010; Fischer, Goswami, Geake, 2010; Hardiman, Rinn, Gregory & Yarmolinskaya, 2011; Howard-Jones & Fenton, 2011; Sylvan & Cristodoulou, 2010), this combination of interest and lack of expertise leaves educators susceptible to unrealistic promises about the potential of neuroscience to help with the practical problems of teaching. In the words of Hardiman et al., "teachers, schools, and school districts may waste time and money pursuing so called 'brain-based' interventions that lack a firm basis in research" (p.1). The aim of this project was to characterize educators' view of the role of neuroscience in education, specifically to determine whether educators are in fact confused about the educational relevance of neuroscience and to learn whether and how knowledge of neuroscience enhances their work beyond the possibility of new methods for teaching.

Controversial, but popular

Neuroeducation has been a controversial field since its beginnings in the 1990s. In an early and influential critique, John Bruer (1997) argued that the path from neuroscience to education is "a bridge too far." He pointed out that our understanding of synaptogenesis and pruning, critical periods and the effects of the environment effects on brain development is incomplete and based almost entirely on studies of visual and motor systems in animals. He stated that this knowledge "cannot provide much guidance for educational policy, classroom practice or early childhood education… There is a gaping chasm between our understanding of what happens to synapses as a result of experience and what happens or should happen in preschool or third grade" (1997, p. 10). Even those sympathetic with the

idea of applying neuroscience to education have criticized the proliferation of low-quality science and misinformation in this area. The Organization for Economic Cooperation and Development popularized the term "neuromyth" to describe common but incorrect beliefs about the brain held by educators and others (OECD, 2002).

Despite criticism from without and within the field, neuroeducation has flourished. An Amazon.com search for "brain education" returns over 2,000 books, of which nearly 900 were published within the last five years. Titles such as *Brain Rules, Brain-Based Learning,* and *Teaching Smarter with the Brain in Focus* (Medina, 2008; Jensen, 2000; Armstrong, 2008) promise to provide useful pedagogical strategies grounded in neuroscience research, while educational programs and packages claim to enhance student learning by tapping into 'brain-based' learning principles (e.g., jensenlearning.com; brains.org). The International Mind Brain and Education Society publishes a peer-reviewed scientific journal and holds biannual meetings. At least five leading graduate schools of education—including Harvard, Cambridge, Dartmouth, Johns Hopkins, and Columbia—offer degree programs in neuroscience and education, and thousands of educators attend semiannual conferences on "Learning and the Brain."

Recent reviews of neuroeducation have highlighted a growing body of scientific research of clear relevance to education (e.g., Ansari, De Smedt & Grabner, 2011; Twardosz & Bell, 2012; Goswami, 2006). For example, brain imaging has enabled researchers to map the anatomy of reading and mathematics and to correlate individual differences in the acquisition of these skills with differences in brain structure and function (e.g., Dehaene, 2009; Gabrieli, 2009; Neider & Dehaene, 2009; OECD, 2002). Such research provides a scientific context within which to understand student learning, and, in the not-too-distant future, might enhance the assessment of readiness to learn or special needs. There seems little room for doubt that neuroscience has provided a scientific context for thinking about education and learning. The more difficult question remains: is neuroscience currently relevant to what teachers do? Can it actually guide pedagogy or support specific educational policies?

Some neuroeducation experts see neuroeducation as ready to be extended to classroom practice. For example, Blakemore and Frith (2005) assert that "There is a vast amount brain research of direct relevance to education practice." They attribute the dearth of successful educational applications of neuroscience to the challenges of interdisciplinary interaction and communication. However, most experts are more cautious about the pragmatic implications of neuroscience for teaching and learning "on the ground." Many call for increased collaboration between neuroscientists and practicing educators before the field of neuroeducation can realize its potential for influencing educational practice (Carew & Magsamen, 2010; Fischer, 2009; Varma, McCandliss & Schwartz, 2008). Many also contrast the field's progress in understanding the basic science of learning and development with the relatively undeveloped state of its contributions to practical problems of teaching. The Society for Neuroscience's Education Summit Report (2009) speaks of an "urgent need to close the gap between laboratory neuroscience research and teachers' practice in their classrooms… it is clear that brain science is not the driving force behind improving education practices" (p. 3). Goswami (2006) writes "there is a gulf between current science and direct classroom applications" (p. 2). Devonshire and Dommett describe the influence of neuroscience on education as "limited to being descriptive rather than prescriptive" (p. 350). Hardiman et al (2011) note that "there is a scarcity of rigorous research from the neuroscience community that is readily translatable" into educational practice (p. 3).

