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WE FEEL, THEREFORE WE LEARN: THE RELEVANCE OF AFFECTIVE AND
SOCIAL NEUROSCIENCE TO EDUCATION

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ABSTRACT

Recent advances in neuroscience are highlighting connections between emotion, social functioning and decision-making that have the potential to revolutionize our understanding of the role of affect in education. In particular, the neurobiological evidence suggests that the aspects of cognition that we recruit most heavily in schools, namely learning, attention, memory, decision-making and social functioning, are both profoundly affected by and subsumed within the processes of emotion. Moreover, the evidence from brain-damaged patients suggests the hypothesis that emotion-related processes are required for skills and knowledge to be transferred from the structured school environment to real-world decision-making, because they provide an emotional rudder to guide judgment and action. Taken together, the evidence we present sketches an account of the neurobiological underpinnings of morality, creativity and culture, all topics of critical importance to education. Our hope is that a better understanding of the neurobiological relationships between these constructs will provide a new basis for innovation in the design of learning environments.

Recent advances in the neuroscience of emotions are highlighting connections between cognitive and emotional functions that have the potential to revolutionize our understanding of learning in the context of schools. In particular, connections between decision-making, social functioning and moral reasoning hold new promise for breakthroughs in understanding the role of emotion in decision-making, the relationship between learning and emotion, how culture shapes learning, and ultimately the development of morality and human ethics. These are all topics of eminent importance to educators as they work to prepare skilled, informed, and ethical students who can navigate the world's social, moral, and cognitive challenges as citizens. In this article, we sketch a biological and evolutionary account of the relationship between emotion and rational thought, with the purpose of highlighting new connections between emotional, cognitive, and social functioning, and presenting a framework that we hope will inspire further work on the critical role of emotion in education.

Modern biology reveals humans to be fundamentally emotional and social creatures. And yet, those in the field of education often fail to consider that the high-level cognitive skills taught in schools, including reasoning, decision-making, and processes related to language, reading and mathematics, do not function as rational, disembodied systems, somehow influenced by but detached from emotion and the body. Instead, these crowning evolutionary achievements are grounded in a long history of emotional functions, themselves deeply grounded in humble homeostatic beginnings. Any competent teacher recognizes that emotions and feelings affect students' performance and learning, as does the state of the body, such as how well students have slept and eaten, or whether they are feeling sick or well. We contend, however, that the relationship between

learning, emotion, and body state runs much deeper than many educators realize, and is interwoven with the notion of learning itself. It is not that emotions rule our cognition, nor that rational thought does not exist. It is, rather, that the original purpose for which our brains evolved was to manage our physiology, to optimize our survival, and to allow us to flourish. When one considers that this purpose inherently involves monitoring and altering the state of the body and mind in increasingly complex ways, one can appreciate that emotions, which play out in the body and mind, are profoundly intertwined with thought. And after all, this should not be surprising. Complex brains could not have evolved separately from the organisms they were meant to regulate.

But there is another layer to the problem of surviving and flourishing, which probably evolved as a specialized aspect of the relationship between emotion and learning. As brains and the minds they support became more complex, the problem became not only that of dealing with one's own self, but that of managing social interactions and relationships. The evolution of human societies has produced an amazingly complex social and cultural context, and flourishing within this context means that only our most trivial, routine decisions and actions, and perhaps not even these, occur outside of our socially and culturally constructed reality. Why does a high school student solve a math problem, for example? The reasons range from the intrinsic reward of having found the solution, to getting a good grade, to avoiding punishment, to helping tutor a friend, to getting into a good college, to pleasing her parents or the teacher. All of these reasons have a powerful emotional component, and relate both to pleasurable sensations, and to survival within our culture. Although the notion of surviving and flourishing is interpreted in a cultural and social framework at this late stage in evolution,

our brains still bear evidence of their original purpose: to manage our bodies and minds in the service of living, and living happily, in the world with other people.

