The Teenage Brain and Technology

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ABSTRACT

The teenage brain is experiencing amazing transformations which set into motion unprecedented academic and emotional growth. As the brain is changing, technology works as a powerful influencer, sculpting and molding the mind. Computer-based instruction, in particular, is impacting the teenage brain as a motivator, tutor, and prolific source of information. Research synthesized from the fields of neuroscience, education, psychology, and technology inform and strengthen pedagogy for teaching secondary students.

Introduction

Technology plays an ever-growing and significant role in our education system; it is embedded into every subject area, at every grade level. The Internet, Smart Boards, computer games, and cell phones reinforce basic skills, promote higher order thinking, and encourage students' motivation. In fact, their use is so pervasive, that it is reported that ninety percent of students in grades six to 12 use computers on a regular basis (Genevalogic Report, 2007). This has changed the way teachers teach and the way students learn. The impact is empiric; the average intelligence of each generation is rising, not only as measured by I.Q. tests, but also by observed behaviors. Researchers speculate that the reason for this advancement is the new technologies embedded in our lives (Sternberg, 1997).

The purpose of this review is to examine technology in the classroom and consider how it interfaces with the processes occurring in the teenage brain. Three questions guide the review, first, what is happening in the teenage brain? Second, how is technology impacting the changes occurring in the teenage brain? Third, which technology-based instructional strategies are compatible with the teenage brain? Practical ideas for teachers are infused.

As a professor and researcher of adolescent development I have authored a number of books on the teenage brain, along with conducting research in public middle schools, adolescent correctional facilities, and secondary schools in developing countries on a Fulbright Scholarship. My ever-present interest in the teenage brain and the plethora of new technology emerging in the classroom piqued my interest and was the impetus for this review.

Prior to delving into the topic, a common understanding of technology terms enhances communication and avoids confusion. E-learning encompasses all forms of electronic teaching and learning, including computer tutorials, simulations, virtual labs, and the Internet (Tavangarian, Leypold, Nölting, & Röser, 2004). Computer-based instruction is more specific and refers to lessons in which computers are the primary method of teaching (Encyclopedia Britannica, 2011). Finally, social networking is associated with relationships and communication fostered through strategies such as websites, discussion forums, and chat rooms.

Teachers are now given the added challenge of being experts in the field of technology, along with their discipline (Anderson, 2004). The wide-ranging use of e-learning tools compels educators to pause and examine their use in relation to the developing teenage brain.

The Teenage Brain

Adolescents are experiencing extensive brain transformations as they move toward cognitive, emotional, and social adulthood. As a result, they are particularly susceptible to outside forces found in the environments of school, home, and recreation. Each new experience interacts and sculpts the brain they will take into adulthood. Of the many external sources interfacing with the teenage brain, technology is prevalent and potent (Galimberti, Bednare, Donato, & Caroni, 2006).

An influential process occurring in the teenage brain involves dendritic branching and synaptic connections. Dendrites are hair-like structures that emerge from neurons when new information is learned; one neuron has between 1,000 and

10,000 dendrites receiving information from other neurons. Each neuron has only one axon which then sends information between neurons. Together, dendrites from one neuron and the axon from another communicate with each other, generating a synaptic connection. Synapses are electrical connections between neurons that aid in information transmission. The production of dendrites and synaptic connections represent knowledge acquisition (Giedd et al., 2009; Paus, Keshavan, & Giedd, 2008). Interestingly, an over-production of dendrites and synaptic connections occur during the teenage years, which creates a unique opportunity for secondary students to learn (Giedd et al., 2009; Paus et al., 2008).

Research indicates there is a relationship between learning and quantity of neural connections. The educational implication is that students who learn a great deal in a subject area grow more neural connections in response. Conversely, neglect of an area inhibits neural connections. For instance, students who dedicate themselves to playing the piano have more neural connections in that module of the brain than those not musically inclined (Le Be & Markram, 2006; Paus et al., 2008). This effect constitutes a strong argument for time on task equating to achievement (Cotton & Wikelund, 1990). However, there is an important caveat to consider: it is the quality of time on task, not simply the time on task that makes the difference in how the brain develops (Evans & Bechtel, 1997).