What are educators seeking, and what are they finding?

Given the near consensus that neuroscience has not yet proven itself relevant to classroom practice, one would not expect working educators view neuroscience as important to what they do. Yet there is evidence that neuroscience is regarded as professionally relevant. For example, Pickering and Howard-Jones (2007) asked three different samples of teachers "How important is an understanding of the workings of the brain" to their educational activities, including everyday practicalities such as the design and delivery of educational programs, and obtained high agreement. Depending on the sample,

67%, 80% and 87% of teachers rated neuroscience as “important” or “very important” for all aspects of teaching listed in the survey except for curriculum content. The popularity of neuroeducation books and conferences indicates that many teachers put their money where their mouth is concerning the relevance of neuroscience in the classroom.

Why is neuroeducation of interest to working educators? Whereas education theorists and researchers might be expected to seek out books and conferences on neuroeducation, what is the appeal for teachers? Are they misinformed or confused about what neuroscience has to offer, as some authors have implied? Alternatively, do educators understand what neuroscience can and cannot offer, and find value in what it does offer – perhaps in ways that have not yet been considered in the literature on neuroeducation? These are the questions this project seeks to address.

Educators’ motivations, beliefs, and pedagogical practices have a critical role to play in improving future work in, and discussions about, neuroeducation. Our goal was thus to learn what working educators look for in neuroscience and what they have found useful. Although teachers’ general level of interest and optimism concerning neuroeducation has been gauged by multiple-choice surveys, we do not know how and why they believe neuroscience to be relevant to education, nor do we have access to the more nuanced understandings they might possess of the neuroscience-education relation that are not captured by checklists and multiple choice questionnaires. To address these questions, we conducted semi-structured individual interviews with a small group of educators who had already demonstrated an interest in neuroeducation through conference attendance. Although this research approach is not able to provide quantitative information about the prevalence of specific viewpoints, beliefs or motivations, it is able to expand the qualitative space of hypotheses about why educators seek neuroscience knowledge and how they believe it benefits them. We were particularly interested in whether they believed neuroscience to be helpful in their work with students, what ways they believed it to be helpful, and whether or not those beliefs were based on misunderstandings or misinformation.

Methods

Subjects. The sample was drawn from practicing educators who had attended "Learning and the Brain" conferences. These conferences feature symposia and lectures by neuroscientists and neuroeducation specialists and are aimed at working educators. Conference organizers provided the authors with contact information for 28 individuals who had attended multiple previous conferences and were willing to be contacted by the authors. The inclusion of repeat attendees biases this sample toward educators who are interested in neuroeducation and find it of value. This is arguably an asset for research aimed at understanding the nature of educators' attraction to neuroeducation.

The authors succeeded in scheduling interviews with 13 of these individuals, including 3 classroom teachers, 3 combined teacher-administrators, 4 learning specialists, 1 gifted specialist, and 2 special education teachers. Respondents had substantial professional experience (median years in education = 28, range = 7- 47), had attended several Learning and the Brain conferences (median = 4, range = 1 – 7) were predominantly women (11 of 13) and predominantly working in private or independent schools (9 of 13).

Procedure. The interviews were carried out by phone by the first author between February and November of 2010 and recorded for transcription. The format was semi-structured, using the questions shown in Table 1. Most respondents answered all questions (9/13) but due to time constraints and occasional redundancy when questions overlapped with interviewees' previous answers, some questions were not asked to some respondents. Interviews lasted approximately one half hour and participants were given a $15 Amazon.com gift card in thanks for their participation.

Transcripts were read by both authors, with the goal of answering two main questions: first, do educators expect neuroscience to help them with concrete matters of educational practice? Second, what else do they seek or find useful in neuroscience, particularly in their daily professional life? In addition, we sought to discover other beliefs and motivations shared among the individuals of this sample that had not yet been discussed in the neuroeducation literature.

Results

A number of themes emerged from respondents' answers. Points made by at least three respondents are summarized here with illustrative quotations.

Educators' motivations

Curiosity. Four participants mentioned pure curiosity as their main motivation for learning about neuroscience. The value of neuroscience was not exclusively in its ability to improve their work performance but as a source of intellectual stimulation and enrichment in its own right.