This realization has several important implications for research at the nexus of education and neuroscience. It points to new directions for understanding the interface of biology, learning, and culture, a critical topic in education that has proven difficult to investigate systematically (Davis, 2003; Rueda, 2006; Rueda, August, & Goldenberg, 2006). It promises to shed light on the elusive link between body and mind, for it describes how the health and sickness of the brain and body can influence each other. And, importantly, it underscores our fundamentally social nature, making clear that the very neurobiological systems that support our social interactions and relationships are recruited for the often covert and private decision-making that underlies much of our thought. In brief, learning, in the complex sense in which it happens in schools or the real world, is not a rational or disembodied process; neither is it a lonely one.

Reasoning, decision-making and emotion: Evidence from patients with brain damage

To understand why this is so, we begin with some history, and a problem. Well into the 1980's, the study of brain systems underlying behavior and cognition was heavily dominated by a top-down approach in which the processes of learning, language, and reasoning were understood as high-order systems that imposed themselves upon an obedient body. It is not that emotions were completely ignored, or that they were not viewed by some as having a brain basis. Rather, their critical role in governing behavior, and in particular rational thought, was overlooked (Damasio, 1994). Emotions were like a toddler in a china shop, interfering with the orderly rows of stemware on the shelves.

And then an interesting problem emerged. In a research atmosphere in which cognition ruled supreme, it became apparent that the irrational behavior of neurological patients who had sustained lesions to a particular sector of the frontal lobe could not be adequately accounted for by invoking cognitive mechanisms alone. After sustaining damage to the ventromedial prefrontal cortex (VMPF), these patients' social behavior was compromised, making them oblivious to the consequences of their actions, insensitive to others' emotions, and unable to learn from their mistakes. In some instances, these patients violated social convention and even ethical rules, failing to show embarrassment when it was due, and failing to provide appropriate sympathetic support to those who expected it and had received it in the past.

These patients' ability to make advantageous decisions became compromised in ways that it had not been before. In fact, there was a complete separation between the period that anteceded the onset of the lesion, when these patients had been upstanding, reliable and foresightful citizens, and the period thereafter, when they would make decisions that were often disadvantageous to themselves and their families. They would not perform adequately in their jobs, in spite of having the required skills; they would make poor business deals in spite of knowing the risks involved; they would lose their savings and choose the wrong partners in all sorts of relationships. Why would patients suffering from compromised social conduct also make poor decisions about apparently rational matters, such as business investments?

The traditional way to explain these patients' symptoms had been that something had gone wrong with their logical abilities or their knowledge base, such that they could no longer make decisions in a rational way. But, in fact, with further testing, it became

apparent that these patients did not have a primary problem with knowledge, knowledge access, or logical reasoning, as had previously been assumed. To the contrary, they could explain cogently the conventional social and logical rules that ought to guide one's behavior and future planning. They had no loss of knowledge or lowering of IQ in the traditional sense. Instead, it gradually became clear that disturbances in the realm of emotion, which had been viewed as a secondary consequence of their brain damage, could provide a better account of their poor decision-making. Those emotional aspects included a diminished resonance of emotional reactions generally as well as a specific compromise of social emotions, such as compassion, embarrassment and guilt. By compromising the possibility of evoking emotions associated with certain past situations, decision options and outcomes, the patients became unable to select the most appropriate response based on their past experience. Their logic and knowledge could be intact, but they failed to use past emotional knowledge to guide the reasoning process. Furthermore, they could no longer learn from the emotional repercussions of their decisions or respond emotionally to the reactions of their social partners. Their reasoning was flawed because the emotions and social considerations that underlie good reasoning were compromised (Damasio, Tranel, & Damasio, 1990; Damasio, Tranel, & Damasio, 1991; Hanna Damasio, Grabowski, Frank, Galaburda, & Damasio, 1994).

