Understanding the Role of Neuroscience in Brain Based Products: A Guide for Educators and Consumers

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ABSTRACT—The term *brain based* is often used to describe learning theories, principles, and products. Although there have been calls urging educators to be cautious in interpreting and using such material, consumers may find it challenging to understand the role of the brain and to discriminate among brain based products to determine which would be suitable for specific educational goals. We offer a framework for differentiating the multiple meanings of the brain based label and guidelines for educators and consumers to use when evaluating educational products labeled as brain based. The guidelines include: identifying educational goals and target student populations, aligning goals and product purposes, reviewing product merits, identifying benefits and limitations of the product, and characterizing the product's impact on behavioral performance.

INTRODUCTION

For the consumers intrigued by the latest *brain based* products, the appeal for the brain's role in educational materials is clear. The term brain based has been associated with learning theories, principles, and products that posit a link to the brain's structure or function. The brain based label can refer to several roles for the brain, however, which are not typically clear for educators. To clarify the ways in which educational resources can be considered brain based, we propose several subdivisions of the term. The ambiguity around the use of the label can also pose a challenge for educators interested in purchasing or using brain based educational products in particular. To foster critical consumerism when considering these products, we offer a guide on brain based product evaluation.

Evaluating brain based products objectively can be especially challenging because of the appeal that neuroscience holds for consumers. For example, the mere presence of brain images in an article is more successful in leading readers to boost their ratings of scientific reasoning in arguments than are other data representations (McCabe & Castel, 2008). Even including irrelevant neuroscience information in articles, without brain images, can sway reader judgment of scientific reasoning (Weisberg, Keil, Goodstein, Rawson, & Gray, 2008). Educators in particular may benefit from recommendations for critical consumerism, an inference supported by a recent survey of educators who express their enthusiasm for educational neuroscience as well as a desire to learn about the brain and mind to inform their decision-making process (Pickering & Howard-Jones, 2007).

Helping educators become more critical consumers of brain based educational products is one important way to ensure that the brain, mind, and behavior are appropriately considered in relation to student learning. It will be especially important to support consumers as the field of educational neuroscience, under which umbrella these efforts reside, expands in terms of impact and presence. The contribution of scientists and educators is equally important, and each perspective can contribute to our understanding of students, with researchers and educators each focusing on often distinct observations, questions, and motivations. Cognitive neuroscience researchers can offer the science behind teaching strategies, for example, which can help educators address the *why* of what they do (Jensen, 2008) in a descriptive rather than a prescriptive way (Christodoulou & Gaab, 2008).

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These efforts also align with the goal of creating collaborative dialogues among stakeholders in educational neuroscience (Christodoulou & Gaab, 2008; Fischer et al., 2007; Geake & Cooper, 2003). Stakeholders agree that guidance and support is important for educators who are to make informed decisions regarding brain based educational ideas and products (e.g., Bruer, 1997, 1998, 1999; Goswami, 2006; Hirsh-Pasek & Bruer, 2007; Jorgenson, 2003; McCandliss, 2003; Solomon & Hendren, 2003; Wolfe, 2001). For example, Jorgenson (2003) posits that educators should be aware that much of the brain based information in the field of education is developed and promoted by educational consultants, few of whom have credentials in the field of neuroscience. However, educators have little guidance when judging the sources of the information available or the credentials of those making scientific claims. As a remedy, Wolfe (2001) recommends that educators develop scientific literacy skills, learn relevant terminology, and read research analytically in order to successfully navigate the field of brain based education. There has also been a push toward developing teacher training programs or formal coursework related to the connections between neuroscience and education (Ansari & Coch, 2006). While developing these skills requires commitment, time, and resources, educators in the short term can be informed by understanding the ways in which neuroscience contributes to brain based educational products.

In this article, our goal is to offer concrete guidance for educators to make informed decisions about brain based products. First, we propose specific terminology to clarify possible meanings of the term brain based. Second, we propose five specific steps that educators can consider when critically evaluating brain based educational products.

PART 1: CLARIFYING BRAIN BASED TERMINOLOGY

Applications of the Brain Based Label

The brain based label has been applied to theories of development and learning, learning principles and instruction guides, training methods, and educational products. Each of these categories is largely distinct from the others although they may overlap. For example, a brain based educational *product* can be based on brain based educational *theory*. Table 1 provides a list of the major outputs of the field with an example of each kind of brain based work.

When navigating brain based educational products, it is important for educators to identify the category the information belongs to. The categorization should guide the evaluation process. Judging the merit of educational theory based on neuroscience is a process different from evaluating an educational product for use in a school setting with a particular student.