This period of overproduction of dendrites and synaptic connections in the teenage brain is followed by pruning: a process that operates on the "use it or lose it" principle. Pruning eliminates unnecessary and unused dendrites and synaptic connections. Information that is not recurrently used is subject to elimination. Due to pruning the brain forgets an acquaintance's name or an insignificant date. However, information frequently used, such as a close friend's name and birth date, is deemed important and preserved. The purpose of pruning is to allow trivial data to wither and die, thereby aiding in functional proficiency. The teenage brain experiences extensive pruning, refining and sharpening its capabilities (Paus et al., 2008).

Finally, there is a significant escalation in myelin production, an insulating sheath that coats axons which increase the teenage brain's speed and efficiency. This process occurs developmentally with the frontal lobes in the final phases. Hence, abstract thought, associated with the frontal lobes, only begins to develop during the young teenage years (Drury & Giedd, 2009). As myelination spreads throughout the adolescent brain, an increase in working memory and an ease and competence with learning is experienced. The teenager is developing an adult brain (Giedd, 2010).

Plasticity is a fascinating attribute of the brain; it is the brain's ability to change throughout the lifespan, be it the infant, adult, or teenager. Plasticity involves the brain creating new connections and discarding unimportant ones. In this venture the environment, along with genetics and the behavior of the individual, allow the brain to reorganize neural pathways with new information and experiences. Plasticity has served the human race well as it progressed from agrarianism, to the industrial revolution, into the information age. In each era the brain learned and adapted to new skills in order to meet the environment's ever-changing needs (Costandi, 2010). The brain's ability to reinvent and mold itself is of particular significance during the teenage years. As discussed, the adolescent brain is experiencing unparalleled change, which results in a brain exceptionally receptive to the environment (Giedd et al., 2009).

Another important discovery regarding the teenage brain involves the emotional part of the brain, the amygdala. The teenage brain, still a work in progress, relies on the amygdala to process feelings. This is in contrast to the adult brain which has developed and learned to rely on the frontal lobes, associated with higher order thinking. Consequently, adults are able to make reflective decisions, logically analyze information, and temper the irrational amygdala. The teenage brain, on the other hand, is only beginning the transition from dependence on the amygdala to the frontal lobes. This explains their emotional reactions, misunderstandings, and struggles with abstract thought. Teachers can expect to see a dramatic difference in emotional control between a 14-year-old and an 18-year-old student due to their progress in brain maturation (Killgore & Yurgelun-Todd, 2007).

The evidence from neuroscience is indisputable: the teenage brain is a brain in transition. Clearly, these changes are heavily dependent upon experiences, in which the medium of technology plays an integral part. However, as we learn more about technology and the brain, it is important for educators to keep in mind that instructional technology is dependent upon good teaching pedagogy and content knowledge, the cornerstones of academic achievement (Anderson, 2004).

Computer-Based Instruction

The Internet

The younger generation fearlessly surfs the Internet, browses social networks, downloads tutorials, and scrolls through PDFs in pursuit of its education. The

Internet, in particular, increases the information available in the classroom. It allows students immediate access to research, fast facts, and experts from around the world. No longer must students travel to a library to thumb through paper documents, instead, instantaneous and unprecedented access to a plethora of resources is provided by the Internet (Green & O'Brien, 2002). This amazing accessibility equates to usability; in other words, learning is facilitated by sheer availability. This potentially opens the door for dendritic branching and synaptic connections. As each bit of information is learned the human brain grows and rewires (Hastings, Tanapat, & Gould, 2000).

Neuroscientists confirm the Internet's positive impact on the brain. Individuals who regularly use the Internet have twice the activity in their frontal lobes as those who rarely use the Web. This means the frontal lobes, associated with application, analysis, synthesis, and evaluation, are performing higher order thinking skills (Takahashi et al., 2007). Additionally, surfing the Internet engages multiple areas of the brain, a sign of complex work being done. In fact, searching and learning on the Internet demands more complex work from the brain than reading a book, which was historically the gold standard. Internet use also increases the brain's ability to store and retrieve memories, adjust and change to new information, and improve motor dexterity—all skills valued in the real world (Small, 2008).

