

How Recent Brain Research Can Inform the Design of Online Learning

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Abstract

Is it possible that recent research into the brain can open the “black box” of student thinking? This review of recent findings from brain researchers can help online educators design better learning experiences for students.

Introduction

Why is it that so many educators are fascinated by recent brain research? What are we looking for? Are we simply looking for answers about what is really going on in student's heads or do we want to find ways to improve our chances that those heads have what we want in them? This is not a facetious question, but a fundamental question about why the brain is so interesting, and especially fascinating to the leagues of educators who are looking for a way into their students' heads or a way to get evidence that the learning required by accreditors and legislators is really in there. For example, the Association for Supervision and Curriculum Development (ASCD), a national organization for the study of effective teaching and learning, has 11 books translating the findings of brain researchers into new techniques and approaches for K-12 educators and college teachers. The brain is seen as a key to unlocking the mysteries of student learning, to shine some light on mysterious processes and help the teacher shine a light into student's educational lives.

Why might brain research be a focus for online educators? We have the same hopes as other educators: to be more effective with more students and to make sure our programs are delivering the kinds of educational experiences that will affect student learning. We want to make sure what we do is derived from the best information about what goes on in student's heads and that it is not based on an adulation of how things have been done in the past. In other words, we want to improve, and we hope that this research on the brain is the key to making the small or wide-ranging improvements that are transformational for students as well as for our view of ourselves as wise professionals of online education.

This article will build on Meyer (2003), and will incorporate new findings from brain researchers and suggest some new ways that this research may be applied to online learning. The 1990s may have been designated as the "Decade of the Brain" by then-President George H. W. Bush, but the research continues and will likely continue to enlighten us about the workings of our students' gray matter. The laboratories of the brain researchers may seem to be in a different world from the online educator. And yet, the two worlds could quickly collide and fuse to make a richer and better learning experience for online learners.

The sections that follow will review research on several topics and relate each to the practice of designing online learning. We will review how brains and culture collaborate to form a brain and how our drive for meaning and a changing environment makes us “prediction machines” and develops a sense of personal self. Next we will take up how the brain’s plasticity is good news for all learners, how emotions and social connections shape the brain, and how our will, attention, and quantum mechanics work to bring about learning and a brain that changes as we learn. The topics covered include:

- Brains and culture;
- Sense-making and the sense of “I;”
- Plasticity and aging;
- Emotions, beliefs, and symbols;
- Need for social connections;
- Role of will and attention;
- Quantum mechanics and nonlocality; and
- The mind is not the brain.

Exploring each topic in turn will help build a picture of how the brain is formed and changed, and how we can effect such change through our own efforts. It culminates in a better understanding of how students can increase their comprehension of how they think and how this affects their lives as well as their brains. Each topic will generate several suggestions for the design of online learning experiences, which may help improve the effectiveness of online courses. A final table presents concrete ideas for using the implications from this brain research in online course design.

Brains and Culture

How are brains formed? Do we as youngsters arrive with our brains fully intact or are they bundles of potential, a *tabula rasa*, or do our genes dictate the twists and capabilities of our brains? This is normally characterized as the nature vs. nurture debate, but Quartz and

Sejnowski (2002) conclude that neither – or both -- is true. Nature and nurture do not compete; they collaborate. And this collaboration acts through the experiences we have to alter the brain.

Thus, our environments, cultures, and educational practices change the brain in a “neural constructivism” (p. 50) that may provide two important insights for online educators. First, if indeed our brains are constructed by interacting with the world, this may provide some modest support for why constructivist learning has a powerful influence on student learning. It also may explain the power and popularity of online learning that capitalizes on activities designed in the constructivist manner. Second, it may also mean that our online environments are as influential in shaping brains as any other part of human culture, and care and caution ought to be taken to ensure our online educational experiences are appropriately designed and allow students to learn important lessons. In other words, our online world may be more powerful than we even expected.

Design Tips

- Design for constructivist learning activities, including real-world projects and complex problem-solving
- Design online experiences that help students learn important lessons.

Sense-Making Machinery and a Sense of “I”

As a result of the brain-culture interaction, humans have a “pathological need for meaning and coherence” (Quartz and Sejnowski, 2002, p. 86) and a drive “to discover the predictive structure of the world” (p. 116). This explains why we construct models of our self and others: we need to make sense of the world. The key to success is unraveling the world of “roles, obligations, and expectations,” seeing into the future, and bringing a future that is desired into being (p. 139). In other words, as the brain improves its prediction of the culture that shapes it, a sense of personal identity is shaped, strengthened, and given complexity and depth.