> *"Mostly just curiosity and just to try and expand my understanding and my knowledge… To gain some new information and reenergize myself rather than hearing the same old conversations over and over again among my peers and the people that I work with." KR, elementary special education teacher*

> *"Just curiosity…I expected to get strategies for better teaching, and I did. But also along the way just a lot of information about the brain. So that became the reason to go back for the next two years, to see what was going on." CN, 5th & 6th grade math teacher*

> *"I was just really curious about it. I think I even heard about it from a colleague… And I'm just interested in learning and the brain anyway. I had been doing some reading on my own, and when I saw this, I thought, "This is great, I want to learn more about it." JG, 12th grade special education teacher*

Building the bridge. Four participants noted the current gap between education and neuroscience.

Their motivation for attending the conference was to better understand the state of neuroeducation and to help promote the integration of the two fields.

> *"I originally started attending because I was intrigued by the idea that there was real conversation between what I'd consider medical research and educational applications. Since I started graduate work, it's something I've always felt has been a hole, a multidisciplinary hole. And so that's what excited me." LB, high school learning specialist*

> *"It seemed like there was a void, not a lot of teachers talking about this sort of thing, and I thought it would be good for me personally, but also for the people around me, just to get people talking about it." JB, elementary gifted resource teacher*

> *"It's like, 'oh yeah, how nice to include the brain in what we are trying to do in schools!' And with the research and medical piece behind it, it's just more holistic. That's what I'd assumed I would get. I got that, and lots of interesting articles, and lots of books to read." EP, elementary teacher and science camp coordinator*

> *"I remember the neuroscientists … talking about how they wanted to build a bridge to the educators, and that they wanted us to build a bridge to them. That was exciting." NS, administrator and teacher, grades 3-8*

Practical applications. Of the five educators who sought out neuroscience in order to gain knowledge they could directly apply in their work with students, two were seeking information to teach to high schoolers within the context of an anatomy or 'Learning and the Brain' class. One found that he could use information learned at the conference to help students understand themselves.

"*Obviously kids like to hear about stuff that you learned... And they just feel so validated (laughs)... That they have some real reasons, neuroscience reasons, for why even the best behaved kids have moments where they just want to take these risks or just throw it all away (laughs). So the kids like that and it helps for them to talk to their parents about." MK, high school science teacher*

"*When you talk to kids about neuroplasticity and the idea that their brains change… It changes the way they think about themselves. In a very sort of fundamental profound way." JB, elementary gifted resource teacher*

While many educators came to their first conference with an interest in gaining knowledge that could inform their teaching, none listed learning new teaching methods as their primary motivation for learning about neuroscience.

Impact on classroom practice

To the key question, "Do you feel that knowledge of neuroscience has changed the way you teach?" all respondents answered "yes." However, eliciting concrete examples of ways teachers had translated neuroscience research into practice proved difficult. Initial answers were often vague, such as:

"Yeah, it definitely has [changed the way I teach]... It's in the interactions you have with kids, and the way you pace it, the kinds of questions you ask." JG, 12th grade special education teacher

"It has really changed some of the teachers I've worked with, it's really changed some of their practice, so that they're carefully thinking and designing and planning their time with students based around, you know, what research shows works well, as opposed to maybe how they were taught or what they learned in their teacher prep programs..." NS, administrator and teacher, grades 3-8

The most specific examples given were incorporating more frequent movement breaks (5 respondents), encouraging students to adopt Dweck's flexible "mindset" (3), employing specific strategies such as graphic organizers or decision trees (3), changing the structure of lessons to engage multiple senses (2), using repetition (2), or modifying the physical classroom environment (1).

One respondent listed several of these examples:

"Creating a homier atmosphere in class. Paying attention to the temperature, the lighting, the smells. Those were very easy to implement and they have an impact in class, I think... John Medina has twelve brain rules for doing well in school. For instance, exercise. I think that's good to incorporate during the school day. And how you remember—you have to repeat to remember. And just being really cognizant or mindful that people learn differently so you have to use all their senses to be an effective teacher." CN, 5th and 6th grade math teacher

With the possible exception of exercise, these practices are not directly supported by neuroscience research. In some cases there is little research support of any kind for them; in others the relevant research comes from cognitive psychology rather than neuroscience.

Distinction between neuroscience and other relevant disciplines.