Different Roles of Neuroscience

The term brain based is used widely for different purposes, making common interpretation challenging. To foster effective

Table 1
Types of Brain Based Material in Education

Types of brain based material	*Sample application*
Brain based educational theories These theories, based partly or entirely on neuroscience, propose a certain framework for understanding how students learn and/or how environments can be optimized to facilitate learning.	Universal Design for Learning (Rose & Meyer, 2002)
Brain based principles and corresponding instructional techniques These principles, also based partly or entirely on neuroscience, are meant to guide the practice of educators indirectly rather than directly.	"Making Connections: Teaching and the Human Brain" (Caine & Caine, 1994) presents 12 principles from brain science that have implications for education. Examples include: • "The brain is a complex adaptive system." • "The search for meaning occurs through patterning." • "Learning is enhanced by challenge and inhibited by threat." (pp. 88–95)
Brain based neurofeedback training These tools are designed to manipulate brain activity directly as a mechanism for changing behavior.	Neurofeedback or brain stimulation for psychiatry training (e.g., improving regulation in attention deficit hyperoctivity disorder) (Hirshberg, Chiu, & Frazier, 2005)
Brain based educational products These products are generally available for purchase and marketed toward educators with claims of explicit connections between the program and neuroscience.	*Brain Gym*® (Dennison, 1994)

communication, cognitive neuroscientists, researchers, and educators can work toward a shared understanding of terminology to accurately credit the role of neuroscience in educational products. For example, it is misleading when the term brain based suggests that educational products are *based* on neuroscience data when in fact researchers are investigating the *impact* of a particular product on brain structure or function.

We propose subcategories for the term brain based to specify the role of neuroscience as brain supported, brain derived, brain driven, or brain inspired. These categories are not mutually exclusive; a product may be both brain supported and brain derived but membership to one category does not necessarily imply the other.

Brain Supported

These are products that have used neuroimaging methods to demonstrate the impact on brain structure or function in relation to behavioral changes. For example, functional magnetic resonance imaging (fMRI) studies may provide evidence that students who completed several weeks of instruction from Program A showed brain activation changes in reading networks that parallel improvements in specific reading skills targeted by the intervention (e.g., single word reading, comprehension) compared to children in the appropriate control group(s). Note that the term brain supported implies positive results for the interventions, although research can also reveal no changes in behavior or brain function (null findings), changes in behavior but not brain findings, or brain but not behavior findings. Furthermore, the changes in behavior or brain activations should be considered in detail so that consumers understand what aspect of behavior or brain activations were studied.

Brain Derived

These are products derived from neuroscience theories (e.g., neuroanatomical theories of dysfunction or empirical evidence from neuropsychology). For example, fMRI studies may show that students with developmental dyslexia show less activation in brain region X associated with psychological construct Y. Consequently, a product is developed which aims to build up specific brain activations and connections. The product's impact on student learning may be demonstrated by behavioral or cognitive studies. To date, there are few examples of this category (i.e., product development based on neuroscience findings). Most brain based programs have emerged from cognitive or behavioral domains, with neuroscience integrated as a subsequent step.

Brain Driven

These are products that manipulate brain activity directly as a mechanism for changing behavior, so that the brain is both the target and the mechanism for change. For example, feedback from electroencephalograms may be used to train individuals with attention deficit hyperactivity disorder (e.g., Hirshberg, Chiu, & Frazier, 2005). With such products, the goal is to use meta-awareness of brain activity to modify these activations directly, ultimately to achieve behavioral changes.

Brain Inspired

These are products inspired by or based on principles related to neuroscience, directly or indirectly. For example, a claim that "learning is enhanced by challenge and inhibited by threat" (Caine & Caine, 1994) inspires the design of a program to optimally challenge but not threaten students. The developers of the program may attribute the claim to neuroscience, but often the claims are rooted in behavioral or cognitive science and not necessarily in neuroscience.

PART 2: FRAMEWORK FOR EVALUATING BRAIN BASED EDUCATIONAL PRODUCTS

In Table 2, we present a summary of five key steps for educators seeking an explicit structure for evaluating brain based educational products. These steps are targeted toward evaluating brain based *products*, although they may also be helpful when considering brain based theories or learning principles. Many elements listed below should be part of educational product evaluation more generally, but we highlight their relevance specifically for brain based products.

Identify Educational Goals and Target Populations

An important step in the process of evaluating brain based educational products is to identify the educational goal

Table 2
Five Steps to Evaluate Brain Based Educational Products

Focus	*Action*
1. Goals	• Identify educational goals and target student populations
2. Match	• Determine if there is a match between educational goals and the purpose of the brain based product
3. Research	• Refer to appropriate evidence and methods to evaluate the merits of the brain based rationale and the empirical research supporting the product
4. Pros and cons	• Identify the benefits and limitations of the product and consider alternatives
5. Impact on behavior	• Characterize the impact of the product on behavioral performance

and the target student or group of students. For example, is the educator attempting to find an appropriate reading intervention for a student with math difficulties? Is the educator looking for a product to assist with behavioral management in a special education or a general education class? Beginning with a concrete goal is a helpful, and essential, way to avoid selecting an educational product with overreliance on the appeal of the brain based label. We recommend that educators clarify their educational goal(s) and target population(s) as precisely as possible.