But because the world changes and changes in uncertain but predictable ways, we are forced to learn from the past and make plausible (and possibly divergent) predictions about the future. “Brains are prediction machines that use information gathered from past experience to predict

future events important for survival” (Quartz and Sejnowski, 2002, p. 101). Changes in our environments therefore create and reinforce a brain that is built to handle, adjust to, understand, predict and propose changes. Obviously, this is true for educational environments as well; changes impact our brains just as our brains create further change. The brain-culture collaboration is complete.

There are four lessons for the online educator in this drive for meaning. First, learners arrive at any educational experience with a drive for meaning; every lesson ought to help them construct that meaning as they interact with the online environment and hypothesize potential predictions more accurately. This builds on learners’ basic needs and motivations. Second, the sense of self that is built by multiple interactions takes a long time to develop; it is not likely to take shape until somewhere in adolescence. This means that learning tasks that depend on the presence of a sense of self cannot occur prematurely, although there may be a role for online learning to help the developing adolescent explore and test that sense of self. Third, presenting changes to students helps them make more useful predictions about the world and learn to adjust to and create meaningful changes in their lives, jobs, and society. And lastly, given that the brain and culture continue to interact long after adolescence to influence the individual’s growing sense of the world and of self, the personality can be termed an “open program” (Quartz and Sejnowski, 2002, p. 130). Personality continues to be shaped by changing circumstances, relationships, and learning so that we can prepare for new roles and change our selves. This argues again for the power and importance of what online educators design and do, as it also indicates that students change as they interact with many parts of their lives, of which we are only one aspect.

Design Tips

- Design with the student’s innate drive for meaning in mind.
- Design recognizing that the sense of self emerges over time.
- Design opportunities for students to understand, adjust to, and handle changes in their environments.
- Design with the knowledge that what students do online can shape their personalities in ways that are not completely understood at this time.

Plasticity and Aging

There is growing evidence that the earlier belief that brains lose cells as we grow older was inaccurate. New neurons are born in adult brains (Quartz and Sejnowski, 2002; Schwartz and Begley, 2002), which is good news for adult students. This is called “neural plasticity,” and it puts to rest the canard that older persons cannot learn new tricks. The factors that are most closely aligned with the growth of new neurons are stimulation, novelty, close relationships, a positive attitude, and exercise (Quartz and Sejnowski, 2002, pp. 242-250). Special kudos are given to constructive learning throughout life or, if we can use a tired term, lifelong learning (but clearly this is not learning that is a regurgitation of facts, but the construction of knowledge through experience and challenge). In a study looking at brain cells, the dendrites in 80-year-old brains versus 50-year-old brains “were a full 35 percent more complex: their total length was greater, as was their number of branches” (p. 240). This is excellent news for online education, since adults comprise a large portion of the current market for well-designed and stimulating online coursework, especially in professional fields. Online education could not only prevent mental decline and be a lifesaver for older persons, but it means that older adults and retirees may be an important market not yet tapped by online educators. In fact, there may not be a student we should think of as “too old.”

Design Tips

- Design for the older student population.
- Design challenge, stimulation, and change into online learning environments.

Emotions, Beliefs, and Symbols

Emotions are important to learning, since a “good mood energizes some people to seek out new worlds and to boldly go where no one has gone before” (Quartz and Sejnowski, 2002, p. 100). And despite its nod to Star Trek, this realization is important: good emotions allow learners to seek out new and possibly uncomfortable learning situations and to risk themselves in a learning task. Fear disables and closes the student off from what might have been a good learning experience. And yet this is not a complete picture. Feelings of all kinds help us predict what might happen if certain actions are taken: they are the “essence of making decisions that affect our life: weighing different options, imagining different worlds, and choosing action” (p. 120).

Feelings help us learn from mistakes, which certainly elevate the importance of such negative feelings of remorse and guilt, and even fear.

Beliefs are more complex. Beliefs about what is good and rewarding are dependent upon the meaning and value the student's group has given them. They are constructed, but not always reliably. In other words, some beliefs are helpful and others not; some may support learning and find value in learning and others may denigrate learning or prevent us from learning from our mistakes (such as, blaming problems or errors on others). Therefore, developing helpful beliefs is important to the young as well as older student. And yet it is the belief that the world can be known that propels a learner into experiences from which understanding can be garnered and sense be made.

