MIND, BRAIN, AND EDUCATION

The Human Nervous System: A Framework for Teaching and the Teaching Brain

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ABSTRACT— The teaching brain is a new concept that mirrors the complex, dynamic, and context-dependent nature of the learning brain. In this article, I use the structure of the human nervous system and its sensing, processing, and responding components as a framework for a re-conceptualized teaching system. This teaching system is capable of responses on an instinctual level (e.g., *spinal cord teaching*) as well as higher order *student-centered teaching* and even more complex *teaching brain teaching*. At the most complex level the teacher and student engage in a synchronistic *teaching flow* that achieves the optimal teaching and learning experience.

In this article, I propose to use the human nervous system as a conceptual framework for exploring the components, functions, and interactions of the teaching brain within the larger context of teaching as a system (see Figure 1). The nervous system has three core functions: sensing, processing, and responding, which are referred to as "limbs" in medicine. Within this framework, the sensing limbs absorb both internal and external stimuli from the teachers themselves, their students, their class, their school, and beyond. This information is then processed within the teaching brain. In order to respond to each student in a distinctive way in each class, teachers engage in student-centered processing, which produces what I have termed *student-centered teaching responses*. As Figure 1 illustrates, only part of the processing ability of the teaching brain is utilized in these responses. Teachers also have the ability to engage in teacher-centered processing, utilizing relevant information from their personal contexts. The combination of student- and teacher-centered information processing produces what I have termed *teaching brain responses*. These responses are built upon the dual feedback in the behavioral interaction of teaching. As the feedback loop continues, the teacher is able to sense any resulting changes in their environment termed *personal context* (student, class, self, etc.) and further process those changes. As this dynamic feedback loop activates and improves, it leads to synchronistic *teaching brain responses*. The teacher and student engage in a teaching "flow" that I propose achieves the optimal teaching and learning experience (Csikszentmihalyi, 1991).

This second issue of the teaching brain series seeks to further redefine teaching and the teaching brain. Kent and Yano explore this teaching framework in different ways. Yano describes a series of experiments in which he uses sensitive monitoring techniques to map human interactions and in the process discovers how human interactions are the key to creating flow and enhancing productivity (Yano, 2013). He concludes that studying the science of human interaction could help to mend the gap between understanding teaching as a social phenomenon versus a physiological one. Kent, on the other hand, invites researchers into her teaching brain by detailing her cognitive processes as she describes several synchronistic interactions of teaching (Kent, 2013). Rather than explaining her best practice strategies, which is the common role we ask teachers to fill in education research, Kent invites readers to look through her lens as an experienced master teacher so that we might gather information on her ability to sense and process using all of her teaching brain. Together, these pieces support the framework for a new teaching system that I am outlining. Within this system teachers are conceptualized as complex processing organisms that weigh imported student information against their personal context to create a synchronous teacher–student interaction (or synchronous educational experience).

THE HUMAN NERVOUS SYSTEM AS A FRAMEWORK FOR TEACHING AND THE TEACHING BRAIN

The nervous system is the control system for the human body (Longo et al., 2012). It is constantly sensing, processing,

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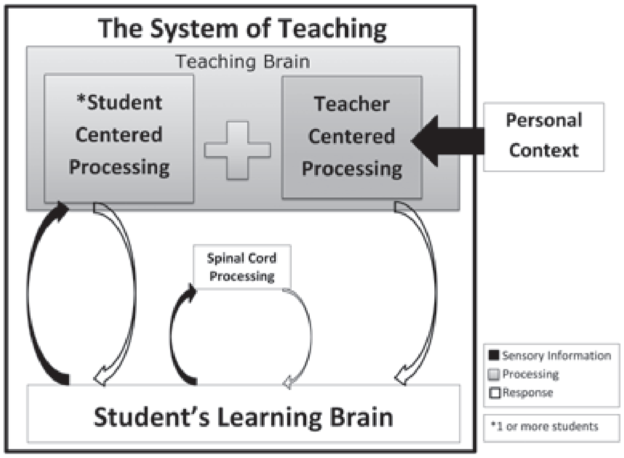

Fig. 1. Schematic depiction of the system of teaching.

and responding to the external and internal stimuli that it encounters. This constant feedback loop is replicated from the simplest to the most complex networks in the body. In its most basic form, a single afferent (sensing) neuron receives a signal from a stimulus (heat, pain, light, etc.) and that information is transmitted to the spinal cord where it is quickly connected to the appropriate efferent (motor or action) neuron so that the body can instinctually respond (e.g., pull its hand away, constrict its pupils, etc.). In more complex situations, these same sensing pathways are combined with many others, both external and internal (feelings, memories, etc.), and are processed by various parts of the brain to drive more complex, often cognitively demanding responses (speaking, writing, empathy, etc.). This basic system is a core resource of humanity and helps to highlight our close connection to animals' basic impulse responses. However, it also highlights human beings' ability to move through the world and to think at a more complex cognitive level than all other species. Taken as a comparative framework and not in direct comparison, the human nervous system is an ideal framework for understanding the core human characteristic of teaching.