The educators who gave examples of ways that neuroscience was of practical help to them were

invariably using an extremely broad definition of neuroscience, which extended into research that would more properly be called cognitive psychology or educational psychology. On the one hand this can be viewed as confusion on the part of the educators; on the other hand, it can be viewed as a reasonable grouping together of sciences that address the nature of learning and memory. One respondent called attention to this directly:

> *"A lot of times there is a neural component, but what I've read more of in the last five years is psychology. Maybe neuroscience creeps in to these people's work—whether it's Carol Dweck or Jon Haidt, or Leonard Sax— but I'm not reading so much about the brain as I'm reading about the mind." JB, elementary gifted resource teacher*

In many cases the authors and speakers whom the respondents cited were clearly encouraging this blurring of disciplines, for example John Medina's use of the term "brain rules" and Carol Dweck's use of "brainology" to label her research on attitudes toward achievement. It seems likely that such terminology was chosen in part to attract attention in the age of "neuro-everything."

Some respondents expressed awareness of the allure of neuroscience and its marketing power (3), as exemplified by this statement:

> *"I think we have to understand that we are just on the cutting edge of some of this stuff, and it gets me kind of crazy when I see some of these programs that are overly packaged... You know, the "Brain Gym" saying about how that if you had the kid rolling around here, they'd be a better reader five years from now, and I'm not buying into that." RS, high school learning specialist*

Other forms of practical benefit

In addition to the viewpoint that neuroscience can inform educational practice, another viewpoint emerged concerning the practical value of neuroscience for educators. Although the educators initially endorsed the relevance of neuroscience to classroom practice, they also generally placed equal or greater emphasis on several other types of benefits that have not heretofore been considered in the neuroeducation literature.

> *"The big change that took place for me was realizing that the most interesting things for educators aren't prescriptive. In other words, you don't go to one of these conferences and find out 'Oh there's this great new program and you follow these steps and do things like this...and research has shown that the brain works like this so you should do this in your classroom.' And that's just not what I've gotten from learning more about the brain." JB, elementary gifted resource teacher*

We identified three general categories of tangible benefit reported by the educators.

Affirmation and authority. Nearly every respondent reported that learning about neuroscience research affirmed their beliefs about what makes for good educational practice (12). Being able to relate their practices to a larger scientific picture of the brain gave them a sense of greater confidence in themselves.

> *"I think it confirmed what I knew or suspected I knew. I've been [teaching] a long time. You can't do it that long without realizing that people take things in differently and need different avenues. But I think it just makes me more aware of the fact that in my class I've got many different brains taking in information in different ways and at different paces, so*

I need to pay attention to that." CN, 5th and 6th grade math teacher

"It further deepens my beliefs. We need to use a variety of methods… We have to engage [students'] emotions and engage their senses and we have to get them excited about it, or it's not going to hold." KR, K-4 special education teacher

"It gave me support, in terms of what I'm thinking, support in knowing that what I'm doing is right, and that there is research out there to back it up... It gave me a sense of community, and the idea that other people out there think the same way... That you have to teach to the whole child, children's emotions and their brains are connected… Children shouldn't be sat drown and drilled." AT, preschool teacher and administrator

"These are things you already know, but you're given the studies to support the ideas and hunches you already have." BD, kindergarten teacher

Three teachers also remarked that neuroscience provided credibility for justifying their decisions to others.

"In this current job [high school learning specialist], I do spend more time citing research because it gives me a little more credibility." RS, high school learning specialist

"It was wonderful to be able to say to people "Yes, this is good practice, and we've known it for years, for these reasons, and guess what? Here is some current research in neuroscience to back that up." NS, administrator and teacher, grades 3-8

"It seems like, everything I teach the teachers about, you know, simple things like children who process slower, or need extended time, just simple learning disabilities things, you know I learn why *at the conferences and I can explain to the teachers why... They hire very exceptional*

people [at this school], you don't tell them to do *something, you tell them* why*." HL, middle school learning disabilities teacher*

Maintaining perspective with difficult students. One of the most difficult parts of teaching is dealing with uncooperative or disruptive students. Maintaining discipline without developing personal resentment towards these students can be an elusive goal. Thinking of students' brains as 'unfinished', or their behavior as not entirely under voluntary control, helps teachers cope with some difficult students.