In retrospect, these patients provided a first glimpse into the fundamental role of emotion in reasoning and decision-making. Missing a brain region that is now understood as needed to trigger a cascade of neurological and somatic events that together comprise a social emotion, such as embarrassment, compassion, envy or admiration, their social behavior suffered. This is significant in itself, but even more intriguing was the

realization that without the ability to adequately access the guiding intuitions that accrue through emotional learning and social feedback, decision-making and rational thought became compromised, as did learning from their mistakes and successes. While these patients can reason logically and ethically about standard cognitive and social problems in a laboratory setting (Saver & Damasio, 1991), out in the real world and in real time, they cannot use emotional information to decide between alternative courses of action. They can no longer adequately consider previous rewards and punishments, successes and failures, nor do they notice others' praise or disapproval. These patients have lost their ability to analyze events for their emotional consequences, and to tag memories of these events accordingly. Their emotions are dissociated from their rational thought, resulting in compromised reason, decision-making and learning.

What does this mean for our argument about relevance to education? In addition to these patients, further evidence from psychophysiological and other studies of brain damaged and normal people has allowed us to propose specific neural mechanisms underlying the role and operation of emotional signaling in normal and abnormal decision-making (Bechara, 2005; Bechara & Damasio, 1997; Damasio, 1996). While the details of these neural mechanisms and evidence are beyond the scope of this article, taken as a whole, they show that emotions are not just messy toddlers in a china shop, running around breaking and obscuring delicate cognitive glassware. Instead, they are more like the shelves underlying the glassware; without them cognition has less support.

To recap, the prefrontal patients we have described have social deficits. We have argued that these are fundamentally problems of emotion, and therefore manifest as well in the realm of decision-making. The relationship between these symptoms is very

informative, in that it suggests that hidden emotional processes underlie our apparently rational real-world decision-making and learning. Furthermore, this relationship underscores the importance of the ability to perceive and incorporate social feedback in learning.

While the relevance of these insights to educational contexts has not yet been empirically tested, they lead us to formulate two important hypotheses. First, because these findings underscore the critical role of emotion in bringing previously acquired knowledge to inform real-world decision-making in social contexts, they suggest the intriguing possibility that emotional processes are required for the skills and knowledge acquired in school to transfer to novel situations and to real life. That is, emotion may play a vital role in helping children decide when and how to apply what they have learned in school to the rest of their lives. Second, the close ties between these patients' decision-making, emotion, and social functioning may provide a new take on the relationship between biology and culture. Specifically, it may be via an emotional route that the social influences of culture come to shape learning, thought, and behavior.

While more work on the educational and cultural implications of these findings is warranted, interestingly, and sadly, some further insights into the biological connections between learning, emotion, and social functioning, especially as they relate to our hypothesis about culture, can be gleaned from another group of patients that has been discovered over the past few years. In this group, patients sustained comparable prefrontal damage in early childhood, rather than as adults. As they developed, these children were cognitively normal in the traditional IQ sense, able to use logical reasoning and factual knowledge to solve the kinds of academic problems expected of students.

However, while smart in the everyday sense of the word, these children slowly revealed themselves to have varying degrees of psychopathic and antisocial tendencies. They were insensitive to punishment and reward, and did not seek approval or social acceptance as typical children do. As adults, they are unable to competently manage their lives, wasting time and squandering resources, and engaging in dangerous, antisocial and aggressive behaviors. By outward appearances, these patients behave in most ways similarly to the patients described above, who sustained prefrontal damage as adults (Anderson, Bechara, Damasio, Tranel, & Damasio, 1999; Damasio, 2005).

Additional investigation of adult patients with childhood onset of brain damage, though, revealed an intriguing difference between childhood and adult-onset prefrontal brain damage. While both groups can reason about traditional cognitive problems in the structure of the laboratory setting and both have normal IQ's in the traditional sense, unlike patients with adult onset prefrontal damage, childhood onset patients appear never to have learned the rules that govern social and moral behavior. While adult-onset patients know right from wrong in the lab but are unable to use this information to guide their behavior, childhood-onset patients have apparently not learned right from wrong or the proper rules of social conduct. They do not know the social and ethical rules that they are breaking.