APPLYING THE MODEL OF THE NERVOUS SYSTEM TO DESCRIBE THE SYSTEM OF TEACHING

Teaching and its underlying processes are complex but we can use the analogy of how the human nervous system functions as a framework for organizing this complex system of teaching. The nervous system has three parts—the afferent or sensing limb, the central processing unit (spinal cord and brain), and the efferent, responding limb (motor functions) (see Figure 1). Similarly, when teachers are engaged in the interaction of teaching, they activate their sensing limb to assess the physical space, the learner, the atmosphere, etc. All of this sensory input affecting the student and the teacher is processed by the system of the teaching brain either in its proposed "spinal cord" or its higher function (the "teaching brain").

The teaching brain processes this information to create a mental model or theory of the student's complete learning brain (ToLB). This includes how the student might respond to various teaching choices (theory of mind) as well as theories of the child's capabilities (theory of cognition), how their learning might be affected by their feelings (theory of emotion otherwise called empathy) and even how far they could push the child to recall information that they believe is stored in the child's mind (theory of memory). Teachers then use this information to command the efferent limb of their teaching brain response. The choices of the response limb are limitless in that they are tailored to the individual teacher's context and their sense of self (multiple meta-processing) in combination with a theory of the student's learning brain (theory of mind, cognition, emotion, memory). This is in contrast to popular best practices which list directive techniques (Boushey & Moser, 2006; Jones, Jones, & Jones, 2000; Lemov, 2010) or progressive instructional frameworks (Atwell, 1998; Calkins, Ehrenworth, & Lehman, 2012; Danielson, 2010).

PART I. THE SENSORY INPUT OF THE TEACHING SYSTEM

The ability to sense information is the first component of this system. Because the teaching system includes the teacher and the learner, teachers ultimately import information from both the students and themselves. This sensory information can be received externally from the student or internally from the teacher's context. Both types of information are feedback which informs the teacher's process and enhances teaching response. This section will review each of the proposed sensory inputs of the teaching system.

Student-Centered Information: Student's Learning Brain

Active and Intentional Feedback

All students have a learning brain which is dynamic and variable (Thomson & Fischer, 2007). Their learning processes are forever changing based on their context. Gathering this information is necessary for the teacher to respond appropriately to the student's needs. This information may come in the form of intentional feedback by the student whereas they may actively inform the teacher of their needs. Animals show active feedback when they exhibit that they have learned to hunt for food or locate water. Human parents also recognize this intentional feedback quite regularly. Imagine a lovely 5-year-old girl named Eva. One morning as they are preparing for school Eva says to her mommy, "I can't close my coat." In turn Eva's mommy understands that Eva does not know how to close buttons. This is what teachers often refer to as "teachable moments." These are the moments where a learner provides active feedback of his or her learning (including lack thereof and misunderstandings) which presents the opportunity for intentional teaching to follow. Later in the response section of this article I will discuss the student-centered teaching response given by Eva's mommy. Classroom teachers receive this intentional feedback in many forms: student exams, assignments, and the raising of hands for questions and answers are all clear examples of intentional feedback.

Inactive and Unintentional Feedback

This type of feedback is sometimes more difficult to identify as student-centered information because it does not solely affect the learner. While internal influences such as their phenotypic and personality traits are specific to the student, they are often influenced by external factors. These external factors are a combination of the people, places, objects, and cultural norms affecting the student. For Eva this might mean that her mommy will hear her stomach grumbling as the afternoon sets in or notice that she lost her favorite headband and that it is her class's picture day. With this information Eva's mommy may offer her a student-centered teaching response but again we'll cover that in the response section. While these pieces of information are less concrete and harder to define they are just as significant in helping the teacher engage in a successful interaction which meets the student's needs. A classroom teacher would access this student-centered information through the child's body language (e.g., Are children following our daily routine? Is the class in or out of sync with me or with each other?), mood (e.g., Did Zac finally hear back from his brother away at college?) and overall climate (e.g., Do the kids fear our debate lesson planned for today or are they excited?). This inactive and unintentional feedback is both tangible (weather, temperature, and sound) and intangible (mood, flow, and climate) requiring complex processing to assess its significance in student learning.

Teacher-Centered Information: Personal Context of the Teacher

Let us again recall that the teaching system must include the teacher as well as the learner. While learning may occur without teaching taking place, teaching does not occur without the dyad of teacher and learner. As the leader in this interaction the teacher gathers information from both the learner and the self and processes what is necessary for the interaction. This factor of the sensory limb is often overlooked in current educational reform efforts (Jones et al., 2000; Ravitch, 2010; Rhee, 2013). However, similar to other human actions, knowledge of self is required in order to effectively understand the inputs and outputs which together create a comprehensive teaching process. While teaching is an interaction between teacher and learner, the act of teaching itself is still filtered through the teacher's lens. Therefore we must understand the personal context of the teacher and how it interacts with the student. A teacher's personal context involves both internal and external sensory information.

Internal Influences

Though internal characteristics are influenced by external factors and vice versa, I have attempted to parse out the distinction for the purpose of understanding the teaching system and a teacher's context within it. A teacher's internal influences can be described as traits (both phenotypic and personality) that are specific to him or her. You might say that they are "just who the person is." Phenotypic traits are those that are obvious and observable such as those that are a result of your DNA (e.g., race and IQ) while personality traits are characteristics like humor or sense of confidence. Each trait has an important influence on the teacher's practice. Though these traits are not modifiable (e.g., race) they need to be understood to fully comprehend how they affect the teaching brain. Similarly, personality traits like humor and self-confidence contribute important information to the teaching process. For example, perhaps Eva's mom may view the "teachable moment" differently depending on her sense of humor and choose a very different teaching response based on this personality trait.