"It's tough sometimes to understand why [my students] act the way they act and do the things they do and how they communicate...If anything [the brain conference] has helped me understand my kids more." BD, kindergarten teacher

"Neuroscience research helps a lot with patience and understanding. Seeing the kids who are not doing well, it was easy for the teacher to say, 'Oh, they're not trying hard enough.' And now we realize that's not necessarily true." MK, high school science teacher

A common observation was that knowledge of the slow development of prefrontal cortex enabled educators to be more patient with students (7):

"We see a lot of students with executive functioning difficulty. And we can now go back and explain to teachers that our students—especially in middle school—that part of their brain is still developing. So yes, they're going to have difficulty with executive functioning skills. But they're not always going to have this difficulty. It does get better. So that has been very worthwhile." PF, middle and high school learning specialist

"The most significant change has been my tolerance of adolescent brains, and realizing ... they're not going to be really fully functional until they're 24, 25. It's given me a lot more patience with them, and it gives me a little more leverage with other teachers I work with, in terms of getting them to include more realistic expectations, and it certainly gives me a good talking point with parents." LB, high school learning specialist

"Just being a whole lot more patient with the younger kids, because being forgetful or having difficulty following multiple steps, being more likely to be risk-takers or having impulse control problems, some of that is coming from that prefrontal cortex remodeling. You can kind of modify your behavior towards them and what you expect of them in terms of that." MK, high school science teacher

Related to this was the sentiment expressed by two educators that the neuroscience of plasticity helped them feel more hopeful for students.

"[Learning about plasticity] makes me feel hopeful, both for the young kids I teach with learning problems and for myself, because I'm an old lady." LB, high school learning specialist

"Knowing that [a dyslexic] brain will compensate in wild circuitous ways to do the same thing that non-dyslexics do automatically, I really internalize that lesson... Knowing that people can do that with their brains all the time, knowing that I did it when I learned music as an adult, that gives me much more concrete hope for people of all levels." JB, elementary gifted resource teacher

Similarly, seeing Asperger's syndrome as a brain disorder or learning about the neural changes caused by child abuse enabled educators to interact with students more effectively and with greater understanding.

> *"I think that it has made the teachers more sensitive to the children [with Asperger's] ... because they didn't actually understand the children, they found them rude. Now they understand that this is a neurological disorder and they are very willing to take the suggestions that I offer and apply them in the classroom, and we've had some tremendous successes." HL, middle school learning disabilities teacher*

Based on Seth Pollak's research with abused children, one respondent recognized a student's difficulty reading nonverbal emotional cues:

> *"I could understand why he was violent… If I hadn't known that, I would have been so pissed off at that kid. As it was, I was able to be compassionate and figure out a way so that… he was able to deal with certain aspects of life and school, like nonverbal behavior." BD, kindergarten teacher*

Professional satisfaction and self-image. Four respondents expressed the sentiment that teachers should learn about neuroscience simply because they are in the business of shaping brains. Just as we expect physicians to study chemistry, despite virtually never using knowledge of organic synthesis in their work, respondents felt that educators should know something about the science of learning and brain development.

"Teachers need to understand that the organ they're working with is the brain, so at least just to have an understanding is really important." JG, 12th grade special education teacher

"[Teachers not learning about neuroscience] is like being a mechanic and not understanding the engine..." AT, preschool teacher and administrator

"I fully well realize that [we don't know everything], but what we do know is profound, and it makes no sense to me to be in schools that more or less ignore what's known about how kids learn from a variety of perspectives and not be using that information." NS, administrator and teacher, grades 3-8

At the same time, three respondents volunteered that they did not expect to be able to understand neuroscience as thoroughly as a scientist would:

"It could be that when I go to these, my own knowledge is limited enough so that each one of the conferences I hear sounds positive and right. But if I were a neuroscientist and I had studied this a lot more I might say 'ugh, this is bogus.'" CN, 5th and 6th grade math teacher

"And it's weird because at work I'm known as the brain guy, and I was a major in political theory and a Russian minor! But I spend a lot of time reading about this stuff, and so I gave a couple talks and so now I'm the 'brain guy', and maybe that's what people like Bruer are trying to counter." JB, elementary gifted resource teacher

"Sometimes I can get insight into what I would try as remedial or compensatory activities, because I can get a sense of what I think is going on neurologically. But I'd never try to call myself a neurologist..." LB, high school learning specialist

Some educators also noted that familiarity with neuroscience empowers them to make more informed choices among so-called "brain-based" teaching methods (3).