What is happening with these patients, and how is it relevant to the argument at hand? Unlike the often remarkable compensation for linguistic and other capacities after early childhood brain damage, so far the system for social conduct and ethical behavior does not show this kind of compensation. It is not that access in an abstract sense to the rules of social conduct requires intact frontal cortices, as the adult-onset patients show,

and it is not that a social or moral conduct center in the brain has been irreparably damaged, as this scenario would not explain changes in general decision-making. Instead, the situation is both simpler and more grave. These early-onset prefrontal patients may be suffering from the loss of what we might term the “emotional rudder.” Without the ability to manipulate situations and to mark those situations as positive or negative from an affective point of view, these children fail to learn normal social behavior. In turn, they lose the commensurate decision-making abilities described earlier. Insensitive to others’ responses to their actions, these children fail to respond to educators’ and others’ attempts to teach them normal behavior.

But there is another intriguing piece to be learned from these children regarding the relationship between cognition and emotion, and the role of the “emotional rudder” in learning. As in the adult-onset patients, it is still possible for these patients to have an operating cognitive system that allows them to be smart on certain measures and in certain contexts, solving standard cognitive tasks in a laboratory or structured educational setting without difficulty. In these contexts, their lack of knowledge is confined to the social and moral domains.

And yet, once outside of the structured school setting, their social deficits manifest as a much broader problem. They have the non-social knowledge they need, but without the guiding effects of the emotional rudder, they cannot use this information to guide their everyday living, even in non-social contexts. What these patients confirm is that the very neurobiological systems that support emotional functioning in social interactions also support decision-making generally. Without adequate access to social and cultural knowledge, these children cannot use their knowledge efficaciously. As

Vygotsky posited more than three quarters of a century ago, social and cultural functioning actually does underlie much of our non-social decision-making and reasoning. Or, more precisely, social behavior turns out to be a special case of decision-making, and morality to be a special case of social behavior (see Damasio (2005) for a more complete treatment of this argument). The neurological systems that support decision-making generally are the same systems that support social and moral behavior. Without adequate access to emotional, social, and moral feedback, in effect the important elements of culture, learning cannot inform real-world functioning as effectively.

A physiological and evolutionary account of emotion and cognition: From automatic responses to morality, creativity, high reason and culture.

In the perspective of the insights described earlier, and of much research in neurobiology and general biology in the two intervening decades, the connection between emotion and cognition is being seen in a very different light. To outline the current position, we shall present a simple scenario. Think of an ant crawling along a sidewalk, carrying a piece of food back to its nest. The ant scurries into a sidewalk crack to avoid being stepped on, then continues industriously on its way. What motivates this ant to preserve its own life? How did it decide, albeit non-consciously and automatically, to carry the piece of food, and to turn toward its nest? Clearly, the decisions to hide to avoid being crushed, to carry the food, and to continue in the direction of the nest are primitive instances of cognition, composed of complex packages of innate responses that enable the ant to react advantageously to particular classes of situations. But what is essential to understand is that these and myriads of other primitive examples of cognition, even in the

lowly ant, act together in the service of an emotional goal: to maintain and promote homeostasis and thus fitness. In short, the ant behaves the way it does because those behaviors promote its survival and efficiency. (Humans, as conscious beings, perceive that efficiency as well being and pleasure.) Every action the ant takes is inherently biased toward helping the ant, or its group, do well.

Taking an evolutionary perspective, even the simplest unicellular organism has within the nucleus of its cell a master controller that permits that living organism to maintain itself for a certain span of life and to seek during that period the conditions that will allow it to thrive. Emotions and the mechanisms that constitute them as behaviors, which humans experience as resulting in punishment or reward, pain or pleasure, are, in essence, nature's answer to one central problem, that of surviving and flourishing in an ambivalent world. Put simply, the brain has evolved under numerous pressures and oppressions precisely to cope with the problem of reading the body's condition and responding accordingly, and begins doing so via the machinery of emotion. This coping shows up in simple ways in simple organisms, and in remarkably rich ways as brains get more complex. In the brains of higher animals and in people, the richness is such that they can perceive the world through sensory processing, and control their behavior in a way that includes what is traditionally called the mind. Out of the basic need to survive and flourish derives a way of dealing with thoughts, with ideas, and eventually with making plans, using imagination, and creating. At their core, all of these complex and artful human behaviors, the sorts of behaviors fostered in education, are carried out in the service of managing life within a culture, and as such employ emotional strategies (Damasio, 1999).