Not all the news is good relating to the Internet: neuroscientists have concerns about the reflexive demands of technology. The Internet and computer games are designed for, and compel, perpetual change. This results in snap decision making and multitasking. It is speculated that today's students have fine-tuned these skills to the point of fostering a reduced attention span. This is a significant finding regarding the learning process. If the ability to pay attention is deficient, learning is jeopardized (Cantor, 2009).

It has also been suggested that the younger generation's dependence on the Internet has weakened its social skills. The older generation learned to read facial expressions and body language as a result of face-to-face interactions. The younger generation, nurtured on technology, chooses an artificial means of interaction in social networking. This brings forth concerns that computer use may stunt their social development (Carr, 2010).

Tutorials

E-learning in the classroom is not limited to the Internet; in fact, well-designed computer tutorials represent educational practice at its best. When quality instructional planning is in place, practice is provided, feedback is immediate, and self-pacing is innate. These instructional components are compatible with the teenage brain, and academically support their developmental needs; however, it is important to note that computer tutorials often focus on basic skills (Pitler, Hubbell, Kuhn, & Malenoski, 2007).

Practice has long been identified as an instructional strategy that improves learning (Marzano, Pickering, & Pollack, 2004). Interestingly, longitudinal studies and meta-analysis show that computer tutorials are particularly effective in delivering practice that increases student achievement on standardized tests (Sivin-Kachala & Bialo, 2000). This aligns with what we know about the human brain. When actions are repeated through practice, synaptic connections are preserved and strengthened in the brain, facilitating mastery learning (Salimpoor, Chang, & Vinod, 2010). For instance, mathematics facts that are practiced to the point of automaticity are easily retrieved, allowing the brain to expend energy on higher-level mathematics skills.

Computer tutorials also allow students to progress at their own rate and level, receiving immediate feedback as they work, supporting a student-centered environment (Inan, Lowther, Ross, & Stahl, 2010). Feedback is essential to the brain. When students are told an answer is incorrect, the associated dendrite and synaptic connections begin to wither, while feedback on correct information is strengthened. Additionally, as students receive positive feedback, an indication that learning has occurred, they advance to more difficult material in the tutorial. This structures an ideal curriculum that challenges, but does not frustrate students (Luo & O'Leary, 2005; Marzano et al., 2004).

Games

Highly interactive and goal-oriented computer games are a popular instructional tool in classrooms (Rieber, 2005). In one study by Clark and Ernst (2010), over 90% of the teachers and students advocated using computer games for instruction. The reason for the enthusiastic reaction can be found in dopamine. The neurotransmitter, dopamine, is released in significant amounts during gaming, providing feelings of satisfaction and joy. This prompts student motivation and plays a critical role in the learning process (Koepp et al., 1998).

However, when it comes to academic achievement the reviews are mixed. One of the best-known studies to highlight a concern involved a comparison between Nintendo games and basic paper/pencil mathematics. Counterintuitively, the basic mathematics stimulated more areas of the brain than the gaming did. The academic implication is that the gaming was disturbingly uncomplicated and undemanding of the brain (Kawashima, 2001). Other research concurred, finding that academic achievement did not increase with gaming, even though satisfaction and motivation grew (Kinzie & Joseph, 2008). However, these results are not conclusive, counter findings were found in research done with high school students studying science. Students' science achievement increased when they engaged in academic gaming as opposed to paper and pencil activities (Papastergiou, 2009).

These findings are of particular significance to secondary teachers as many teenagers spend hours gaming on a daily basis, bringing forth the question of how much is too much gaming? Preliminary research by neuroscientists suggests an addictive power in computer games; they ominously resemble addictions to drugs and alcohol. Compulsive game players are much more aroused by the game cues than occasional players. The game becomes a cue to the addictive activity, resulting in excessive amounts of dopamine being released, and finally a craving for the game develops (Duven, Müller, & Wölfling, 2011). Neuroscientists believe the adolescent brain is particularly vulnerable to addictions due to the substantial transformations occurring in their brain (Giedd, 2004). The educational implication for teachers is to be cognizant of appropriate and inappropriate duration of academic gaming in course assignments.