Writing and other cultural symbols are "ways of using the world to hold ideas" so that a society may have the capacity for "systematic thinking that would be impossible otherwise" (Quartz and Sejnowski, 2002, p. 234). This is one way the brain externalizes into culture as a way to modify itself and open itself to change and new learnings. Ideas are constructed and thrust onto symbols that reflect back to the young what has been believed by the old. And yet symbols also change, words evolve into new meanings, and symbolic learning must be done and redone and revised year after year. In other words, our brains are built to create and be created by emotions, beliefs, and symbols.

There are three powerful messages for the online educator in such knowledge. First, learning is not solely an intellectual endeavor; it requires and depends upon emotions. The whole student can and should be involved in their learning, and online courses should be designed to touch the individual's emotions and intellect. Second, instilling appropriate beliefs may be the parents' primary responsibility for the child, but the online educator should probably create opportunities for the student to develop and reinforce positive beliefs about learning, the learner, and the knowability of the world. Third, online course designers need to understand the importance of symbols, and especially symbolic learning. Symbols and words do not simply carry meaning, they are meaningful. The essence of learning is not only to understand symbols and words, but to use them to make oneself understood. And yet these tools of learning are in constant flux and

being changed by the students themselves. That makes keeping online materials up-to-date essential, lest the designer of online coursework use a term that was innocent in her day but carries a far different meaning for today's youngster.

Design Tips

- Design to touch the student's emotions as well as his/her intellect.
- Design opportunities for the student to form positive attitudes toward learning and themselves as a learner.
- Design with symbols and to help students understand the meaning of symbols.
- Design using current meanings of symbols, and keep online sites up-to-date.

The Need for Social Connections

The brain depends upon first parents and then family to provide it with the culture, rules, and qualities it needs to form. This early dependence on others may have also created a brain that requires social connections for health and growth. This recipe for brain development also contributes to developing an ability to trust in the young. In fact, such a brain drives us to seek the company of others. Given this early experience, it is no surprise that face-to-face communication substantially increases levels of cooperation. Indeed, no other variable appears to have as consistent and strong an effect . . . when players are allowed to communicate through computer terminals by passing messages, the levels of cooperation are far below those of the same game played face-to-face communication (Quartz and Sejnowski, 2002, p. 158).

If cooperation and trust are the outcomes of having some face-to-face communication, then it is important for online educators to try to provide some ways that this can be accomplished, either through providing some face-to-face meeting time by requiring travel to a central location, streaming video, or static pictures of the students and instructor. These are not impossible to do at reasonable cost. And yet, the importance placed on face-to-face interactions may be somewhat misplaced: most students have many relationships other than those online, including family, friends, colleagues at a job, and contacts in the community. Perhaps the one worry that is

legitimate for those of us offering online education is to watch for the isolated individual who is dependent on the online environment for the majority of their social contacts.

Design Tips

- Design opportunities for students to see the instructor and other students.
- Design to involve all students.

The Role of Will and Attention

Knowledge about the brain's plasticity is good news for us all. Neuroplasticity captures the ability of "neurons to forge new connections, to blaze new paths through the cortex, even to assume new roles . . . [it] means rewiring the brain" (Schwartz and Begley, 2002, p. 15). The next question is, however, how does the brain become reformatted, if a computer term is appropriate?

Research by Schwartz (2002) on individuals with obsessive-compulsive disorder (OCD) provides a clue. OCD patients were given a process to follow whenever an obsessive thought occurred to them; the four-step method involved relabelling the thought as a symptom of a disease, reattributing the thought to a brain malfunction, refocusing on a constructive behavior, revaluing the thought as having no value or power over them. In trials, patients were able to distance themselves from these thoughts and change their behavior. Subsequent testing found that their brain circuitry had changed as a result of the four-step work: new paths had been forged and the earlier, dysfunctional one weakened. This argues for the important role of volition and will on the part of the patient, and by corollary, the student. What is attended to tends to strengthen, and the decision to attend is a choice – an act of will – that the individual makes.

Attention is important because it "magnifies, stabilizes, clarifies, and otherwise makes predominant one thought out of many" (Schwartz and Begley, 2002, p. 325). Attention makes clear the relationship between ourselves and our thoughts, some of which arise unbidden and unwanted. We are not all of our thoughts, but we can choose which thoughts we attend to. The will works through attention to select what is to be attended to (and what is not) and what is

focused on (or not). And attention exerts a physical effect on the brain. In fact, brain research finds that when one is focused on vision, that portion of the brain activates. It also reduces the activity in regions of the brain responsible for other senses. In addition, attention may be important for helping new connections take hold in the brain by repeatedly firing a set of synapses so that they become stronger.

