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Neuroscience and Special Education

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The purpose of this document is to provide a brief overview of how links are being developed between the rapidly expanding field of neuroscience and the practice of special education. The first part of the document introduces definitions and terminology, provides an overview of how findings from neuroscience are being applied to the field of special education, describes outcomes from the limited research bridging the two disciplines and discusses how institutions of higher education (IHEs) and other organizations are creating interdisciplinary links between neuroscience and education/special education. The second part of the document profiles three programs currently serving students with disabilities that base their curriculum in part on findings from the field of neuroscience. Project Forum at the National Association of State Directors of Special Education (NASDSE) completed this document as part of its cooperative agreement with the U.S. Department of Education's Office of Special Education Programs (OSEP).

NEUROSCIENCE AND SPECIAL EDUCATION: AN OVERVIEW OF CRITICAL ISSUES

Definitions and Terminology

Neuroscience draws from the field of neurology, psychology, physiology and biology (Goswami, 2008). Perhaps most relevant to the field of education is the development of brain "imaging" techniques, including positron emission tomography (PET), functional magnetic resonance imaging (MRI) and electroencephalography (EEG). These tools, while limited in their diagnostic and predictive capabilities, hold promise for identifying which parts of the brain are implicated during which types of cognitive tasks. In terms of special education, the use of brain imaging allows comparison of typical with atypical patterns of neural activity.

Although experts use a wide array of terms including "neuroscience and education" (Bruer, 1997), "neurolearning" (Bruer, 2003), "educational neuroscience" (Varma, McCandliss, & Schwartz, 2008), "cognitive neuroscience" (Goswami, 2008) and "brain-based education" (Jensen, 2008), Howard-Jones (2008) points out that regardless of the term used, all refer to a common goal of linking the scientific understanding of how the brain functions (including how the brain learns) to an understanding of educational best practices. Jensen (2008) posits that "Brain-based education is about the professionalism of knowing why one strategy is used instead of another. The science is based on what we know about how our brain works" (p.409).

Applying Neuroscience to the Field of Special Education

Bruer (1997) believes that thoughtful application of findings from cognitive neuroscience will likely be most relevant to the education of special populations, including individuals with disabilities. He cites as examples the fact that cognitive neuroscience helps us understand how instruction supports the acquisition of "culturally transmitted skills" such as literacy and numeracy, and that cognitive psychology combined with brain imaging allows us to see how learning and instruction alter the brain's wiring. This opens the possibility of comparing learning-related changes in typical and atypical populations. Bruer suggests that comparative studies will provide insight not only into the nature of specific learning disabilities, but also into the compensatory strategies and alternate neural pathways available to individuals with learning disabilities—insights that can lead to better, more targeted instructional interventions.

One example of how brain-based studies may one day help diagnose and remediate specific learning disabilities is the use of brain imaging to better understand dyslexia. Experts now realize that not all struggling readers are suffering from the same problem and according to Katzir and Pare-Blagoev (2006), "Neuroscience holds the promise of differentiating among different etiologies that exhibit similar outcomes" (p. 59). In other words, brain imaging may help us distinguish between students with attention deficit/hyperactivity disorder (AD/HD), cognitive impairments and limited language exposure. This kind of information could help teachers determine which brains would respond best to which therapies.

Another promising link between neuroscience and special education has to do with "biomarkers." These neural indicators, visible through brain imaging, can sometimes show the presence of cognitive or learning impairments prior to the appearance of any behavioral symptoms (Goswami, 2008). Research on biomarkers is currently being conducted on specific language impairment, autism spectrum disorders, ADHD and learning disabilities, including dyslexia and dyscalculia. Goswami (2008) cautions, however, that while early identification can benefit children, premature diagnoses can potentially lead to discrimination and/or stigmatization.

Jensen (2008) reminds us that schools provide multiple opportunities for impacting the development of brains using means other than direct instruction. For example, growth can be fostered through exercise, stress reduction, positive social conditions and good nutrition. Studies from the field of neuroscience have shown that each of these factors positively impacts brain growth and studies from the field of education have further linked each of these factors to improved learning in students (e.g., Jensen, 2008).