External Influences

The teacher's personal context also involves the people (relationships), culture (lifestyle), places, and objects (environment) that exert external influence. The teacher's context is constantly informed by the surrounding world. Other people, including family, friends, other teachers, administration, and colleagues all influence the teacher's personal context. This influence is highlighted by the important role that mentor teachers serve in the teaching education literature (Clark & Lampert, 1986; Donaldson, 2008; Johnson & Suesse, 2005; Johnson & Birkeland, 2003). Similarly, the weather or current events which influence the teacher's personal context in turn change teachers' processing within the teaching system. For example, a major flood, a war, or just a steady week of rain may change the mood of the teacher and how he or she perceives the students and his or her self during that period. Similarly, a teacher's personal context is a product of how his or her sense of career, life plan, and income tangibly affect the daily teaching environment (Johnson, 1986; Johnson & Project on the Next Generation of Teachers, 2004; Kapadia, Coca, & Easton, 2007; Levin, Mulhern, & Schunck, 2005).

PART II. THE PROCESSING ABILITY OF THE TEACHING SYSTEM

The processing aspect of the teaching system is the most complex. Consider again the framework of the nervous system;

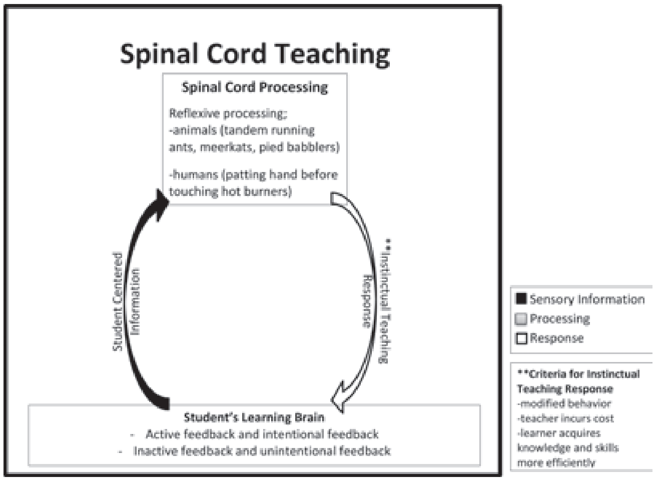

Fig. 2. Schematic depiction of spinal cord teaching.

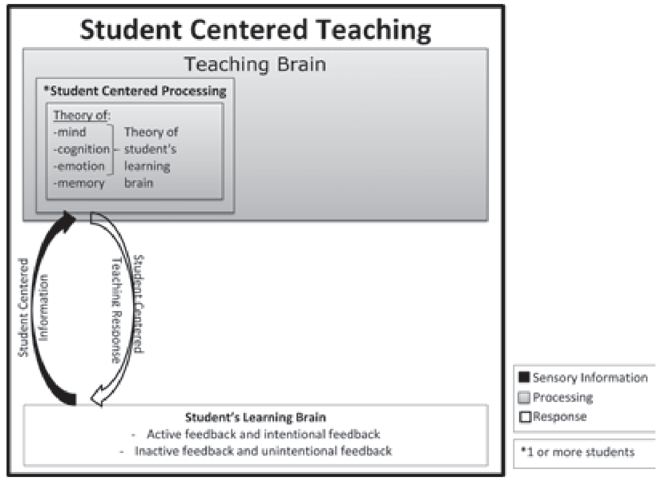

Fig. 3. Schematic depiction of student centered teaching.

processing is the function of the brain and spinal cord (see Figure 1). However, they both work differently. As sensory neurons come in through the spinal cord, some of their information is minimally processed as reflexes while other signals are passed along to the brain. The brain's function is a much more complex process where many sensory neurons enter at the same time. The information is categorized and distributed to specific areas of the brain for processing. Most fascinating, however, are the infinite patterns that the brain assesses and the resulting triggers that are ignited to form appropriate responses.

Spinal Cord Processing

I use the term spinal cord processing to describe the most basic forms of teaching (see Figure 2). It can be found in humans and animals. Several arguments for the universality of teaching have identified this act as the adjustment of behavior in response to learner cues (Thornton & Raihani, 2008). The only sensory information used is acquired from the student while ignoring the personal context of the teacher. This reflexive form of teaching is minimally processed and is what animals such as tandem running ants, meerkats, and pied babblers (the prototype animal teaching models) demonstrate (Franks & Richardson, 2006; Raihani & Ridley, 2008; Thornton & McAuliffe, 2006). In humans, spinal cord processing is seen in early toddlers before they develop higher-order teaching skills (Csibra & Gergely, 2011). This processing is also common in "cookie-cutter" teaching methods where a priori student types are presented and matched to a set list of teaching actions (Lemov, 2010). Teachers or computers (virtual teachers, e-learning labs, etc.) then carry out responses to teach the student based on this reflexive processing (Herrera, 2011; Spencer, 2012). Spinal cord approaches do not require a complex understanding of the student's learning brain nor are they inclusive of the teacher's personal context.