Another issue regarding computer games is the quick responses required for success. Fast-paced decision making promotes impulsivity, a behavior that exists during the game and for a significant time afterward. The reason behind impulsivity is that continued play tends to over-engage the amygdala, the emotional part of the brain, and put the frontal lobes to sleep, creating an unhealthy brain balance. Consequently, the adolescent becomes less able to make reflective, well thought-out decisions. Instead, snap decisions, short attention spans, and high emotion are the behaviors of choice (Mathews et al., 2006).

While violent video games are not allowed in schools, they are played in some homes, indirectly impacting schoolwork. Testosterone levels increase with gaming, agitating the amygdala and increasing the likelihood of explosive outbursts. Research has found that this type of gaming desensitizes players and intensifies aggressive behavior for a significant time after the game has been discontinued (Oxford, Ponzi, & Geary, 2010). Serious concerns surround violent video games, deserving of serious adult control.

Graphic Organizers

Expanding e-learning's potential is the new "normal" in the classroom. Broadening the scope of computers to include complex tasks, problem solving, and decision making activates the frontal lobes, prompting analysis, synthesis, and evaluation, higher order thinking skills (Klopfer, Osterweil, Groff, & Haas, 2009). Computer-based strategies, in the form of simulations, e-labs, and graphic organizers, that challenge, encourage exploration, and provide variety, are capable of meeting these academic demands (Rice, 2007).

Of the various modes of e-learning, graphic organizers are especially adept at promoting higher level thinking skills through compelling visuals (Jonassen, 2002). Educationists found that the visual support of information provided by graphic organizers assist students in scaffolding learning, using logical reasoning skills, and applying knowledge (Inspiration, 2003). Neuroscientists conducted fMRI's showing there was increased activity in the brain and retention of information when graphic organizers were part of the learning process (Coates, 2008; Jonassen, Beissner, & Yacci, 1993; Stevensold & Wilson, 1990). Evidently, the collaboration between the eyes and brain is unique. Perhaps this is because the retina is a piece of the brain that grew into the eye. These two organs work together to depict three-dimensional images that gain the brain's attention and focus (Koch et al., 2006).

Transfer

Transfer, the ability to learn a skill in one area and use it in another context, is basic to the purpose of education. The lion's share of research on this topic has been in the area of gaming and the findings point to computer games being limited in scope when it comes to transfer. While gaming skills improve with play, those skills do not extend into the real world. However, one study by Jaeggi, Buschkuehl, Jonides, and Perrig (2008) defies the findings of the majority. These researchers investigated gaming in terms of short-term working memory and fluid memory, which is the ability to solve original problems where previous learning has not occurred. They found that the more an individual played a game, the greater his or her short-term working memory and fluid memory.

The research of Jaeggi et al. offers hope to educators that a skill learned on the computer will transfer into real-world activities. Continued study of technology's impact on transfer is worthy of neuroscience research and the results are worthy of continued awareness by educators.

Cooperative Learning Groups

We know through educational research that cooperative learning groups meet both the academic and social needs of students (Marzano et al., 2004). Research from neuroscience adds to these findings, informing us that positive social interactions, such as that found in group work, release oxytocin. This hormone assists in bonding and social recall, elevating our ability to connect with others and reduce stress (Heinrichs & Domes, 2008). E-learning assignments that require students to create wikis, webquests, and Google Write are brain-compatible cooperative learning tools.

Cooperative learning groups also act as a protective factor against loneliness. Individuals who are lonely suffer with more stress, higher blood pressure, and lower immune systems. Additionally, the caudate nucleas, an area of the brain associated with rewards, is not as active in lonely people. This translates into feelings of dissatisfaction and unhappiness (Cacioppo, 2009). Educators have limited influence on student friendships; but assigning group work is in the realm of classroom assignments. This strategy builds social interaction and is an antidote to feeling alone.

Learning Through Observation

Mirror neurons are a set of complex neurons that have a unique function in video games. These neurons fire with observation. In other words, mirror neurons fire in the individual observing the action, as well as neurons firing in the brain of the individual doing the action. For instance, if a person watches someone smoke a cigarette, they take a puff in their brain. This enables our brain to smile when we see a winning race or cry when someone is hurt; empathy in action (Iacoboni, 2008).