The topic of willpower may sound too arcane to the modern youngster, as it ignores the entire field of social conditioning and the victim mythology so popular in today's thinking. But there is evidence from our own brains that we do have free will to choose how to respond to our own thoughts and external triggers. "Free will serves as the gatekeeper for thoughts bubbling up from the brain" (Schwartz and Begley, 2002, p. 308), as William James (1983) also hypothesized. We can change our thinking by altering and strengthening new neural paths in our brains.

Overall, this is a hopeful message to all learners. It doesn't minimize the difficulties of making the choice to attend to one task and not another one, nor does it simplify the process of exercising one's will on behalf of learning. It does say that effort can and does make a difference, and it makes a difference by changing the patterns and connections in the brain. There may be ways good designers of online learning experiences can help students practice how to make different choices, develop their will for learning, and provide the rewards that make learning worth pursuing and worth the effort.

Design Tips

- Design opportunities for students to learn and practice attention.
- Design ways for students to exercise a will to learn, and reward that effort.

Quantum Mechanics and Nonlocality

Why is attention and will so efficacious? What might explain how a choice changes the brain? Schwartz and Begley (2002) think there is an answer in the theory of quantum mechanics, and especially its principle of nonlocality.

The physical science is intriguing: Sir John Eccles proposed in 1986 that the probability that neurotransmitters operate to cross a synapse and transmit their contents to a nearby neuron depended on quantum mechanics, which, he added, depended on an act of will. In other words, probabilities exist in the abstract until the will acts and collapses the probabilities into one act. This is also known as the Heisenberg Principle, where the observer chooses what will become real by his or her choice of what to observe. This is a world that comes into being as we gain knowledge of it, as a result of a choice that we have made; it is not far to propose that we create the world with our questions, our choices, and acts of will. This is no longer a theory of physical reality, say Schwartz and Begley (2002), but a theory about knowledge. Knowledge in the quantum view is tentative and provisional, shifting as a result of new choices and new questions.

A further development from the quantum science world also has implications for learning. In an experiment, a pair of electrons separated by a distance would, after one electron had its spin changed, change the spin of the second electron. They coordinated their spins, as if they could communicate over impossible distances. John Bell in 1987 proposed that the universe was nonlocal, or in other words, the world is closely interconnected in some fashion. “The universe must be arranged so that what one freely decides to do *here* must in certain cases influence instantaneously what is true *there* – and *there* is as far away as one would like, from the other side of the laboratory to the other side of the galaxy” (Schwartz and Begley, 2002, p.347). Einstein called this “spooky action at a distance” (p. 348).

This sounds fantastical, but at root it may be the same mechanism that attention plays on the brain. The choice of what to observe in one place affects what we call reality in another place. What is non-physical affects what is physical and thus, the mind and world are not as separate as we might like to believe. The mind – through attention, will, and choice – can and does impact the brain and change its configuration, but it also alters the world.

This may seem far away from the world of online learning. And yet we can and should recognize that students and their choices affect what we do as instructors and designers of online courses, and that our choices affect them. Quantum science seems to imply that knowledge is the result of our preconceptions, our beliefs, our attention and choices. And knowledge is

tentative, always changing, and open for further work. In other words, it requires additional and continuous learning. This thought may be very uncomfortable to some students who wish things to be stable and permanent and known, but perhaps this may be another useful design goal for online learning: to shake up and wake up, fire new synapses into action, and change brains rather than stuff them full with facts and figures. And nonlocality may be a useful explanation for why online learning can be effective even though an instructor and student are separated by miles and time zones, and why an online class can gel into a community of learners despite hurdles of time and space.

Design Tips

- Design courses to be an active, joint production of students and faculty.
- Design to startle students and question their knowledge with new learning opportunities that defy norms and expectations.

The Mind Is Not the Brain

How then can we understand the mind and brain? It is clear that they are not the same, and that the mind cannot be reduced to mere brain activities. We know the mind – through choice, attention, and will – can affect the brain and that the mind can work nonlocally on the brain through the same mechanisms. Philosophers can shed some light on this relationship: “Leibniz, Berkeley, Hume, Kant, Mach, and James contended that matter is but a uniquely objective and substantial form of mind” (Schwartz and Begley, 2002, p.35).