Emotion, then, is a basic form of decision-making, a repertoire of know-how and actions that allows people to respond appropriately in different situations. The more advanced cognition becomes, the more high-level reasoning supports the customization of these responses, both in thought and in action. With evolution and development, the specifications of conditions to which people respond, and the modes of response at their disposal, become increasingly nuanced. The more people develop and educate themselves, the more they refine their behavioral and cognitive options. In fact, one could argue that the chief purpose of education is to cultivate children's building repertoires of cognitive and behavioral strategies and options, helping them to recognize the complexity of situations and to respond in increasingly flexible, sophisticated, and creative ways. In our view, out of these processes of recognizing and responding, the very processes that form the interface between cognition and emotion, emerge the origins of creativity-- the artistic, scientific, and technological innovations that are unique to our species. Further, out of these same kinds of processing emerges a special kind of human innovation: the social creativity that we call morality and ethical thought.

As the childhood-onset prefrontal patients show, morality and ethical decision-making are special cases of social and emotional functioning. While the beginnings of altruism, compassion and other notions of social equity exist in simpler forms in the non-human primates (Damasio, 2003; Hauser, 2006), human cognitive and emotional abilities far outpace those of the other animals. Our collective accomplishments range from the elevating and awe-inspiring to the evil and grotesque. Human ethics and morality are direct evidence that we are able to move beyond the opportunistic ambivalence of nature; indeed, the hallmark of ethical action is the inhibition of immediately advantageous or

profitable solutions in the favor of what is good or right within our cultural frame of reference. In this way, ethical decision-making represents a pinnacle cognitive and emotional achievement of humans. At its best, ethical decision-making weaves together emotion, high reasoning, creativity, and social functioning, all in a cultural context (Gardner, Csikszentmihaly, & Damon, 2001).

Returning to the example of the ant: our purpose in including this example was not to suggest that human emotions are equivalent to those of the ant, or that human behavior can be reduced to simple, non-specific packages that unfold purely non-consciously in response to particular situations. Although some aspects of human behavior and emotion could be characterized in this way, such reductionism would be grossly misplaced, especially in an essay about connections to education. Instead we aimed to illustrate that most, if not all, human decisions, behaviors, thoughts and creations, no matter how far removed from survival in the homeostatic sense, bear the shadow of their emotive start.

In addition, as the prefrontal patients show, the processes of recognizing and responding to complex situations, which we suggest hold the origins of creativity, are fundamentally emotional and social. As such, they are shaped by and evaluated within a cultural context and, as we described in the previous section, are based upon emotional processing. No matter how complex and esoteric they become, our repertoire of behavioral and cognitive options continues to exist in the service of emotional goals. Neurobiologically and evolutionarily speaking, creativity is a means to survive and flourish in a social and cultural context, a statement that appears to apply from the relatively banal circumstances of daily living to the complex arena of ethical thought and

behavior. In beginning to elucidate the neurobiological interdependencies between high reasoning, ethics, and creativity, all of which are fundamentally tied to emotion and critically relevant to education, we hope to provide a new vantage point from which to investigate the development and nurturance of these processes in schools.

Toward an evidence-based framework

In general, cognition and emotion are regarded as two interrelated aspects of human functioning. However, while it is perfectly reasonable and in fact necessary to distinguish between these two aspects in studying learning and development (Fischer & Bidell, 1998), the overly stringent preservation of this dichotomy may actually obscure the fact that emotions are comprised of cognitive as well as sensory processes.