> "Neuroscience is a sexy topic. Everyone is selling it, and the field is being seduced. But we have to be very cautious. The field of education is so hungry for answers. The major message is that we must make sure findings are well grounded in research."
>
> ***Carol Kochhar-Bryant, George Washington University***

Experts agree that the primary risk of linking neuroscience and education or special education, is that people hear the term "neuroscientific" referring to a program or product and assume that this means "evidence-based." There is limited evidence, for example, that many so-called "brain-based" software programs are effective in improving outcomes for students with or without disabilities. Another concern is that general and special educators will hail neuroscience as a panacea. However, experts note that while neuroimaging may provide useful information about lower-level processing like phonological understanding and basic numeracy, it may be less appropriate for examining higher-order cognitive processes such as reading comprehension and making inferences (Katzir & Pare-Blagoev, 2006).

Research and Outcomes

Research linking neuroscience with educational/special educational outcomes is extremely limited. In terms of research related to educational neuroscience, findings have primarily helped identify the parts of the brain that are activated — or, in the case of students with disabilities, *fail* to activate — during different types of tasks. For example:

- Brain imaging shows that more than one neural system is used for representing numbers: A "number sense" system in the intraparietal areas is activated when comparing numbers (Dehaene, Dehaene-Lambertz, & Cohen, 1998), numerical knowledge such as "number facts" (e.g., rote knowledge such as multiplication tables) is stored in the language system (Dehaene, Spelke, Pinel, Stanescu & Tsirkin, 1999) and more complex calculations seem to involve visuospatial regions of the brain (Zago, Pesenti, Mellet, Crivello, Mazoyer & Tzourio-Mazoyer, 2001). A better understanding of the various brain bases for difficulties with math will hopefully help us develop more targeted approaches to remediation.

Other types of neuroscientific studies not only validate the effectiveness of specific interventions, but also shed light on *why* these interventions are effective. Goswami (2004, 2006), for example, reports the following:

- Students with dyslexia showed reduced activity in the temporo-parietal region of the brain during tasks such as deciding whether different letters rhyme, but targeted remediation in terms of phonological awareness increased activity in this region (Simos, Fletcher, Bergman, Breier, Foorman, Castillo, Davis, Fitzgerald & Papanicolaou, 2002).
- In typically developing children, amygdala activation is linked to the processing of emotional and social signals, and the mirror neuron system is also involved in understanding others' emotional states. EEG and MRI studies suggest that children with autism, who experience significant challenges in the area of social cognition, show no or limited activity in these areas of the brain (Dapretto, 2006; Dawson, Webb, Carver, Panagiotides, & McPartland, 2004; Dapretto et. al., 2006). Targeted interventions, however, have been shown to help students with autism decode emotions (e.g., Silver & Oakes, 2001).

Goswami (2004) suggests that neuroscience also offers a means of comparing different educational theories. For example, some maintain that dyslexia has a visual basis (e.g., Stein & Walsh, 1997), whereas others argue that dyslexia is the result of a deficit in the cerebellum (e.g., Nicholas & Fawcett, 1999). Neuroimaging could both show which parts of the dyslexic brain are differently activated while reading, as well as measure the impact of interventions developed in response to each theory. Goswami (2004) notes that neuroimaging can further be useful in distinguishing between deviance and delay, helping us to answer questions about remediation for individuals with specific language impairment, autism and other disabilities.

Findings using brain imaging to measure the efficacy of specific interventions, however, have often been inconsistent (see, for example, Katzir & Pare-Blagoev's 2006 discussion of research using Fast ForWord, a software program, to address dyslexia). Tommerdahl (2010) also warns that when creating links between neuroscience and education/special education, findings from the laboratory cannot be directly transposed to the classroom. She provides a five-tiered model for "bridging" the two disciplines which begins with research in the field of neuroscience followed by research in cognitive neuroscience, psychological mechanisms, educational theory, and ultimately classroom practices, with each tier building on the one before it.

