



Informing Pedagogy Through the Brain-Targeted Teaching Model

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“Because of its broad implications for individual and social well-being, there is now a consensus in the scientific community that the biology of mind will be to the twenty-first century what the biology of the gene was to the twentieth century.”

Eric Kandel (21), p. xiii

Improving teaching to foster creative thinking and problem-solving for students of all ages will require two essential changes in current educational practice. First, to allow more time for deeper engagement with material, it is critical to reduce the vast number of topics often required in many courses. Second, and perhaps more challenging, is the alignment of pedagogy with recent research on cognition and learning. With a growing focus on the use of research to inform teaching practices, educators need a pedagogical framework that helps them interpret and apply research findings. This article describes the Brain-Targeted Teaching Model, a scheme that relates six distinct aspects of instruction to research from the neuro- and cognitive sciences.

INTRODUCTION

The call for a new way to approach teaching and learning can be heard from all sectors of the educational community, including school districts, professional associations, and institutions of higher education, as well as policymakers and leaders of business and industry. To reform education, much attention has been given to the notion of “21st century skills”—the set of skills students will need to become creative problem-solvers who can lead our nation forward in discovery and innovation (see *Partnership for 21st Century Skills* www.p21.org). In many PK–16 classrooms, a mismatch exists between the need for 21st century skills and current teaching practices that are driven predominantly by a curriculum that is an “inch deep and a mile wide.” It is unclear why “coverage” is emphasized above all else in many curricula, despite the fact that teachers at all levels commonly express concerns that they lack instructional time to cover what is required and engage students in deeper investigation and application of knowledge (14). Because instructors have to cover so much in so little time, they rely on modes of teaching that run afoul of recent scientific research indicating how students think, learn, and apply what they know.

It is clear that in order to make room in the curriculum for activities that help students develop 21st century skills, the amount of content instructors are required to cover within a semester or school year must be reduced. Instructors of biology have already begun to come to this realization.

Gregory et al. (13) argue that undergraduate introductory biology courses address too many different topics, leaving little time for instructors to employ pedagogical methods that promote deeper conceptual understanding and the application of knowledge in real-world contexts. After conducting a national survey of biology faculty, they found widespread agreement that course content should be streamlined to allow more time for deeper engagement with content. Gregory and colleagues have already taken the important first step of identifying a more reasonable scope and sequence for the biology curriculum, allowing for a greater emphasis on creative problem-solving.

One room has been made in the curriculum, what remains is the question of how to provide students with 21st century skills. In order to understand how these skills are developed, educators must first know how students best acquire, retain, and apply knowledge in creative ways. The emerging field of neuroeducation has much to offer in this regard. From early childhood settings to university classrooms, research from the neuro- and cognitive sciences has the potential to improve pedagogical practices and foster the development of creative problem-solving abilities.

However, turning to science to improve instruction presents new challenges. When educators start looking for helpful research, they often feel overwhelmed by the abundance of information they find about purported applications of neuroscience and cognitive science to education. Scholarly sources, including many journal articles and some books, often provide useful ideas that are indeed supported by science. However, many books, popular articles, and seminars—especially those associated with the moniker “brain-based learning”—make claims that may be wholly unfounded. More and more, instructors at all levels need a way to distinguish research-based applications of science from commercial products that serve only to perpetuate “neuromyths” (38). They also need

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a coherent strategy for applying relevant research findings to their everyday teaching practices.

The Brain-Targeted Teaching (BTT) model (16, 17) is a pedagogical framework that seeks to bridge research and practice by providing educators with a cohesive, usable model of effective instruction informed by findings from the neuro- and cognitive sciences. The BTT model is neither a marketed product nor a curriculum. (See Sylvan and Cristodoulou (38) for a guide for evaluating educational “brain based” products and theories). Rather, it is a framework intended to help educators acquire and apply sound scientific knowledge to further pedagogical goals—including the development of 21st century skills—so that all students can become creative and innovative thinkers and learners. Through the use of the BTT model, biology educators might cover less, but their students will learn more as they engage in deeper and more meaningful thinking and learning.