The Teaching Brain: Student-Centered Processing

The complexity of human teaching is more similar to brain processing in the nervous system rather than spinal cord processing. An understanding of this complexity has been well established within the teacher education literature. However, this exploration has typically focused on student-centered processing alone (Clark & Lampert, 1986; Peterson & Clark, 1978). A core concept is that a theory of mind is a necessary prerequisite for human teaching (Premack, 2010; Premack & Woodruff, 1978; Strauss & Ziv, 2012). Cognitivists have argued that in order for student-centered teaching to take place the teacher must form a mental model of the student. This mental model, or theory of the learner's mind (ToM), is what enables teachers to understand the mental state which caused the learner's behavior.

However, in the teaching system I am outlining, I suggest that human teachers employ more than a ToM when they are processing student-centered information in the teaching brain (see Figure 3). In addition to ToM, teachers form theories of the learner's brain processing as a whole. When a teacher is forming a theory of the student's cognition, they consider what the child is thinking and the knowledge that he or she has accrued over time. Teachers can then use this model to guide not only what the student thinks and knows but also what he or she is capable of. Forming a theory of memory allows teachers to "push" students to learn concepts that students themselves think may not be possible.

Similarly, teachers create a theory of emotion that enables them to have a sense of how the student is feeling and how it affects his or her ability to learn. On the basis of how they perceive their students' emotional state, incorporating key sensory information such as trouble at home, depression, ADHD, and so on, skillful teachers are able to alter their teaching response. These multiple theories of the whole student are what a teacher uses to create a comprehensive map of the student's learning brain (aka ToLB), providing half of the required information for optimal teacher–student interactions.

The Teaching Brain: Teacher-Centered Processing

In order to teach, one must process information both for oneself and as a learner. I am not proposing that there is literally a separate brain that is our teaching brain. Instead identifying the teaching brain is an attempt to highlight a pattern within brain processing that can characterize the complexity of master teaching. Teaching is unlike learning in that it is not and cannot be an independent endeavor. When we suggest that we have taught ourselves, we are actually just stating that we have learned. Teaching is an interaction between two entities: the teacher and the learner. Therefore the information input and then processed cannot be solely self-generated or in this case learner generated. Instead the teacher is the gatekeeper of the information generated from both themselves and their learners. All of this information is passed through their brain for processing and then used to enhance the teaching–learning interaction.

Meta-Processing

As described in the sensory input section (Part I), the teachers' personal context—both internally and externally—is a rich source of information that represents the other half of information processed by the teaching brain (see Figure 4). This information is traditionally ignored in even the most progressive brain-based education models (Jensen, 2008; Sousa, 2010; Tokuhama-Espinosa, 2011). The teacher's personal context allows him or her to develop models of his or her own knowledge, emotions, and memories—making it possible to manipulate, store, and recall this information rapidly when needed (Clark & Lampert, 1986). These models of their own personal context exist on the "meta" level, creating meta-cognitions, meta-memories, and meta-emotions; essentially they are comprehensive mental models of the teacher's own personal context. For example, teachers' meta-memory enables them to know what knowledge they would remember if they focused on recalling it. A teacher's meta-emotions provide an understanding of their own emotions about other's emotions (self, student, etc.). These meta-processes are critical to enabling the master teacher to manage the overwhelmingly complex and constant stream of sensory information available from the student and teacher contexts.

Putting It Together: Meta-processes and Theories of the Learning Brain

However, teachers' multiple meta-processes are consistently interspersing with additional levels of awareness and theory of their students' minds, cognitions, memories, and emotions. While parents also exhibit this regularly with their own child, master classroom teachers form theories of the learning brain (ToLB) for each child in their classroom. Keeping all ToLBs active while allowing them to remain variable and