Determine If There Is a Match Between Educational Goals and the Brain Based Educational Product

It is important to ensure that there is a match between the educational goals, the needs of the educational setting or program, and the target population. This step not only aligns goals with what the product can offer, but is also intended to clarify other important information such as the kind of background knowledge that is assumed or required and the types of students who are intended to use the product. For example, a consumer may find that a brain based reading program is targeted to help native-English students who struggle with reading multisyllabic or irregular words but assumes secure knowledge of sound–letter correspondence for that language. This step is hardly specific to brain based products, but serves as a reminder that any product should be evaluated in the context of educational needs and goals.

Refer to Appropriate Evidence and Methods to Evaluate the Merits of the Brain Based Rationale and Empirical Research Supporting the Product

Arguably, the most difficult step is evaluating the merits of the brain based rationale and the empirical research supporting the product's efficacy. The responsibilities of a critical consumer are not easy or convenient, but fulfilling them can prove worthwhile in the short and long term. In Part 1, we reviewed various ways in which the brain based label can be used. A next step is to evaluate the efficacy of a brain based product by looking at rigorous and scientific investigations.

Although the process of finding information about a product may seem daunting, there are a number of available resources that can facilitate the process. Educators can draw from several guides to evaluate scientific research offered by government-affiliated organizations and others with experience in both research and practice (e.g., National Institute for Literacy, 2005; National Reading Panel, 2000; Stanovich & Stanovich, 2003). A recommended first setp is to search through the Web sites of organizations that produce systematic reviews of a number of educational products or clinical interventions. These systematic reviews describe the extent to which various educational interventions or treatment approaches are supported by the evidence without making specific recommendations for use in educational settings. These Web sites can be useful for educators evaluating educational products, and in particular brain based products (see Table 3 for a list of organizations and Web sites).

In addition to evaluating information from Web sites, it is advisable to find and evaluate empirical papers written by scientists or practitioners regarding or related to specific brain based interventions. We recommend reviewing peer-reviewed journals to find articles on a topic of interest. These journals typically have stringent specifications for the quality of articles that they will publish, and all published articles go through a peer-review process. Through the peer-review process each article is subjected to the scrutiny of some experts in the same field. However, although looking for articles in peer-reviewed journals is highly recommended, publication in a journal is not a guarantee of quality. It is also important to note that studies that do not report significant changes as a result of using a brain based product (i.e., null findings) may not be submitted for publication in journals. In order to find peer-reviewed journal articles, it is helpful to use a search engine such as ERIC (Educational Resources Information Center) which is sponsored by the U.S. Department of Education, Institute of Education Sciences (http://www.eric.ed.gov). ERIC catalogs more than 1.2 million bibliographic records of journal articles and other education-related materials and, if available, includes links to full text for a portion of the articles.

Some brain based product websites have empirical studies, peer-reviewed or otherwise, available for download. Conflicts of interest may arise when products are evaluated only by the product developers. Consumers should be cautioned of the possibility that product information may exclude studies which suggest that the interventions have limited or negative effects.

Identify the Pros and Cons of Using the Brain Based Product

Each product will have benefits and limitations that are important to be aware of. A cost–benefit analysis would be helpful to balance, for example, the cost of the educational program, whether the school has the resources for this product, the extent of training required, the recommended duration of use, and whether expected gains in student performance are feasible. It does not make sense to invest energy evaluating a product with characteristics that do not match the educational setting or goals. Also, it is important to consider alternatives to using brain based educational products. Often a product marketed as being brain based is not the only way to meet an educator's goal. Alternative products and programs exist on the market, and it is critical for educators to compare the merits of all programs whether they are marketed as brain based or otherwise. Educators should be aware of and carefully identify the benefits and limitations of the educational product