The Brain-Targeted Teaching Model for higher education

The pedagogical framework of the Brain-Targeted Teaching Model focuses on six distinct aspects of the teaching and learning process. Although these are presented as individual topics, the model is not a rigid guide for instruction. Rather, it represents an organic system for guiding pedagogy based on sound scientific research. The description of each of the six “brain targets” below highlights some research relevant to each target, and lays out instructional strategies based on this research that are useful in higher education classes in areas such as microbiology and biology.

Brain Target One: Establishing the emotional climate for learning

Once thought to be separate systems, we now know that emotion and cognition interact in a variety of important ways. Research continues to demonstrate how emotional arousal, both positive and negative, affects memory, attention, and higher-order thinking. For example, although mild stress in some contexts may enhance performance, prolonged stress reduces the ability to acquire and recall information (20). Schwabe and Wolf (35) demonstrated a 30% decline in performance when undergraduate student participants were placed in a stressful situation while learning new words. Conversely, positive emotions can enhance a broad array of cognitive processes, resulting in better performance on measures of creative thinking (11, 12). Joseph LeDoux (24) explains that information reaches the brain structures associated with emotion before it reaches the regions associated with higher order thought. He points out that emotion systems significantly affect cognition, strongly influencing how information is processed in cortical regions underlying conscious thought.

Educators can no longer ignore the importance of creating a positive learning environment that reduces the negative effects of stress. Below are several strategies that are appropriate for young adults:

- Establish personal connections with students and be accessible to those who may want help. Studies have found stronger academic performance and reduction in risk-taking behaviors among students who report having personal connections with caring adults (15, 31). Create opportunities for connection and collaboration among students through peer-tutoring and cooperative group work. Consider ways to reduce competition and encourage collaboration.
- Provide clear expectations for academic performance and apply those expectations consistently. Allow reasonable choices in how students demonstrate learning, a technique that has been shown to provide a sense of agency or control over outcomes and is associated with increased levels of motivation and achievement (40).
- Use humor to help reduce stress. Research has shown that students perform significantly better in classes that include humorous (although not sarcastic) interactions (34, 41).

Brain Target Two: Creating the Physical Learning Environment

The next brain target focuses on how the physical environment, like the emotional climate, can influence attention and engagement in learning tasks. In particular, novelty can be a powerful tool to enhance attention, engaging the brain’s alerting and orienting systems (30). Smith et al. (37) found that simply alternating the room where undergraduate students studied significantly improved retention of material. In addition to novelty, Brain Target Two focuses on factors in the physical environment that affect attention. For example, optimal lighting—that which most resembles natural light—has been shown to have a positive effect on attention and learning (8, 18). In contrast, poor lighting appears to negatively influence the activity of the pineal gland, which plays a role in arousal and produces hormones that regulate mood (27). Windows not only provide natural light, but also allow students to have views of the outdoors. Tanner (39) argues that the presence of distractions that require only “soft attention” such as gazing out a window leaves students better able to redirect attention to academic tasks compared to distractions that demand more cognitive focus such as doodling in a notebook or texting on a cell phone.

Similarly, certain sounds in the environment appear to compete for attention. Hygge (19), for example, found that subjects had significantly poorer memory for information after exposure to typical but harsh environmental sounds. Finally, we all know that students often create their own distractions by “multi-tasking” while in class or while studying. Researchers point out that switching back and forth between two tasks, such as listening to a lecture and texting, results in a net loss of attention, referred to as “task-switch cost” (36).

Although it may be difficult to control the classroom environment in a typical higher education setting, the

following tips can help instructors take advantage of novelty and reduce negative environmental factors:

- Create novelty by changing seating arrangements or reconfiguring the classroom. When possible, change class locations, utilizing other parts of the campus such as research labs, outdoor space, a theater, museum, or an art center.
- Vary how course materials are presented. For example, change font colors and styles for each content block, and vary modes of presentation by replacing text with images on PowerPoint slides.
- Monitor the use of technology in the classroom. Consider periodically banning the use of computers or even note taking, and instruct students to instead listen closely to the presentation and participate fully in discussion. Presentation notes can always be posted later.