Furthermore, the aspects of cognition that are recruited most heavily in education, including learning, attention, memory, decision-making, motivation and social functioning, are both profoundly affected by emotion and in fact subsumed within the processes of emotion. Emotions entail the perception of an emotionally competent trigger, a situation either real or imagined that has the power to induce an emotion, as well as a chain of physiological events that will enable changes in both the body and mind (Damasio, 1994). These changes in the mind-- involving focusing of attention, calling up of relevant memories, learning the associations between events and their outcomes, among other things-- are the processes with which education is most concerned. Yes, rational thought and logical reasoning do exist, although hardly ever truly devoid of emotion, but they cannot be recruited appropriately and usefully in the

real world without emotion. Emotions help to direct our reasoning into the sector of knowledge that is relevant to the current situation or problem.

In Figure 1 we provide a graphical depiction of the neurological relationship between cognition and emotion. In the diagram, we have used the term “emotional thought” to refer to the large overlap between cognition and emotion. Emotional thought encompasses processes of learning, memory, and decision-making, in both social and non-social contexts. It is within the domain of emotional thought that creativity plays out, through increasingly nuanced recognition of complex dilemmas and situations, and through the invention of correspondingly flexible and innovative responses. Both the recognition and response aspects of creativity can be informed by rational thought and high reason. In our model, recognition and response processes are much like the concepts of assimilation and accommodation proposed by Piaget (1952; 1954). However, Piaget focused almost exclusively on cognition and the development of logic, and although he recognized a role for emotion in child development (Piaget, 1981), did not fully appreciate the fundamentally emotional nature of the processes he described.

In the diagram, high reason and rational thought also contribute to high-level social and moral emotions, to form the specialized branch of decision-making that is ethics. Motivated reasoning works in a similar manner, and refers to the process by which emotional thoughts gain additional significance through the application of rational evidence and knowledge. In the other direction, rational evidence can be imposed upon certain kinds of emotional thought to produce the sort of automatic moral decision-making that underlies intuitive notions of good and evil (Greene, Nystrom, Engell, Darley, & Cohen, 2004; Greene, Sommerville, Nystrom, Darley, & Cohen, 2001; Haidt,

2001). For example, in evaluating the morality of incest, experimental evidence suggests that people decide quickly at the subconscious and intuitive level, and later impose ad hoc rational evidence on their decision (Haidt, 2001). Conversely, complex moral dilemmas such as whether to send a nation to war are (one hopes) informed by an abundance of rational evidence.

On the left side of the diagram, the bodily aspects of emotion are represented as a loop from emotional thought to the body and back. Here, emotional thoughts, either conscious or non-conscious, can alter the state of the body in characteristic ways, such as by tensing or relaxing the skeletal muscles or by changing the heart rate. In turn, the bodily sensations of these changes, either actual or simulated, contribute either consciously or non-consciously to feelings, which can then influence thought. (Simulated body sensation refers to the fact that sometimes imagining bodily changes is sufficient; actually tensing the fists, for example, is not necessary.) This is the route by which rational deliberations over, say, a nation's wartime decisions can produce high-level social emotions such as indignation, as well as the bodily manifestations of these emotions, such as tensed fists, increased heart rate, or loss of appetite. The feeling of these bodily sensations, either consciously or not, can then bias cognitive processes such as attention and memory toward, in this case, aggression. The end result may be an unprovoked argument with one's friend over a topic totally unrelated to the war, the creation of a bleak and angry abstract painting, or a generally tense mood.

In addition to the evidence discussed above, support for these relationships between the body, emotion and cognition comes mainly from neurobiological and psychophysiological research, in which the induction of emotion, either directly by a

stimulus in the environment or indirectly via thoughts or memories, causes mental changes as well as physiological effects on the body. In turn, feelings of emotion rely on the somatosensory systems of the brain. That is, the brain areas associated with interoception (the sensing of body states) are particularly active as people feel emotions such as happiness, fear, anger or sadness (Damasio et al., 2000).

To conclude, in presenting this model, our goal is not to devalue established notions of cognition and emotion, but to provide a biologically based account of this relationship, and to begin to specify the nature of the overlap between cognition and emotion in a way that highlights processes relevant to education. These processes include learning, memory, decision-making and creativity, as well as high reason and rational thinking. They also include the influence of the mind on the body, and of the body on the mind.

Educational implications: A call for further research.