If matter is but mind taken shape and density, then mind chooses who we will be in the immediate moment and these choices affect both physical form and the self that is expressed in our thoughts and actions. This is no longer a New Age piece of philosophy, but an assertion that is finding support among brain researchers and physicists alike. Our efforts at introspection, thought, and consciousness not only “redraw the contours of the mind . . . [they] can rewire the circuits of the brain” (Schwartz and Begley, 2002, p. 330). This is no small argument for practicing mindfulness (as Buddhists describe it), or meditation (as many sects propose), or prayer (as in Western traditions). It is, however, an important argument for taking our thoughts

and choices very seriously. It is an argument for helping young people learn to choose how to use their attention and will to create a mind that will help them shape a life that is worth living.

Online educators can give students of whatever age practice and proof of this relationship by experiencing change in themselves as they have changed their minds. This is the ultimate in opening the “black box” of student thinking which instigated research into the brain. Learning need not be solely directed toward achieving standards established by the state, but it can contribute to the student’s understanding of his or her mind and brain and how the individual can affect both. Online learning can support these objectives, not just by sharing this information with students, but by helping them experience it and learn how they construct knowledge and why knowledge varies from person to person. It can help them understand and detach from their own thoughts, practice attention, and see the efficacy of will and choice. It can help students become mindful, not only in the Buddhist sense of the word of being detached and attending to the mind, but mindful in the sense of being thoughtful, aware, and cognizant of themselves and the world (let alone the connections between the two, courtesy of their own brains).

Design Tips

- Design opportunities for students to discover how their thinking affects them and provide examples of when their thinking (and selves) changed.
- Design opportunities for students to reflect on their thinking, how it changes, and what changes it.

Conclusions

Online educators need to monitor the findings of brain researchers, and seek ways to make students’ online learning experiences support and augment what we know about brain development and change. While brain research is ongoing, its implications could transform what we do and help make online education a transformative experience for students. In the interim, online educators may want to consider designing research studies that clarify how and to what extent online learning is either affecting brain development or changing brain patterns. A second important area of research will be focused on determining whether online learning is successful

in helping students develop will, attention, and a better comprehension of the efficacy of their own thinking.

These may be revolutionary ideas: to use online learning in ways that support the brain's ongoing development, change its functioning, and teach students to use their attention and will to change their own brains. It may be revolutionary to help students understand their minds and their thinking and how these affect them. But then again, perhaps online education is meant to be the kind of education that is fundamentally revolutionary.

Suggestions for the Online Teacher or Course Designer

Brain Research Area	Learning Experience Implications
Brain and Culture	<ul style="list-style-type: none"> • Assign real-world projects to students • Develop rich, complex problems for students to solve • Design case studies that can elucidate important lessons • Have students identify their own projects or problems to work on
Sense Making Machinery and a Sense of “I”	<ul style="list-style-type: none"> • Capitalize on students’ need to understand and predict • Encourage students to predict the next course component, skill, or task • Ask students to reflect on past events to help predict current or future trends • Help students identify when predictions have been wrong and understand why • Help students reflect on their sense of self, how it has changed over time, how it might change in the future • Identify times, situations, environments when a personality trait or characteristic changed
Plasticity and Aging	<ul style="list-style-type: none"> • Stimulate and challenge all students • Change course environments regularly • Provide opportunities to learn on topics that are of interest to older adults
Emotions, Beliefs, and Symbols	<ul style="list-style-type: none"> • Encourage positive emotions during learning and try to limit situations that students fear • Support and use emotions to solidify learning or to learn from mistakes • Develop beliefs in students that learning has value • Help students identify beliefs that are not supportive of learning (e.g., blame) • Identify meanings and emotions behind symbols • Identify how symbols change • Clarify how students use symbols to make themselves understood

Need for Social Connections	<ul style="list-style-type: none"> • Provide a space in the online environment for photos of instructors and students • Provide opportunities for students to chat or discuss personal or social issues that are related (or unrelated) to course topics • Ensure the involvement of all enrolled students
Role of Will and Attention	<ul style="list-style-type: none"> • Ask students to describe their thinking • Have students practice choosing to attend to different thoughts, and note the effects of doing so • Provide opportunities for students to make intelligent choices and provide rewards as well
Quantum Mechanics & Nonlocality	<ul style="list-style-type: none"> • Help students reflect on how knowledge is constructed and changed • Startle students with new insights into old knowledge • Challenge norms and expectations
Mind Is Not the Brain	<ul style="list-style-type: none"> • Encourage introspection and reflection • Help students understand what “mindfulness” is and how it affects them • Ask students to explain their thinking and how their mind works • Ask them to describe when or how their thinking changed

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