Table 3
Resources for Information on Brain Based Educational Products

Resource	*Information available from this resource*
American Academy of Pediatrics (AAP) www.aappolicy.aappublications.org	Many of the AAP policy statements provide overviews of research related to educational products. There is a search engine that is useful in guiding users to appropriate articles.
American Speech and Language Hearing Association (ASHA)[a] www.asha.org	ASHA journals provide articles reviewing the theoretical basis and empirical evidence associated with a variety of speech and language intervention programs.
Best Evidence Encyclopedia www.bestevidence.org	This website, created by the Johns Hopkins University School of Education's Center for Data-Driven Reform in Education provides information on the strength of the evidence supporting a variety of programs available for kindergarten to 12th grade students.
Campbell Collaboration www.campbellcollaboration.org	The Campbell Collaboration provides reviews and research articles on various interventions from social science, behavioral science, and educational perspectives.
Cochrane Collaboration[a] www.cochrane.org	The Cochrane Collaboration provides reviews of the evidence for and against the effectiveness of a variety of interventions and treatments in the fields of medicine and education.
Florida Center for Reading Research (FCRR) www.fcrr.org	The FCRR provides reports of reading programs. The reports describe specific programs and their use, as well as information regarding the consistency of the programs with scientifically based research in reading.
The International Dyslexia Association (IDA) www.interdys.org	The IDA website offers a matrix comparing multisensory, structured-language reading programs, some of which have served as interventions in neuroimaging studies.
What Works Clearinghouse www.ies.ed.gov/ncee/wwc	The What Works Clearinghouse reviews and collects empirical research on educational products and provides reviews based on its evaluation of the available empirical research.
The Center on Instruction www.centeroninstruction.org	A partnership of five organizations that provides resources including research reports on educational products for reading, math, science, special education, and English language learning.
SharpBrains www.sharpbrains.com	SharpBrains includes a useful checklist for brain fitness software and training games, as well as other resources relevant for brain based products.

[a]A fee may be required to access Web site content.

as well as identify how this product compares to others before purchasing or selecting a brain based product for their practice. Considering alternatives to brain based educational products helps to ensure that educators practice critical consumerism.

Characterize the Product's Impact on Behavioral Performance

Educators should be aware of the hierarchy of information in evaluating educational products. The most important determinant of program efficacy to date is the impact on changing behavior in students, whether in the form of reading scores, math skills, or science facts. So, educators should always consider whether there are behavioral data supporting the brain based program. The measurable goal should be to change behavior, not only the brain, and behavioral evidence should be a priority. Furthermore, performance on a single test may not be sufficient evidence for change in student learning, so it is also important to carefully consider how improved test scores relate to contextualized student performance and

program efficacy. Educators are in an important role as they can actually note changes in student behavior, understanding, and transfer over a longer time frame, which empirical studies often do not focus on.

There are several reasons that behavioral evidence should be a priority. First, imaging experiments that evaluate established intervention programs, for example, often use tasks that are limited in scope. For example, a task used for an fMRI study can measure phonological awareness (analyzing the sounds of words) for an intervention program that targets many aspects of reading. Therefore, the neuroscience findings are informative on that aspect alone, not necessarily on a reading brain network more completely. Using fMRI for empirical work is expensive and time intensive and requires many resources, so understandably research is often limited to a narrow task. Further, brain changes and behavioral changes do not always show a positive relationship. In other words, it is possible to find no brain changes when behavioral changes occur, and vice versa. Until the brain–behavior dynamic is better understood, the ability to interpret these findings will be limited. However, the guidelines offered in this article highlight how becoming more critical consumers can help educators *do* research, rather than relying exclusively on others to conduct and translate empirical findings.

CONCLUSION

As the field of education continues to evolve in terms of its relationship with neuroscience and as more brain based educational products are developed, it will be increasingly important for educators to become critical consumers. Part of being a critical consumer is to understand and use the appropriate terminology to differentiate the roles of various brain based products. We propose four subcategories for the term brain based that make explicit the role of neuroscience in a program's development: *brain supported* for programs that have been shown to change the brain function or structure, *brain derived* to describe products derived from neuroscience-related theories, *brain driven* to describe products that manipulate brain activity directly, and *brain inspired* for products inspired by principles related to neuroscience directly or indirectly. The use of such specific terminologies should clarify some misconceptions regarding the meaning of the term brain based and be a key step in facilitating a thoughtful evaluation of brain based products.

Another pivotal part of being a critical consumer is being systematic about product evaluation. We offer five steps to support systematic evaluation of brain based products: identifying educational goals and populations, aligning goals and product purposes, reviewing product merits, identifying the product's benefits and limitations, and characterizing the product's impact on behavioral performance. By following these steps, educators can be more critical consumers of educational products bearing the brain based label. Such careful evaluations will encourage investment in interventions with strong scientific evidence.

The future is open for educational neuroscience research to improve the questions and practices of researchers and educators. In the near future, researchers may determine whether neuroimaging tools are more useful than current practices in determining, for example, if a prereading child is at risk for a reading disability (e.g., Gabrieli, 2009). It will take time and resources for educators to participate in and to gain a deeper understanding of the emerging field of educational neuroscience. As this process unfolds, educators can take an active role in shaping the field by striving to be critical consumers of educational products, collaborating with researchers, and becoming researchers. Such critical consumerism will ensure that the latest advances in neuroscience are considered in the appropriate educational contexts.

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