Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2009 Volume IV: How We Learn about the Brain

How the Brain Learns

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Introduction

As teachers, we strive each day to teach students and to enrich their lives with the delight of knowledge. No knowledge is more fundamental to creating a lifetime learner than beginning to understand neurological function and the actual process of learning. Over the course of four weeks, this unit will introduce high school students to the basic components of the brain, the process of learning, and variables and strategies that can increase or decrease learning success.

This unit is designed for instruction in a high school special education resource classroom. All of the students are mainstreamed into regular classrooms, but spend one period of their school day in the resource classroom for pre-teaching, reinforcement, and support on assignments from the regular curriculum. The students in my resource classroom are in all grades of high school, and similar to the regular education setting, the students span a range of abilities, though they all have an identified disability qualifying them for special education services.

Although the school district focuses on full inclusion of special education students in the regular classroom, many of the special education students need additional support to be successful. To be enrolled in a Resource Class, a student must have an active Individualized Education Program, and it must be determined by a pupil personnel team that the student is impacted by his or her disability in a way that requires additional instruction and support outside of the regular education classroom. Individualized learning goals and objectives are established to address each student's specific weaknesses. These goals are regularly monitored and progress reports are sent home to the parent quarterly. The Resource Course is intended to support regular education content and individual skill deficits through specialized instruction, accommodations, and pace.

The diagnosed disabilities of students in the classroom include learning disabilities, autism, speech/language disorders, attention deficit disorder, and emotional disorders. Many of my students have verbal weaknesses, auditory processing deficiencies, and read below grade level. Many of them also have working memory or long-term memory retrieval difficulties, which significantly impact their learning success. As a result, the instruction in this unit will be highly adapted for their specific learning needs--including lower reading level of materials, extended pacing for instruction, and accessing multiple intelligences. This unit is also written

specifically for the small number of students and low student-to-teacher ratio that are defining characteristics of a resource classroom.

The unit will begin by teaching students about the basic components and function of the brain--cerebrum/cortex: occipital, parietal, frontal, and temporal lobe; cerebellum, limbic system, and brainstem. Through activities such as coloring images, students will learn the locations and functions of each part of the brain. The coloring activity will be coupled by digital videos on the brain from United Streaming Discovery Education database, a human skull--so the students can understand where the brain sits within the skull. This portion of the unit will also include a trip to the anatomy lab at Yale Medical School, so that students can see an actual brain.

The second section of the unit will address how the brain learns and develops, including some information on disabilities. Many of my students are very frustrated and feel inadequate in the regular classroom. Having a better understanding of their brains and the biological differences between them and their peers will alleviate some of these feelings of inadequacy and help them become better self-advocates. This section of the unit is also designed to expose students to the different capacities of the brain. This will be explored through different videos of savants and incredible feats of memory.

The final aspect of the unit will examine different things people can do to affect brain function. Based on biology and brain function, students will learn strategies and techniques to facilitate learning and memory. Does nutrition and sleep play a part in brain function? How many times do you have to practice things before you learn them? In tandem with learning about how to improve brain function, the unit will explore how the brain's learning capacity be disrupted by things such as drugs, alcohol, or brain injury.

Unit Objectives

At the conclusion of this unit, resource students will be able to:

- Identify location and basic function of lobes in the brain (cerebrum/cortex: occipital, parietal, frontal, and temporal lobe; cerebellum, limbic system, and brainstem)
- Identify and explain several brain-based strategies for improving learning/retention
- Identify and explain activities that can disable the brain's ability to function

Students have very little exposure to any anatomy in the high school curriculum, except through the upper

level science elective "Anatomy & Physiology." Just as there are certain novels that are accepted into the literary canon, basic knowledge of the brain is assumed in newspaper articles, by doctors, and by teachers. This unit is designed to provide students with a working vocabulary and basic understanding of how their own minds work, so that they can be more successful.

This unit will reflect the goals of Special Education in that it will present material at the students' instructional level, while helping them prepare them for the immediate academic challenges of high school. All Connecticut students take the Connecticut Academic Performance Test in March of their sophomore year. Though special education students can receive accommodations, such as extended time and alternate setting, many special education students do not pass and must retake the tests during their junior year. Embedded within the unit are skill-building exercises from the core curriculum areas such as assessing lab reports, identifying the hypothesis, independent variable, and controls, interpreting graphic representations, creating graphs of data, and analysis, comprehension of non-fiction reading materials, and interdisciplinary writing.

Preparing for Transition: Real-World Skills and Self-Advocacy

In the realm of special education, once a student reaches the age of 15, planning begins for the transition from a supported high school environment into a post-school job, school, or training program. There have been recent shifts in special education policy which have re-emphasized the role of high school personnel in transitioning a student. Although not all students are headed into a university program, I work to create a classroom of life-long learners. While students will be striving towards different goals, they all need support in developing knowledge of their own learning and how their own behavior can affect that learning. Central to this unit is developing students' self-knowledge. How do they learn best? What can they do to remember instruction? What can they learn about themselves as learners so that they can be more successful? The second half of this unit will provide students with biologically and research-based methods to improve their learning.