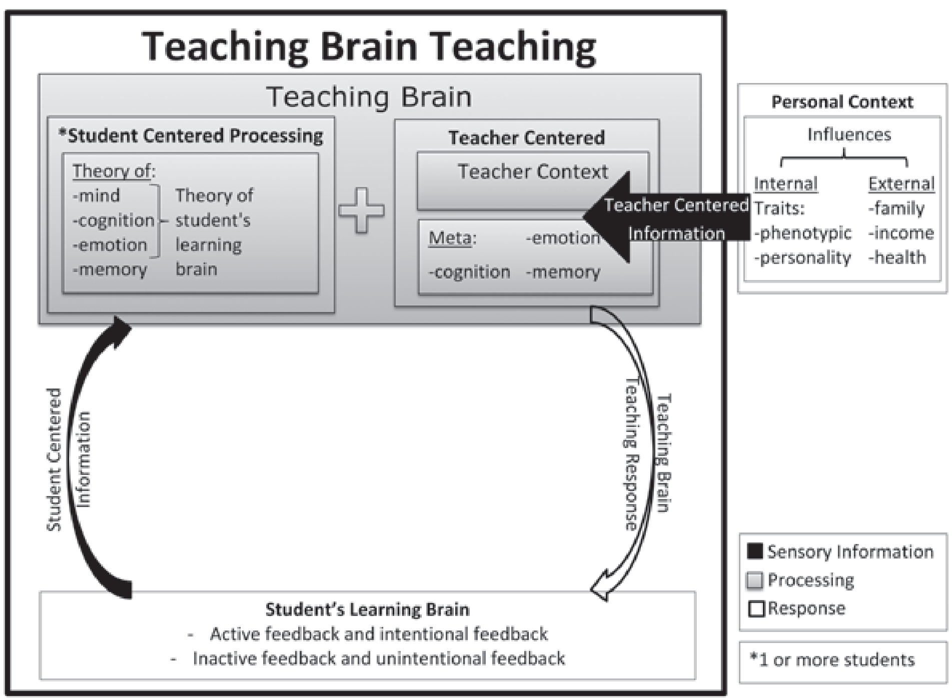

Fig. 4. Schematic depiction of teaching brain teaching.

dynamic, simultaneously affecting and changing one another is an extremely sophisticated process. Teachers not only understand the cause of a student's behavior (ToM) based on having an understanding of their mental state, but they also know what their students know and what they are capable of doing (meta-cognition) (Cherubini, 2010; Premack & Woodruff, 1978). Teachers are not only aware of how they are feeling about their own feelings but they are also aware of how they feel about their student's feelings (meta-emotions). These multiple meta-processes coupled with multiple theories of a student's learning brain are what make up the patterns of the teaching brain.

Manifestations of the Teaching Brain in the Classroom Teacher

This complex brain processing, integrating the student and teacher context, allows teachers an ability to leverage this understanding and use tailored strategies to enhance their students' learning. Master teachers often describe this process as discovering their students' triggers, breaking down their walls, or figuring out their patterns of thinking. In this process, they detect the students' context along with patterns in the students' context over time. Then using their teacher context as a lens, they search for a pattern of success involving their interaction with this type of student. Teachers probe the students for the right "triggers" to break down their "walls" or barriers to learning which will allow the teacher–student interaction to flow.

This process will be different for each teacher–student dyad due to the fact that their personal contexts are different. Some teachers may employ more humor, others more empathy, still others may take a "hard line" knowing that a particular child is capable of more and needs a "push". Similarly, teachers describe their use of meta-emotion and the student's theory of emotion as employing empathy in their teaching—an often cited key component of master teaching (Clark & Peterson, 1986; Immordino-Yang & Damasio, 2007; Lampert, 1985; Peterson & Clark, 1978). Teachers, guided by these mental models, choose how to respond (or sometimes not respond) in terms of lesson plans, curricular decisions, word choice, their affect, cajoling, or comforting students, group building, or individual focus, and so on. A teacher has to sense all these factors and compare them to what she or he brings into the mix and what every student also brings. As they sense the students' mood they are comparing that to their own (e.g., Will they know that I didn't sleep all night?), body language (e.g., Can they tell that I'm anxious to get started with our debate lesson?), or classroom climate (Can they sense my excitement for this lesson?).

The tangible responses are those that are routines and strategies (e.g., keeping an agenda on the board so students know what to expect, requiring student exit slips as a daily check of student learning, or connecting content to the student's life). However, there are also intangible responses. Some of them are embedded in the reasoning behind the tangible task but others are sheer human instinct with intent for reaching synchrony (e.g., telling a joke to redirect the mood, sharing a personal story to connect to the vibe of the room, sitting next to a child rather than standing at the front to show joined purpose). The next section will explore the infinite responses available to teachers when their teaching brain is functioning at a complete and optimal level.

PART III. RESPONDING

Instinctual Teaching Response

When a teacher thoughtfully employs the teaching brain to cognitively process the students' and teacher's sensory information she or he is analyzing complex social processes. Spinal cord teaching (see Figure 2) on the other hand is equivalent to Caro and Hauser's (1992) definition of teaching that requires three basic criteria: (1) the teacher alters his or her behavior in the presence of the learner; (2) the teacher suffers a cost from the interaction; and (3) the learner learns more efficiently from the interaction as compared to learning on his or her own. Many researchers promote this basic definition because it provides testable criteria to explore teaching in all species. By categorizing teaching as functional instinctual behaviors, researchers can consider the evolutionary nature of teaching in both animal and human species (Thornton & Raihani, 2008). I equate this form of teaching to the role of the spinal cord in the nervous system as these basic criteria do not require complex processing as the examples below demonstrate.

Three commonly cited examples of instinctual teaching responses in animals are described in Thornton & Raihani (2008). Tandem running ants modify their behavior in the presence of a naïve learner. In order to teach it how to complete a food run, they require that the learner ant taps them repeatedly with their antennae before they continue to show them the route to the food. The teacher's route takes much longer to complete but as a consequence the learner ant now knows how to find the food independently (Franks & Richardson, 2006). Meerkats have also been identified as participating in spinal cord teaching: Adult meerkats offer their young learners live prey in order to teach them how to handle what is roughly 50% of their food source. Though the meerkat is risking the loss of this additional food, the learner meerkat is ultimately better able to handle the prey as a result of this interaction (Thornton & McAuliffe, 2006). If the learner meerkat loses interest in the prey, the teacher meerkat reengages with it. Lastly pied babblers (a type of bird) teach their young to associate certain calls with feeding periods. This requires the adult teacher to consistently have food available to train the learner to rely on this feeding call.