Brain Target Three: Designing the learning experience

Next, we examine how to plan and present course content to promote global understanding of how concepts are related. In contrast to traditional practice, which addresses topics sequentially and rarely relates what is currently being learned to a broader context, Brain Target Three emphasizes “big picture” connections between major topics, themes, and concepts. Instruction that frequently relates content to a broader context takes advantage of the natural inclination to seek patterns and associations between memories (30). As Bransford et al. (2) point out, knowledge is not a list of facts and formulas. Rather, knowledge is organized around core concepts. Visual representations like concept maps help students make connections within and across content areas. Brain Target Three helps teachers apply research indicating that concept mapping increases memory and deepens conceptual understanding (1, 4, 25, 26).

The following strategies can be used during the design and delivery of instruction:

- Identify the major content themes of the course or unit of study, and display their relationships via a graphic organizer. Simple paper and pencil figures can be expanded into more detailed visual representations using word processing programs, PowerPoint, or other software programs.
- Once major areas of content are identified, consider ways to impart information through unique in-class activities and assignments other than lectures and readings. Each different activity can be represented along with associated content in the concept map.
- Determine how major content themes and sub-themes will be evaluated during and at the end of the course. Unique evaluation measures, including real-world applications of knowledge, can also be included in concept maps.

- Encourage students to create their own concept maps when they study to depict the relationship among concepts in a reading and to increase memory for content.

Brain Target Four: Teaching for mastery of content, skills, and concepts

In addition to attending to the emotional climate, physical learning environment, and the “big picture,” instructors must seek out and use pedagogical methods that lead to “mastery”—successful acquisition and long-term retention of content, skills, and concepts. Mastery depends heavily on memory processes; for information to be retained, it must be attended to and then moved from temporary stores to long-term memory systems. Research continues to expand our knowledge of how memories are encoded and retrieved. Nobel Prize winner Eric Kandel (21) has shown that to form temporary memories, synapses in the brain rely on existing proteins inside the cell; however, the conversion of temporary memories to long-term memories requires the brain to produce a different set of regulatory proteins. Thus, long-term memory for information is not just a psychological phenomenon, but also a *neurophysiological* phenomenon that occurs through biochemical processes in the brain, and the formation and reorganization of neural connections.

The challenge for instructors and students is to determine what methods of presentation and activities best promote retention of important content. Research from cognitive science and psychology is beginning to shed light on activities that appear to produce stronger memories. Karpicke and Roediger (22), for example, found that intermittent testing of students’ knowledge produced significantly greater retention than did students’ intermittent studying. They posit that the act of retrieving information reinforces memory for that information; more passive forms of studying (e.g., rereading information) appear to be considerably less effective. This is just one example; cognitive psychologists have identified numerous activities that improve memory for information including rehearsal, elaboration, and enactment of information. Memory is also better for pictorial representations and for information that arouses either positive or negative emotions. Interestingly, all of these effects are naturally leveraged through activities that incorporate the visual and/or performing arts (32). Thus, engaging students with instructional content through artistic activities may be a useful means to enhancing their retention of that information.

Mastery of content can be increased via the following strategies:

- Teachers should find ways to prompt students to actively retrieve what they have learned during class as well as through course assignments. Quizzes are one strategy, but retrieval need not be evaluative—active retrieval occurs when students apply knowledge to solve a problem or critically examine what they know. Instructors can encourage students

to argue different points of view, summarize their knowledge in multi-media presentations, or discuss content in-person or online.

- Use a variety of activities to take advantage of factors known to enhance memory for information. The arts and technology can be particularly helpful: consider having students create graphic designs, songs, works of visual art, and films.
- Encourage students to use their time outside of class not to simply reread information, but to quiz themselves so that they actively retrieve content. Only when they cannot retrieve a desired piece of information should they reread information, and then they should quiz themselves shortly thereafter. Oftentimes, students interpret “studying” to simply mean rereading chapters, listening to lectures, or looking at notes. However, flashcards and mock quizzes that require students to actively retrieve information from memory are much more effective than rereading. Online diagnostic quizzes that provide immediate feedback can be a powerful tool for retention of content.