Adaptations for the Regular Classroom

Although this unit is designed to function in a special education setting, much of the material can be easily adapted for used in the regular education classroom. Parts of this unit may be appropriate for a Biology or Anatomy and Physiology course. One of the lessons included is for a CAPT interdisciplinary writing practice, which could be taught in a Social Studies course. Suggestions for the regular education setting include: increased pace, more challenging texts, independent reading, and homework assignments.

Strategies

Digital Natives

Technology allows for unimaginable connections between people around the world, or within the same classroom. As Marc Prensky argues in his article, "Digital Natives, Digital Immigrants," "as a result of this ubiquitous environment and the sheer volume of their interaction with it, today's students think and process information fundamentally differently from their predecessors" (Prensky, 2001, p.1). Prensky believes that as teachers, we should adapt to this new "digital native" student and provide information in new media forms. This unit will employ digital texts, such as interactive Shockwave web programs and video clips to illustrate

brain functions and abnormalities and to allow students to connect to the information through different intelligences. Digital texts, video, and interactive technology also increase student engagement and access multiple intelligences (Gardner, 1993).

Data Team Process

Schools within New Haven are expected to employ the five-step data team process, with instructional units. The most essential component of this process is the use of pre- and post-tests. These tests should be nearly identical in structure and content so that they provide an accurate model of student knowledge growth and an indicator of topics that need re-teaching. This unit will utilize this process on the unit level--beginning with a pre-test and ending with a parallel summative assessment.

Daily Structure

Many of my students require numerous repetitions and a very slow pace in order to grasp new material. During the first part of the unit, when students are learning about the different parts of the brain, each day's lesson will have a warm-up activity that reviews the prior day's topic and an exit slip that review's the day's topic. Students will be given a graphic of a brain to label and space to explain the primary functions of each part of the brain. Simple graphics of the brain are easily available online to use for this exercise. These two informal assessments will be indicative of student learning and comprehension and will guide the pacing of the unit.

What is the Brain?

In order to activate and assess student prior knowledge, the first day of the unit is devoted to basic information and fun facts about the brain. After administering the pre-test, I will show a slideshow full of images of the brain and full of fun facts. The average human brain weighs about three pounds, which is the same as about a half-gallon of milk. The human brain is adult size by about age six. Although the brain is only about 2% of the body's weight, it uses 20% of the oxygen and blood flow. If brain cells do not get oxygen for 3 to 5 minutes, they begin to die. For this session, I will also bring in a human skull with a hinge so that students can visualize the brain fitting inside our heads.

This is also a great time to involve students with optical illusions that play on the brain's natural assumptions, such as MC Escher's work or after images. Hello Red Fox by Eric Carle (1998) is a children's book that involves contrast after-images. There are extensive video clips available online listed in the teacher resource section. Although all of these topics are not covered in depth in the unit, these explorations will engage students with the topic.

What is the Brain Made of?

Before specific learning strategies or skills can be introduced, the students must have some basic understanding of the parts of the brain. Instruction will only cover basic structures within the brain and their fundamental function. Elements covered include: cerebrum/cortex: occipital, parietal, frontal, and temporal lobe; cerebellum, limbic system, and brainstem. A digital slideshow and accompanying worksheet will be used in the instruction of each element of the brain. On the worksheet will be a lateral view of the brain, each element will have an assigned color and the student will color in and label all elements that they have learned thus far. This will reinforce the prior instruction, while also addressing multiple learning styles and a universal design for learning (Gardner, 1993).

There are also numerous digital resources for exploring basic neuroanatomy. Some recommended sites are included in the teacher resource section of this unit. Allow students time to explore these websites that include digital photos of actual brains, activities with the brain as a puzzle, comparative photos of animal brains, and psychological brain interactives.

Cerebrum/cortex

The folds of neural tissue associated with higher brain function such as thought and action. It's divided into four lobes: occipital, parietal, frontal, and temporal.

Occipital

The region at the back of each cerebral hemisphere that contains the centers of vision and reading ability (located at the back of the head).

Parietal

The middle lobe of each cerebral hemisphere between the frontal and occipital lobes; it contains important sensory centers (located at the upper rear of the head) and is important in spatial navigation.

Frontal Lobe

This lobe occupies the top, front regions of each of the cerebral hemispheres. It functions as the center for reasoning, emotions, judgment, and voluntary movement and is a center of active change during adolescence.

The most common story used to illustrate the role of the frontal lobe is the case of Phineas Gage (1823-1860). Gage, a railroad worker, was clearing rocks using explosives. While tamping down explosive powder, a spark ignited it, sending the tamping iron up through his left cheek, directed through his frontal lobe, and out the top of his skull, landing 30 yards from the site. Within six months of the accident, Phineas was able to lead a normal life. However, soon afterwards significant personality changes appeared. He started using profanity regularly, was disagreeable, obstinate, and changed his plans frequently. He seemed to have lost the social inhibitions controlled in the frontal cortex (Deakin Psychology Department, 2006).