Making the Link in Organizations and Institutions of Higher Education

First formed in 1988, the Brain, Neuroscience and Education Special Interest Group (SIG)[1] of the American Educational Research Association may be the oldest organizational entity dedicated to linking neuroscience and education. Since then, several major universities in Great Britain and the United States have begun to create such links. Examples include the University of Cambridge's Centre for Neuroscience in Education[2] established in 2005; the Oxford Cognitive Neuroscience- Education Forum[3] at Westminster Institute of Education in Oxford; and Harvard University's Master's degree in "Mind, Brain and Education."[4]

> "It was clear to us that the next generation of special education teachers would need to be familiar with bench science and the work of cognitive neuroscientists."
> ***Maxine Freund,***
> ***George Washington University***

George Washington University's doctoral program in applied neuroscience in special education[5] may be the only special education program to make this link an explicit part of its required curriculum. The purpose of the program is to prepare graduates who are able to conduct "translational research," in other words, to draw from findings in the field of neuroscience in order to develop research projects that are meaningful to the field of special education. The curriculum includes four foundation courses that address brain development, both typical and atypical, across the age spectrum and is coupled with extended opportunities for interdisciplinary field-research.

In terms of personnel preparation policy, the National Institute of Child Health and Human Development and the National Council for Accreditation of Teacher Education (NCATE) found significant gaps between the current level of knowledge about human development and what is taught as part of teacher education programs (NCATE, 2010). In a 2010 report published by NCATE, the organization made a series of recommendations as to how education preparation programs, accrediting bodies, state education agencies, and the U.S. Department of Education can all play a role in improving the integration of the developmental sciences, including neuroscience, into the preparation, certification, licensing and practice of educators.[6]

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[1] For more information on the SIG, see http://www.aera-brain-education.org/SIGHome.aspx.
[2] For more information on the Centre for Neuroscience in Education, see http://www.cne.psychol.cam.ac.uk/.
[3] For more information on the Oxford Cognitive Neuroscience-Education Forum, see http://www.brookes.ac.uk/schools/education/rescon/ocnef/ocnef.html.
[4] For more information on the Mind, Brain and Education program, see http://www.gse.harvard.edu/academics/masters/mbe/.
[5] For more information on George Washington University's doctoral program in special education, see http://gsehd.gwu.edu/SpedDoc.
[6] For a copy of the report, titled How the Developmental Sciences Can Prepare Educators to Improve Student Achievement: Policy Recommendations, go to http://www.ncate.org/dotnetnuke/LinkClick.aspx?fileticket=gY3FtiptMSo%3D&tabid=706.

EXAMPLES OF HOW NEUROSCIENCE INFORMS PROGRAMS SERVING STUDENTS WITH DISABILITIES

Data Collection

In February of 2011, Project Forum staff developed an interview protocol to be used with programs serving students with disabilities that base their curriculum in part on findings from the field of neuroscience. Dr. Carol Kochhar-Bryant and Dr. Maxine Freund, faculty members from George Washington University's doctoral program in brain science and special education, recommended several programs, as did Betsy Hill, President of Learning Enhancement Corporation. Based on these recommendations, Project Forum interviewed the directors of the following three programs: the Model Asperger Program at Ivymount School, the Specialized Transition Program at Kennedy Krieger Institute and the Gillen Brewer School. Findings from these discussions are reported in the following section of this document.

Program Descriptions

The Model Asperger Program

The Model Asperger Program (MAP)[7] at Ivymount School in Rockville, Maryland was founded in 2005 in response to a lack of local programs designed to meet the unique needs of students with Asperger Syndrome, particularly those students with average or above average cognitive abilities who were "falling between the cracks" academically due to their difficulties understanding social cues. These students were being placed in programs for students with emotional disturbance and other disabilities that did not take into consideration the unique brain basis for the symptoms associated with autism.

MAP grew out of the Take Two Summer Camp that began in 2004 with the support of professionals at the Children's National Medical Center's Center for Autism Spectrum Disorders (CASD) in Rockville. Both MAP and the Take Two Summer Camp were based on the notion that the use of evidence-based practices such as the teaching of social skills strategies will only succeed if implemented consistently, and if sufficient opportunities are provided to practice generalizing skills to other contexts.

> "We look at the etiology [of autism] and create interventions that build on that."
> ***Monica Adler-Werner, Model Asperger Program, Ivymount School***

Forty publicly-placed 2nd through 10th grade students from school districts in Maryland, Virginia and Washington, D.C. currently attend MAP. Most students, but not all, are diagnosed with Asperger Syndrome. Eligibility requirements for MAP include good expressive and receptive language skills, cognitive ability to achieve at grade level and problems with social cognition. The school is licensed through 12th grade, but so far students have been transitioning to less restrictive placements prior to their junior year.