As a result adults are able to use this same call to signal their young away from danger regardless of whether there will actually be food available (Raihani & Ridley, 2008).

These forms of instinctual teaching for survival purposes are also found in human parents and their children. Let's again consider the toddler David whom we introduced in the first issue of this Teaching Brain Series. David is a clever little toddler who understood that if he wanted to play a game with his friend who did not know how to play, he would have to teach him. David is not only a teacher but he is a learner as well. After reaching towards the hot stove one day his father instinctually reacts by patting David's hand saying, "No." David's father taught him not to touch the hot burner. This type of teaching requires minimal processing (hot burner = burned hand) and in return has a quick response (patting hand and saying, "No"). This spinal cord teaching helps us to pass on basic skills from generation to generation that are extremely important for survival (Chazan, 2012; Sterelny, 2012; Tomasello, 1998). Whether in animals or humans, the difference between instinctual teaching responses and student-centered ones involving the teaching brain is their lack of complexity; student-centered responses require complex inferences based on sensory input, processing, and response in interactions with students.

Student-Centered Teaching Responses (Human Specific: Partial Teaching Brain Processing)

Student-centered responses take account of the student's learning brain. When Eva's mom uses her teaching brain to process the student-centered information from Eva, she is able to offer a response that takes account of Eva's learning brain. Rather than just buttoning Eva's coat for her, she kneels down and responds, "You can't button your coat? That must be really frustrating for you. Would you like to learn how to button your coat?" Here Eva's mom is being responsive and sensitive to Eva's needs while also providing her with the autonomy to choose when she would like to learn this new skill. If Eva is too frustrated to engage in this teaching–learning interaction right now, the mother can continue by asking Eva, "Why do you think we button our coats before we go outside?" in an attempt to interest Eva by encouraging her to analyze why everybody else does it! To continue promoting Eva's cognitive development her mom might begin brainstorming with Eva about other things that require buttoning or ask Eva how buttons are different from zippers. This scaffolded response supports Eva in learning how previous knowledge can help her in solving her current dilemma. And finally the mother may say, "I wonder how we could get this round button to fit into that slit on the other side of your coat? Why don't you tell me what you tried and why it didn't work?"

These student centered responses are extremely complex, requiring a ToLB that is sophisticated. Student and teacher interactions have been demonstrated to be fundamental to learning and development; highlighting the importance of ToLB even further (Greenberg, Domitrovich, & Bumbarger, 2001; Hamre & Pianta, 2007; Morrison & Connor, 2002; Pianta, 2006; Rutter & Maughan, 2002). Many education reformers and researchers have therefore focused their attention on developing models and evaluations for teaching that offer emotional, organizational, and instructional support centered around the student.

In one such attempt, Medina (2008), a developmental molecular biologist, wrote a popular book offering several examples of student-centered or what many call brain-based teaching. Medina outlined a teaching approach where all teachers are evaluated based on their advanced theory of mind skills to determine how well they can customize instruction. He advocated individualized student instruction because of the fact that human brains are all individually wired. Medina also cited the learning brain's limited ability to pay attention as a guideline for teaching. Since the brain cannot multi-task, holds attention for only 10 min at a time, and can recognize patterns better than details, Medina suggested that teachers teach in 10-min segments beginning by explaining the entire topic in 1 min and connecting it to a core concept. Each 10-min interval should then end with a hook that gives the learner enough emotional arousal to interest him or her in the next 10 min. In the average K-12 teacher's day this would require five distinct topics to be taught in one 50-min period. Medina suggests that because repetition is helpful to the student's long term memory, schools should actually divide periods into 25 min where students would cycle through the same 25-min lesson three times in one day for repeated exposure (Medina, 2008).

Many other common brain-based curriculum reforms focus specifically on the learning brain and recommend teaching with only the student in mind. For example, Universal Design for Learning has designed a foundation for curriculum development of goals, methods, materials, and assessments grounded in evidence of brain networks (Council for Exceptional Children, 2005; Hall, Meyer, & Rose, 2012). Student-centered teaching responses such as these focus on analyzing the learner's dynamic and variable brain, which is grounded and affected by their context (Fischer & Bidell, 2006; Jensen, 2008; Willingham, 2009). However, since the teacher's response is, by design, specific only to the student's information, it utilizes only part of the available processing of the teaching brain (see Figure 1).

Though the teacher is actively receiving the student-based sensory information, this information is not processed independently. Instead it merges with the teacher's personal context. Teaching methods designed around the student and the learning brain attempt to limit teaching responses to only a theory of what is occurring in the student's learning brain. This flawed and unrealistic approach ignores the teacher's personal context. To create a comprehensive teaching response that combines student information with teacher context, the teacher must process the information in the student–teacher interaction.

Teaching Brain Responses (Human Specific: Full Teaching Brain Processing)

Consider that complex teaching is not a one-way street but an interactive human behavior. A teacher has to sense all the factors that may affect the learning interaction and compare them to all the feedback contributed by students and themselves. While Medina should be commended for suggesting teaching methods based on how the brain learns, all of these recommendations are ignorant of how the brain *teaches*. Is it possible for a teacher to refocus their attention every 10 min so that they can change their teaching topic regularly? Is it sustainable for a teacher to teach the same lesson three times a day to the same group of students in the same way? Or eight times for four different groups over the course of one school day! Medina does not consider these issues that focus on the teaching brain. Instead his approach and that of so much of the brain-based education literature utilizes an empty vessel theory of teaching, which ignores the individual nature of the teaching brain much the same way it did for learning.