"[Now] if I want to attend a one-day conference or workshop in this area... I look at what their credentials are. Rather than just saying 'great title, great subject matter,' I'm a lot more picky about what I go to." KR, K-4 special education teacher

"People are easily led by marketers. If you are saying people shouldn't market "brain based" programs to teachers to give a false sense of security about brain based research, that's fine. But I think if teachers can hear some of these things [neuroscience research] and internalize some of these things, all the better." JB, elementary gifted resource teacher

"*There are a lot of workshops out there, a lot of people selling stuff out there, that are just really thin on research, or you know very "faddish," but when you go to these you hear directly from the researchers, so you get the first of it, you get you know the whys and the where for it, you're not expected to watch someone's PowerPoint and take their word for it. So I get a lot of information out of it." JG, 12th grade special education teacher*

Finally, teachers find learning about this research to be interesting and exciting, in turn helping them to feel more excited about their role as a teacher (3):

> *"[This research] is really amazing and the opportunity for continuing learning is pretty exciting. I think once you get experience under your belt, and you've got the basics, just dealing with kids and parents and whatever kind of usual stuff, you'll be ready to take on bigger challenges and deeper learning. I think it just opens that door to continuing that professional learning." JG, 12th grade special education teacher*

> *"[Attending the conference] has given me more of a desire to try and learn more about the children. I just find it exciting to learn about this research, and what's coming about. The better understanding that I have, and the more excited that I am about how people learn, the more excited I am going to be as a teacher, and the more excited I am as a teacher, the better my children are going to respond to it." KR, K-4 special education teacher*

Conclusion

Neuroethicists have expressed concern that the popularity of neuroeducation may lead teachers to a premature and uncritical acceptance of "brain-based" teaching methods. Our respondents presented us with a more nuanced picture of educators' expectations for neuroscience. Although some were seeking new pedagogic methods and some blurred the distinction between neuroscience and cognitive psychology, on the whole they recognized that the potential for translating neuroscience research into

classroom practice is currently limited. Instead, they sought intellectual stimulation, new ways of thinking about their students and their own work, and new ways of explaining and justifying their educational practices within the framework of neuroscience. As one of them put it:

> *"People picture educators waiting for knights in white lab coats to come and tell us how to do our jobs. The thing is teachers have their noses in grade books—we have a lot of s**t to do... Neuroscience is not just going to come along and change everything teachers do... But I'm working with kids, and their brains are going to change with my help or not, so I think the more I know about this work the better." JB, elementary gifted resource teacher*

Little research until now has considered teachers' own opinions on the ways neuroscience can contribute to educational practice. The current study is a step towards filling that hole in the literature. Initially our respondents did not distinguish between neuroscience's role in guiding specific instructional practices and its role in other aspects of their professional lives. This may have been due, in part, to the very broad range of research methods that respondents considered to be neuroscience. Numerous authors have commented that interdisciplinary collaboration is critical to the future success of neuroeducation (e.g., Szűcs & Goswami, 2007; Bruer, 2008; Hardiman et al., 2010). That the educators in this study cited a wide range of cognitive research suggests just such a crossing of traditional disciplinary boundaries. By including cognitive psychology research in their definition of neuroscience, respondents may have been led to give credit to neuroscience for specific teaching strategies such as repetition or graphical organizers. However, once they focused on a more conventional definition of neuroscience, their responses revealed other ways in which neuroscience enhanced their work with students, beyond impacting their specific teaching methods. These enhancements affect the daily work of these educators, yet they have received little attention in the

neuroethics and neuroeducation literatures.

Our evidence indicates that educators use neuroscience to maintain patience, optimism and professionalism with their students, to increase their credibility with colleagues and parents, and to reinforce their sense of education as a profession concerned with shaping students' brain development. None of these motivations presupposes an unrealistic view of neuroscience or neuroeducation.

It is true that some subjects' responses indicated a blurring of the distinction between neuroscience and other fields, or adoption of so-called 'brain based' pedagogical methods not directly supported by neuroscience research. However, the potential for misunderstandings should not prevent neuroscientists from sharing their findings with teachers. On the contrary, evidence suggests that learning about neuroscience research can help prevent teachers from falling prey to misguided 'brain based' practices and marketing (Howard-Jones, Franey, Mashmoushi, & Liao, 2009). A greater understanding of educators' motivations for learning about neuroscience, their understanding of what neuroscience means, and what it has to contribute to teaching practice can only serve to strengthen the relationship between neuroscientists and educators. Improving dialogue between the two disciplines will enrich research and practice in the field of neuroeducation, ultimately helping to build a better science of learning and the brain.

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