In teaching children, the focus is often on the logical reasoning skills and factual knowledge that are the most direct indicators of educational success. But there are two problems with this approach. First, neither learning nor recall happen in a purely rational domain, divorced from emotion, even though some of our knowledge will eventually distill into a moderately rational, unemotional form. Second, in teaching students to minimize the emotional aspects of their academic curriculum and function as much as possible in the rational domain, educators may be encouraging students to develop the sorts of knowledge that inherently do not transfer well to real-world situations. As both the early and late-acquired prefrontal damage patients show, knowledge and reasoning

divorced from emotional implications and learning lacks meaning and motivation, and is of little use in the real world. Simply having the knowledge does not imply that a student will be able to use it advantageously outside of school.

As recent advances in the neurobiology of emotions reveal, in the real world, cognition functions in the service of life-regulating goals, implemented by emotional machinery. Moreover, people's thoughts and feelings are evaluated within a socio-cultural context, and serve to help them survive and flourish in a social, rather than simply opportunistic, world. While the idea that learning happens in a cultural context is far from new (Tomasello, Carpenter, Call, Behne, & Moll, 2005), we hope that these new insights from neurobiology, which shed light on the nested relationships between emotion, cognition, decision-making, and social functioning, will provide a jumping off point for new thinking on the role of emotion in education. As educators have long known, it is simply not enough for students to master knowledge and logical reasoning skills in the traditional academic sense. They must be able to choose among and recruit these skills and knowledge usefully outside of the structured context of a school or laboratory. Because these choices are grounded in emotion and emotional thought, the physiology of emotion and its consequent process of feeling have enormous repercussions for the way we learn and for the way we consolidate and access knowledge. The better educators come to understand the nature of the relationship between emotion and cognition, the better they may be able to leverage this relationship in the design of learning environments.

In conclusion, new neurobiological evidence regarding the fundamental role of emotion in cognition holds the potential for important innovations in the science of

learning and the practice of teaching. As researchers struggle with new directions and techniques for learning about these connections, a biological framework may help to constrain possibilities and generate new hypotheses and research directions. Just as neuroscience is coming to inform other education-related topics and problems (Goswami, 2006), the study of emotions, creativity and culture is ripe for interdisciplinary collaborations among neuroscientists, psychologists and educators. After all, we humans cannot divorce ourselves from our biology, nor can we ignore the high-level socio-cultural and cognitive forces that make us special within the animal kingdom. When educators fail to appreciate the importance of students' emotions, they fail to appreciate a critical force in students' learning. One could argue, in fact, that they fail to appreciate the very reason that students learn at all.

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REFERENCES

- Anderson, S. W., Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1999). Impairment of social and moral behavior related to early damage in human prefrontal cortex. *Nature Neuroscience*, 2(11), 1032-1037.
- Bechara, A. (2005). Decision making, impulse control and loss of willpower to resist drugs: A neurocognitive perspective. *Nature Neuroscience*, 8(11), 1458-1463.
- Bechara, A., & Damasio, H. (1997). Deciding advantageously before knowing the advantageous strategy. *Science*, 275(5304), 1293-1295.
- Damasio, A. R. (1999). *The feeling of what happens*. New York: Harcourt Brace.
- Damasio, A. R. (2003). *Looking for Spinoza: Joy, sorrow and the feeling brain*. Orlando: Harcourt.
- Damasio, A. R. (1994). *Descartes' error: Emotion, reason and the human brain*. New York: Avon Books.