Common elements to student-centered responses are teaching practices and curriculum strategies such as including multiple modalities of teaching to support all learners and stating clear steps that identify expectations for achieving learning tasks (Pianta, 2006). Teaching brain responses are not chosen solely on the basis of the student perspective. They are the result of a sophisticated theory of the learner's brain (ToLB) and multiple meta-processes of the teacher self.

To illustrate the teaching brain response let's imagine a classroom that is embarking on a standard student centered lesson of choosing a "good fit" book. Typically this lesson is taught such that it supports Gardner's (1983) multiple intelligences of students and recommends varied approaches to how a student can choose an appropriate book (Atwell, 1998; Calkins et al., 2012). Teachers are trained to teach "mini-lessons" that last only 10–15 min in order to hold student attention. They use large white chart paper to brainstorm ideas so that students feel they have an investment in what will become the class's protocol for choosing a book. Class charts are limited to three colors or less to avoid overstimulation and confusion for students. All charts must include borders so that students can focus on the important information at the center of their visual field. These large student-centered charts are then displayed in the room so that students can enjoy the print-rich environment which is meant to support and stimulate their language acquisition (Danielson, 2008; Ehrenworth, 2003). Students are also instructed to look at the picture on the book cover (visual stimulation), read the back cover (interest level), and use the five finger rule (if after reading a page you do not know five words then it is too challenging a read). Every year, the teacher carries out the same lesson which is packed with "best practices," that is, those practices that have been identified as successful because successful teachers utilize them (Danielson, 2010).

Now re-imagine this student-centered experience as a comprehensive teaching brain response. In this classroom, when the students were asked, "How do you choose a good book?" one young boy replied, "I date the book." The teacher, Miss Claire, an eight-year veteran and literature major, chooses to take advantage of this unique and clever suggestion. Miss Claire chooses to reveal that in college she would often look up the date a book was written and consider the current events of the time, the biography of the author, and the time period it was representing. This would reveal a lot of information about theme and plot of the text, which in turn could help in deciding whether it was a good fit to read. On the basis of her experience, she perceives the suggestion by this adolescent boy as quite sophisticated so Miss Claire was excited to hear more about his suggestion. However, Sam corrects her quickly, "No I date it. You know I take her out on the town, bring her to dinner and see if I'd rather go watch a movie or just go back home and stay up talking with her all night." The difference between a student-centered response and a teaching brain response is illustrated by the sequence of events that follow.

Rather than just having Sam share his example and then moving forward with the evidence-based lesson, Miss Claire is a big fan of humor and with a hint of her typical sarcasm she replies, "Well, aren't you the ladies' man, Sam? Why don't you tell us how you know she's the one!?" Sam continues to share his method for choosing a good-fit book. Meanwhile, his sensory information is constantly interacting with Miss Claire's personal context and rather than simply laughing along with the class, she processes the experience and allows it to drive the creation of an entirely new and unexplored interaction. The result of this dynamic interaction was a new, collaborative class project called Speed Date a Book in which students chose two of their six summer readings and figured out how to get their peers to agree to "date" their book.

The project represents a full teaching brain response because it is a mixture of student and teacher context. This project incorporated the student context because it was student-generated and connected to a contemporary concept (speed dating) that was highlighted in a recent adolescent blockbuster movie. However, it still maintained traditional student-centered lessons. Students searched their books or "dates" for their best attributes (theme, plot, characters, etc.)