Mirror neurons mimic positive and negative characteristics and actions. Research has only begun on this subject, but scientists are finding that playing computer games that simulate caring of others influence teenagers to be more thoughtful in real life (Gentile et al., 2009). Unfortunately, compelling research also shows that adolescents, regardless of level of natural aggression, are impacted by violent video games. The more they play the game the greater the tendency to imitate the violent actions in the real world. In fact, mirror neurons make it hard for the brain to resist actions, good or bad, because they work at a subconscious level, reducing the individual's control (Iacoboni, 2008).

Mirror neurons shed an important light on learning through observation. When selecting games and other e-learning tools for the classroom it is important for teachers to consider the hidden and secondary observed curriculum, as well as the intended curriculum.

Motivation

Adolescents' passion for e-learning is palpable as they hyper-focus attempting to win, achieve, and enjoy. Researchers found that task and persistence increased for students with each correct answer, along with their levels of satisfaction. Amazingly, this time and persistence continues once they leave the schoolhouse doors, into homework time (Becta, 2004; Kinzie & Joseph, 2008). No wonder educators are eager to harness this positive energy; motivation often makes the difference between the student who struggles and the one who succeeds.

Dopamine plays a significant role in intrinsic motivation. Positive energy explodes onto the brain when dopamine is released, driving and inspiring behavior (Willis, 2011). Its affirming influence can be seen in studies done with rats. Scientists reinforced rats with dopamine every time they pressed a lever. The rats found the dopamine so addictive that they pressed the lever up to 2000 times, to the point of exhaustion, in order to receive a dopamine rush (Kalat, 2004). Similar desire and response to dopamine is seen in humans; it propels determination and accomplishment, creating feelings of euphoria and pleasure.

The trigger for a dopamine rush is receiving a reward, such as achieving an academic goal, winning a race, or kissing a mate. All create a natural high in the brain. This same pleasurable feeling is realized in computer-based instruction. When computer feedback indicates a correct prediction or answer, dopamine is released. Each jolt of dopamine triggers happiness and the craving for more in students, fueling the activity.

In this quest for dopamine a challenge is compulsory. In schools this means the content must become more rigorous as students progress—the status quo is never good enough. Once something is learned the amount of dopamine released becomes weaker and weaker with continued practice (Willis, 2011). Therefore, academics must increase in complexity to continue to be a motivating factor for students to continue the activity (Cohen et al., 2010).

Conclusion

The teenage brain experiences remarkable change as it transitions from childhood to adulthood. Quantity and quality of thinking improves due to an over-production of dendrites and synaptic connections, pruning, and myelination. Adolescents become capable of thinking abstractly, problem solving at complex levels, and applying rational and logical thought. Additionally, the analytical frontal lobes begin to control the emotional amygdala during the teen years. This assists teenagers in emotional control and improves their ability to make good decisions. Due to the streamlining and upgrade in the teenage brain, they are particularly vulnerable to environmental stimuli.

Academically, computer-based instruction, in the form of the Internet, tutorials, and other technology, is capable of increasing achievement and engaging students. Gaming and tutorials are particularly effective in providing practice and reinforcing basic skills; graphic organizers and the Internet are conducive for encouraging higher order thinking. The case for computer-based instruction is furthered strengthened by its effectiveness as a motivator. In fact, it is difficult to find another strategy that can compete as an academic motivator for teenagers. Students are drawn to e-learning and feel a comfortable affinity for this approach to learning.

However, computer-based instruction is not without limitations and drawbacks. Research suggests gaming addictions, reflexive responses, and reduced attention spans are aggravated with computer-based instruction. These findings are worrisome and compel educators to approach e-learning with caution and balance.

Technology is shaping the world we live in, and as a result our students' brains are rewiring and restructuring. Burgeoning findings on e-learning's impact on the teenage brain help inform instruction. Tutorials, gaming, and graphic organizers are all compatible with the teenage brain. However, while computer-based instruction provides the medium, it's important for educators to recognize that the instructional design ultimately determines the level of effectiveness (Pitler et al., 2007). Crafting effective computer-based instruction is dependent upon considering in combination the research on the teenage brain and instructional technology.

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