- Damasio, A. R. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex. *Transactions of the Royal Society (London)*, 351, 1413-1420.
- Damasio, A. R. (2005). The neurobiological grounding of human values. In J. P. Changeux, A. R. Damasio, W. Singer & Y. Christen (Eds.), *Neurobiology of Human Values*. London: Springer Verlag.
- Damasio, A. R., Grabowski, T. J., Bechara, A., Damasio, H., Ponto, L. L. B., Parvizi, J., et al. (2000). Subcortical and cortical brain activity during the feeling of self-generated emotions. *Nature Neuroscience*, 3(10), 1049-1056.
- Damasio, A. R., Tranel, D., & Damasio, H. (1990). Individuals with sociopathic behavior caused by frontal damage fail to respond autonomically to social stimuli. *Behavioral Brain Research*, 41, 81-94.
- Damasio, A. R., Tranel, D., & Damasio, H. (1991). Somatic markers and the guidance of behavior: Theory and preliminary testing. In H.S. Levin, H.M. Eisenberg & A. L. Benton (Eds.), *Frontal Lobe Function and Dysfunction* (pp. 217-229). New York, NY: Oxford University Press.
- Damasio, H. (2005). Disorders of social conduct following damage to prefrontal cortices. In J. P. Changeux, A. R. Damasio, W. Singer & Y. Christen (Eds.), *Neurobiology of Human Values*. London: Springer Verlag.
- Damasio, H., Grabowski, T., Frank, R., Galaburda, A. M., & Damasio, A. R. (1994). The Return of Phineas Gage: Clues about the brain from the skull of a famous patient. *Science*, 264(5162), 1102-1105.
- Davis, H. A. (2003). Conceptualizing the role and influence of student-teacher relationships on children's social and cognitive development. *Educational Psychologist*, 38(4), 207-234.
- Fischer, K. W., & Bidell, T. R. (1998). Dynamic development of psychological structures in action and thought. In R. M. Lerner (Ed.), *Handbook of Child Psychology: Theoretical Models of Human Development*. (5th ed., Vol. 1, pp. 467-561). New York: Wiley.
- Gardner, H., Csikszentmihaly, M., & Damon, W. (2001). *Good Work: When Excellence and Ethics Meet*. New York, NY: Basic Books.
- Goswami, U. (2006). Neuroscience and education: From research to practice? *Nature Reviews Neuroscience*, 7(5), 406-411.
- Greene, J. D., Nystrom, L. E., Engell, A. D., Darley, J. M., & Cohen, J. D. (2004). The neural bases of cognitive conflict and control in moral judgment. *Neuron*, 44(2), 389-400.
- Greene, J. D., Sommerville, R. B., Nystrom, L. E., Darley, J. M., & Cohen, J. D. (2001). An fMRI investigation of emotional engagement in moral judgment. *Science*, 293(5537), 2105-2108.
- Haidt, J. (2001). The emotional dog and its rational tail: A social intuitionist approach to moral judgment. *Psychological Review*, 108(4), 814-834.
- Hauser, M. (2006). *Moral minds: How nature designed our universal sense of right and wrong*. New York, NY: Harper Collins.
- Piaget, J. (1952). *The origins of intelligence in children* (M. Cook, Trans.). New York: International Universities Press. (Originally published, 1936).
- Piaget, J. (1954). *The construction of reality in the child* (M. Cook, Trans.). New York: Basic Books. (Originally published, 1937).

- Piaget, J. (1981). *Intelligence and affectivity: Their relationship during child development*. (T. A. Brown & C. E. Kaegi, Eds./Trans.). Palo Alto, CA: Annual Reviews Monograph. (Originally presented as lectures, 1953-1954).
- Rueda, R. (2006). Motivational and cognitive aspects of culturally accommodated instruction: The case of reading comprehension. In D. M. McInerney, M. Dowson & S. V. Etten (Eds.), *Effective schools: Vol. 6: Research on sociocultural influences on motivation and learning* (pp. 135-158). Greenwich, Connecticut: Information Age Publishing.
- Rueda, R., August, D., & Goldenberg, C. (2006). The sociocultural context in which children acquire literacy. In D. August & T. Shanahan (Eds.), *Developing literacy in second-language learners: Report of the National Literacy Panel on language-minority children and youth*. (pp. 319-340). Mahwah, NJ: Lawrence Erlbaum Associates.
- Saver, J. L., & Damasio, A. R. (1991). Preserved access and processing of social knowledge in a patient with acquired sociopathy due to ventromedial frontal damage. *Neuropsychologia*, 29, 1241-1249.
- Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing of intentions: The origins of cultural cognition. *Behavioral and Brain Sciences*, 28, 675-735.