Brain Target Five: Teaching for the extension and application of knowledge—creativity and innovation in education

Building from the tenets of Brain-Target Four, which aims for mastery of knowledge, Brain Target Five focuses on applying knowledge through creative activities that require critical thinking and real-world problem-solving. According to Harvard Professor David Perkins (29), creative thinking activities require “break-through” or “out-of-the box” processing and involve patterns of thought that differ from ordinary problem-solving. Research suggests that this kind of thinking is related to particular physiological differences in the brain. Using electroencephalography (EEG), Fink and colleagues (9), found differences in brain activity for tasks that required subjects to generate creative, original responses rather than conventional ones.

Although creative thinking is sometimes associated with intelligence or special giftedness, a growing body of research supports the notion that creative thinking is distinct from intelligence and can be taught (e.g., 5, 6, 7, 33). The following strategies for encouraging deeper engagement with content come from a professor of microbiology and bioinformatics who sought to promote creative thinking in his teaching:

- Rather than assigning “cookbook” laboratory exercises with lab projects, students are given materials and a goal to design lab experiments themselves. This requires students to form a hypothesis, test it, and modify their thinking based on data. Thus, rather than simply following a “recipe,” students creatively apply content, much like a chef improvising in the kitchen.
- Instead of merely reading topics such as how certain enzymes relieve the supercoiling of DNA, students

can use simple materials (e.g., a belt and telephone wire) to demonstrate the concept, an activity that promotes originality, greater understanding, and deeper thinking.

- Students can demonstrate understanding of concepts like gene inheritance and gene expression by examining case studies and developing pedigrees that depict how certain traits are inherited.

Brain Target Six: Evaluating learning

The final brain target focuses on how to provide students with feedback on their performance. Evaluation is not just a way to assign grades—it is a valuable tool for enhancing learning and memory. For example, Pashler et al. (28) found that learning the correct answer following an incorrect response improved recall of the material by 494%. Moreover, Finn and Metcalfe (10) demonstrated how memory is improved by “scaffolding” feedback—providing incremental hints that allow students to arrive at the correct answer themselves. In addition to the type of feedback provided, both the timing of the feedback and students’ *beliefs* about when they will receive feedback appear to affect performance. In a recent study, Kettle and Häubl (23) told students they would receive feedback on a presentation at varied time intervals, some receiving feedback the same day and others at intervals up to 17 days after the presentation. Results indicated that performance increased in direct relation to the proximity of the feedback; that is, students who knew they would receive quick feedback performed significantly better than those who anticipated feedback after an extended delay. This finding suggests that the mere anticipation of timely feedback can motivate performance. Finally, critical thinking skills can be enhanced through the use of alternative assessments that require more than simple recall (3). Taken together, these findings support the following recommendations regarding evaluation:

- Feedback on students’ assignments should be as timely as possible, and students should know in advance of doing an assignment that they will receive feedback soon.
- To further enhance effects of feedback, provide incremental hints to help students arrive at correct responses themselves.
- Creative thinking can be enhanced through the use of alternative assessments such as work portfolios and projects that infuse technology and the arts. Rubrics, given to students in advance, provide a clear metric as well as expectations for performance.

In summary, the Brain-Targeted Teaching Model represents a unified pedagogical framework that is grounded in research from the neuro- and cognitive sciences. Instructors in higher education settings, including those teaching biology and microbiology, can use the BTT model to improve emotional and physical learning environments, increase global understanding of the “big picture,” deepen mastery of content,

encourage students to apply knowledge in real-world contexts, and benefit from appropriate feedback and evaluation techniques. For a more comprehensive description of the Brain-Targeted Teaching Model, see Hardiman (16) or visit www.braintargetedteaching.org.

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