The primary goal of MAP is to help students develop compensatory strategies to address social cognition[8] and executive function[9] issues. One of the curriculum features that sets MAP

[7] More information about the Model Asperger Program can be found at http://www.ivymount.org/Aspergers.cfm.
[8] The MAP social cognition curriculum is based in part upon the work of Michelle Garcia Winner (http://www.socialthinking.com/).
[9] For more information on the MAP curriculum promoting greater cognitive flexibility, see *Unstuck and On Target* by Lynn Cannon, Lauren Kenworthy, Katie Alexander, Monica Adler Werner, and Laura Anthony (Brookes Publishing, forthcoming).

apart from other programs is that it does not only use a "rule based" or prescriptive approach to teaching social skills. Students are also taught strategies that promote flexibility, better enabling them to navigate a wide range of contexts, each with its own set of social expectations. Staff first teaches strategies explicitly and then infuses the use of these strategies into everything students do. For example, if students are taught a skill for problem solving and enhanced flexibility, MAP staff ensures that this same strategy is being used on the playground and during history class. In this way, social cognition and problem solving skills are continually reinforced in order to further support generalization of curriculum across contexts. Parents are also taught to use many of these strategies at home.

In addition to academics, major components of the MAP curriculum include problem-solving and self-advocacy. In order to facilitate successful problem-solving, MAP supports the development of critical skills such as planning, initiation and cognitive flexibility. Task analyses and checklists, for example, enable students to complete tasks in a methodical fashion, with students eventually being taught to make their own checklists in preparation for greater independence. In terms of self-advocacy, interventions focus on emotion regulation and behavior support. Because emotional experiences are difficult for individuals on the autism spectrum to understand, MAP provides explicit instruction to students on "reading" their own and others' emotions and strategies for monitoring their emotional states.

> "My guess is that as much as what we're doing now is cutting edge, we'll look back in five years and see it as very primitive. We're at the beginning of a revolution in human understanding."
> ***Monica Adler-Werner, Model Asperger Program, Ivymount School***

MAP currently augments its curriculum by filming student interactions using digital cameras as a way of facilitating greater self-awareness. In the coming year, MAP will introduce several new technologies, including a galvanic skin response sensor that helps students monitor their emotional reactions and software such as CogMed[10] and Mind Reading[11].

MAP interventions are based on an understanding of the etiology of autism and the assumption that people on the autism spectrum experience the world through differently structured brains. For example, one of the key challenges individuals on the autism spectrum face has to do with "theory of mind," or the ability to understand other people's perspectives. Recent studies have shown that individuals with autism likely possess dysfunctional mirror neuron systems, resulting in difficulty decoding people's intentions and feeling and expressing empathy in conventional ways. The MAP curriculum addresses this dysfunction by helping students develop cognitive strategies to problem solve theory of mind situations by breaking down, in a mechanical fashion, what a teacher or peer might be thinking or feeling.

MAP is funded via student tuition from local education agencies as well as private donors, and a recent National Institutes of Health (NIH) grant will support a pilot of the MAP program in public school settings this coming year. MAP is staffed by teachers, assistant teachers, related service providers including speech language therapists (SLTs), occupational therapists (OTs), mental health providers and a behavior specialist. Professional development activities for all staff emphasize the importance of considering the brain-based learning and perceptual differences of students on the autism spectrum.

[10] For more information on CogMed, see http://www.cogmed.com/.
[11] For more information on Mind Reading, see http://www.jkp.com/mindreading/.

Although MAP staff does not conduct regular evaluations of program effectiveness, a follow-up study of the eight students who have transitioned to less restrictive placements is currently underway.

The Specialized Transition Program

The Specialized Transition Program (STP)[12] at the Kennedy Krieger Institute in Baltimore, Maryland was developed in 1995 as an outgrowth of the inpatient rehabilitation program for children with traumatic brain injury (TBI). The goal was to smooth students' transitions from Kennedy Krieger's inpatient program back to students' home schools, which are often unprepared to meet these students' continually shifting educational needs. STP provides a combination of medical rehabilitation and special education. Although STP operates independently, it is part of a continuum of care at Kennedy Krieger Institute that includes acute care, a home based program and outpatient services.