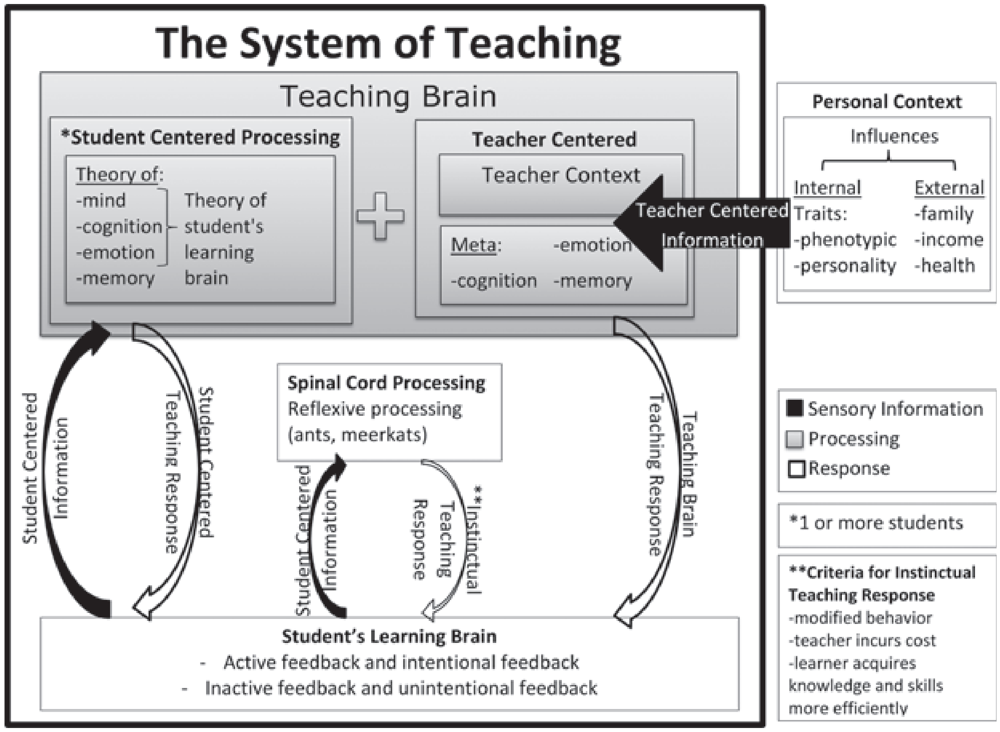

Fig. 5. Schematic depiction of the system of teaching with detail.

and planned how to best represent them to others. Students then used the vehicle of speed dating in which they sat across from a semi-interested peer and had 2 min to convince them to date their book. A successful book interaction resulted in a student adding their peer's book to their reading list. This project tapped into the student's theories of mind, cognition, and emotion—giving the lesson that critical "hook" or "trigger" to increase their motivation and understanding (Danielson, 2010; Wiggins & McTighe, 2005). It also incorporated the teacher's context, her preference for literature, careful use of humor, awareness of current trends, and rapid ability to assimilate the student context with her own to create synchronous teacher–student interactions (see Figure 5).

Moreover, the project met all the same content and skill requirements of the previous "best practice" models, but in the re-imagined scenario the educational experience is a dynamic combination of student and teacher context. Student needs were still being met as the teacher experimented with a new project, even though this dynamic process would clearly controvert current trends in education for standardization of classroom interactions to enhance reliability, accountability, and transparency (Lemov, 2010; Mathews, 2009; Tough, 2008). Furthermore, the freedom to "invent" unscripted teacher–student interactions motivates the teacher's own interests, challenges her ability to plan a new project and to extend the bonds that she shares with the class such as when they all laughed over Sam's unique way for choosing a book. The resulting project transcends the curricular requirements of providing evidence of student's summer reading for the purpose of assessing their appropriate reading level. Miss Claire uses the student responses not only to assess her students' reading level but to evaluate the success of her own project design, creativity, and teaching skill. These are important validators and motivators for continued efforts over the long term (Pink, 2009). This type of complex teaching brain response produces many benefits for student and teacher as it solidifies their bond and encourages the class to work as a unit providing each other with feedback and moving towards a synchrony of action and thought.

THE NECESSITY OF DUAL FEEDBACK FOR INTERACTION MOTIVATION: SYNCHRONY & COLLECTIVE ATTENTION

Inevitably a teacher's response is an effort to move towards a connected social system (Clark & Lampert, 1986). The response is about reaching synchrony of action and thought. This is similar to how the learning brain works, but the most significant difference is that teaching, unlike learning, cannot be carried out independently. Teaching requires human interaction and it requires a feedback loop between teacher and student that displays "success" in order for the process to continue. When this works well we reach a level of synchrony in which teacher and learner have joined in "knowing" and the process begins again, renewing itself (Csikszentmihalyi, 1991; Schippers, Roebroeck, Renken, Nanetti, & Keysers, 2010; Yano, 2013).

This cycle of recursive processing (see Figure 1) is a continuous loop where the student and his or her learning brain respond to the teacher's actions and alter the sensory input that the teacher receives. This provides critical iterative feedback that the teaching brain processes to adjust responses; for example, it alters the act of teaching. This constant feedback loop is what I suggest is the source of the intangible synchrony that occurs in teaching, between teacher and student (Rodriguez, 2012). This is also what the articles in this section by Yano and Kent describe. The give-and-take between teacher and student, this human interaction, creates a "by-product" of human synchrony that is hard to define, but you know it when you see or feel it. It is the flow that drives creativity and higher human thought (Csikszentmihalyi, 1991). It is the X factor that makes in-person teacher–student relationships irreplaceable as this feedback loop is based on the full body of interaction—not simply voice, visual, or textual. The teacher–student interaction is the engine behind the synchronous educational experience that characterizes the best teaching and learning brains.

CONCLUSION: THE TEACHING BRAIN

The teaching brain involves a dynamic, complex process that mirrors the core functions of the human nervous system itself (e.g., sensing, processing, and responding). Animal definitions of teaching are more analogous to spinal cord teaching, while educational reform efforts are limited by their student-centered approaches that ignore 50% of the student–teacher interaction (the teacher part). This myopic vision constrains teachers and students. It creates a drive for standardized, scripted curricula that interrupt the student–teacher feedback loop. A comprehensive loop feeds off the context of both student and teacher and is the raw material for a more complex, synchronous student–teacher experience akin to "flow" and other higher-order cognitive states that teaching is supposed to encourage. Future research needs to explore this broader paradigm of the teaching brain and study its components to determine how educators can modify and encourage this dynamic feedback loop between student and teacher—creating a truly brain-based education in which teachers continue to play a central role.

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