In order to be eligible for STP, students must be deemed candidates for rehabilitation, medically stable enough to reside at home and be transported to the program each day, and between the ages of 18 months and 22 years. At any one time, STP serves 10 to 15 students, and an average enrollment period ranges from six weeks to six months. Although most students are diagnosed with TBI, some participants, have other diagnoses (e.g., complex seizure disorders or orthopedic needs), yet still benefit from the supported transition from hospital to home school provided by STP. Although almost all students leave STP with an individualized education program (IEP), most students are new to the special education system when they arrive at STP.

"It's not as though we used a set of neurological findings to build our program. Research is valuable, and we read and look at evidence all the time, but [the children in our program] are not a homogeneous group, so treatments are very individualized."
Joan Carney, Specialized Transition Program, Kennedy Krieger Institute

In addition to providing instruction, STP staff are in constant contact with students' home schools, inviting staff to observe teaching strategies and learn how to operate students' new assistive technologies (AT) and providing training and supports to ensure students' successful transitions back to their community schools.

STP's teaching staff uses a diagnostic prescriptive teaching model to assess students' strengths and weaknesses and identify the most effective means of instruction. For example, team members use graphic organizers, backwards chaining and visual or auditory cues as appropriate. Because students attending the program are in a period of brain recovery, changes to their education and therapy plans are frequently necessary. Lessons are based on curricula currently being used by students' home schools. However, while students have often retained a lot of previous learning from before their injuries, novel tasks present a significant challenge. Consequently, the curriculum focuses not only on academics, but also on relearning executive function skills (e.g., screening out distractions and thinking flexibly). Many students need to relearn tasks such as organizing their desks and backpacks, understanding daily schedules and managing simple hygiene sequences. Memory building and other executive function skills are taught discretely and infused throughout the day. A third component of STP curriculum is teaching coping strategies so that students can better understand the impact of their brain injuries and explain their behaviors (such as repeating what they say) to others.

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12 For more information about the Specialized Transition Program, see http://www.kennedykrieger.org/kki_cp.jsp?pid=2044.

Although STP does not use much specialized software as part of its curriculum, many students use iPads, iPods and iPhones to communicate via "texting" and/or manage their schedules. For example, students may use iPod applications to prompt them to take their medications or reinforce specific task sequences (e.g., getting ready for school in the morning or transitioning from one activity to another). These technologies can be used discretely, and are less stigmatizing than more specialized technologies designed for individuals with disabilities. Software for adults with stroke (e.g., programs that help students practice articulation) are also often effective for use with pediatric TBI patients enrolled in the program, as are standard educational software and bio-feedback tools. For example, one device facilitates upper extremity motor function but interfaces with a computer program that includes increasingly complex matching, sorting, categorizing and visual problem solving tasks.

STP is funded via insurance, although the program was originally intended to be funded by LEAs as a school placement. Each student's rehabilitation team includes a teacher; neuropsychologist; related service providers including an SLT, OT and physical therapist (PT); and one or more medical professionals. Professional development in the area of TBI is ongoing, especially for related service providers. Quarterly staff trainings address topics such as behavior management and cognitive strategies.

The effectiveness of STP is evaluated in two ways. First, when a student is admitted to the program, the team develops a treatment plan and sets goals and when a student is discharged from the program, staff tracks the number of goals met. In addition, the Kennedy Krieger Institute has its own instrument for assessing program effectiveness and client satisfaction. STP publishes these outcomes in the form of an online fact sheet. Recent findings indicate that 100% of family members were satisfied with the program, 94% of appropriate school services were in place at discharge and 95% of admissions goals were met or exceeded.

The Gillen Brewer School

Founded in 1992, the Gillen Brewer School (GBS)[13] serves students with a wide range of disabilities including learning disabilities, autism spectrum disorders, language issues and emotional and behavioral challenges. Gillen Brewer's therapeutic program gives equal priority to academic and pragmatic/socialization curricula. During February 2011, GBS launched a pilot program for a limited number of students that focused specifically on improving executive function skills using a software program called BrainWare Safari.[14] The impetus for this pilot program was the fact that this particular group of students was struggling with short- and long-term memory and organizational functioning, and BrainWare Safari offered a targeted, evidence-based approach to addressing these specific areas of deficit. Although many students were already familiar with the software program, GBS had never used it in a systematic and deliberately therapeutic way.

Participants in the pilot program were eight 6- to-9-year-old students with a range of disabilities, all of whom exhibited significant challenges relating to executive function. Prerequisite skills for the pilot program included familiarity with the alphabet and ability to count backwards and forwards from 1-20, motor skills necessary to operate a mouse and

[13] For more information about the Gillen Brewer School, see http://www.gillenbrewer.com/.
[14] For more information on BrainWare Safari, a software program designed to develop underlying cognitive skills in students with a wide range of disabilities and/or support needs, see http://www.brainwareforyou.com/.

sufficient frustration tolerance to withstand 20 minutes using BrainWare Safari each day (although this requirement was waived in the case of one student who required a 1:1 aide in order to remain on task for the full 20 minutes).

The goal of the pilot program was not only to improve students' executive functioning using BrainWare Safari, but also to enable teachers to use the software diagnostically in order to better understand how students were learning and identify the skills they were using to problem solve different types of task.

Student independence is emphasized throughout and all were taught to set up their own laptops, plug in their mouse and head phones, and log on to the program. Students were also taught how to navigate the program and play individual "games." In terms of problem solving, students are encouraged to work with teachers to develop their own strategies, such as making a song out of a series of seven letters in order to memorize the series more readily.

> "There are different ways of going about the same task. Brains work very differently. The majority of kids in our program have atypical development and come at things in a very skewed way. [Using Brainware] unpacks the process, and helps teachers identify what needs to be taught explicitly in order to provide a more efficient strategy."
> ***Donna Kennedy, Gillen-Brewer School***

BrainWare Safari software allows students to practice 41 cognitive skills in the following six areas: attention, memory, visual processing, auditory processing, sensory integration and thinking. Students can choose from 20 exercises or "games," each of which targets several of the 41 skills. Reports on student progress and/or areas of continuing difficulty can easily be generated and used diagnostically. For example, if a student makes 30 attempts to get to Level 3, the report enables teachers to identify where the student's problem solving skills are breaking down and focus on specific skill development. Teachers are also encouraged to use results to inform regular classroom instruction. For example, teachers can replicate the types of exercises available in video form in order to engage students in higher level thinking throughout the day.

Staff at GBS is hopeful that the use of BrainWare Safari will help pinpoint which specific underlying cognitive deficits are obstructing students' progress, so that teachers can target instruction in a meaningful way.

Tuition at GBS, including tuition for students participating in GBS' pilot program, is paid for by New York City school districts. In terms of training for the pilot program, a representative from the Learning Enhancement Corporation (which produces BrainWare) trained GBS staff on how to use and integrate the program into daily instruction.

The school is gathering extensive data in order to measure the effectiveness of the pilot program for improving students' executive functioning and determine whether or not to expand use of BrainWare Safari throughout all classrooms. Baseline data were gathered for students in terms of how independently they were able to pack and unpack their backpacks each day (a task for which students received explicit instruction, but which remained an ongoing challenge as the result of executive dysfunction). Data include how many minutes it takes students to complete the task, how many prompts they require to stay on task and the type of prompts used. Post-intervention data will be collected at the end of the academic year. Although BrainWare suggests a 12-week period, this timeframe may be modified based on student need.

CONCLUDING REMARKS

Neuroscience is a rapidly expanding field and researchers, personnel preparation programs and education-related groups and organizations are increasingly looking for ways to create links between neuroscience and education/special education. In order to ensure that these links are successful in improving outcomes for students with disabilities, it is critical that policymakers and IHEs foster collaborations between neuroscientists and special education researchers (Katzir & Pare-Blagoev, 2006), as well as prepare leaders in the field of special education with both a nuanced understanding of brain development across the lifespan and an ability to understand the language and research of both neuroscientists and educators are prepared. It is also important to remember that while neuroscience holds much promise for the field of special education, the process of translating brain research into classroom practice must be handled methodically. Perhaps the most important lesson is that educational policies and practices, as with the three programs described in this document, should be guided by our knowledge of how brains (both typical and atypical) work and learn.

> "Educators and scientists need to talk, and translational educators are the ones to help begin the dialogue in a rational way."
> ***Carol Kochhar-Bryant***
> ***George Washington University***

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