Temporal Lobe

This region at the lower side of each cerebral hemisphere contains centers of hearing and memory (located at the sides of the head). The temporal lobe also houses the gustatory cortex, which is the center of the sense of taste. The hippocampus, located within the temporal lobe, is considered responsible for spatial memory and is famously enlarged in cab drivers, who must create and manipulate a mental map of a city (BBC News, 2000).

Like humans, elephants are large mammals with large brains and dependent offspring. With the largest brain of any land animal, weighing about nine to twelve pounds, the brain only makes up about 0.08 percent of an elephant's body mass. In comparison, a human brain weighs about three to four pounds and makes up on average about six percent of body mass (Holdrege, 2001). Interestingly, the elephant has an abnormally large temporal lobe. Although elephants do not compare to humans and apes in cognitive tests, they have shown significant abilities that have been linked with the temporal lobe. The larger temporal lobe allows elephants to distinguish and communicate with a variety of sounds. Distinguishing between different acoustic features, elephants can recognize about 100 different individual calls from 1-1.5 kilometers away ((Hart B.L., Hart L.A.,

& Pinter-Wollman, N., 2008). Research has also shown that elephants also have extraordinary long-term spatial memories, regularly travelling hundreds of kilometers to find waterholes (Hart B.L., Hart L.A., & Pinter-Wollman, N., 2008).

Another illustrative example of the function of the temporal lobe is the case of Clive Wearing. Formerly a renowned musician, due to herpes encephalitis, Wearing is left with a memory span of only a few seconds. In addition, nearly all of his past memory was erased, except for some ability with music and his recognition of his wife. As a result, he experiences nearly every moment as his first awakening. In keeping a journal, he writes "I am awake for the first time," every few minutes (Sacks, 2007, p. 1). The BBC and other television shows have captured his tragic and poignant story in numerous video clips available online. Showing students some of these clips will illustrate the importance of a functioning memory system in the temporal lobe.

Cerebellum

This part of the brain lies below the back of the cerebrum and just above the brainstem. It regulates balance, posture, movement, and muscle coordination. Damage to the cerebellum can lead to loss of coordination of movement, the inability to judge distances, a staggering wide walk, and slurred speech.

Limbic System

It includes the hypothalamus, the hippocampus, and the amygdala. It is primarily responsible for our emotional life, pleasure sensation, and the formation of long-term memories. The hypothalamus controls thirst, hunger, body temperature, and sleep cycles. An abnormally large amygdala has also been linked to autism and joint attention--the ability to process faces and emotions (Dellorto, 2009).

Brainstem

The lower extension of the brain where it connects to the spinal cord. The brainstem is responsible for basic survival functions, like breathing, digestions, heart rate, and blood pressure, as well as conveying information between the brain and the body

How Does it Work?

Now that students have some understanding of each part of the brain, they can begin to understand how it works. When a child is born, they have about the same number of nerve cells as their adult brain. During development, these neural cells grow in size and form more complex connections. Glial cells are made in large number in infancy and to some extent throughout life. The average brain cell has 1000 synapses, or connections with other cells, though if connections are not regularly used, they may be eliminated.

Connections are formed through dendritic spines, which appear as branches on a stain of a brain cell. Research on rats has shown that an enriched environment during development will significantly increase dendritic spines throughout the brain (Johansson & Belichenko, 2002). Prior research by Volkmar and Greenough (1973) and Kolb (1995) confirms that healthy rats, raised in an enriched environment increases not only the number of dendritic spines, but also increases dendritic branching and the number of synapses. Dendritic spines and synapses are the basis of communication within our central nervous system. As these increase, so too does the potential for connections and learning within the brain. These studies have larger implications on the type of environment young children should be raised in to optimize their cognition.

The basis of memory, and thus learning, relies on something called Long Term Potentiation (LTP) (Kimball,

2006). Neurons in the brain are separated by small gaps called synapses. To communicate stimuli, neurotransmitters are released, travel through the synapse and are received by receptors in another neuron. As the exposure of a synapse increases, so does the response to the stimulus. The axon-receiving cell is also stimulated to create more receptor cells. Simply put, the more frequently a stimulus is initiated the stronger the connection. Extended, this principle explains how practiced and reinforced information is more easily recalled.

Researchers have found that the hippocampus, part of the brain's limbic system and located within the temporal lobe, is critical to long-term potentiation. The hippocampus is the part of the brain where new neurons are produced through life. New neurons are particularly sensitive to LTP and thus to learning (Kimball, 2006).

One of the activities embedded in this unit is designed to explore the brain's reaction function, but also to support the science and math curriculum, as well as Connecticut Academic Performance Test (CAPT) preparation. In order to better understand how the brain functions, over several days students will complete a mini-lab exploring the effect of cognitive requirements on the reaction time of students. Students will first begin a lab report for the activity, identifying the independent and dependent variables, hypothesis, problem statement, and procedure. Using a computer lab or computers in the room and an internet application (http://serendip.brynmawr.edu/bb/reaction/reaction.html), students will take turns measuring their reaction times in four situations of increasing complexity: act, think-act, read-think-act, read-think-negate act. Students will do five trials for each case, and then using their summary data, will create a graph of their summary data. The class will then aggregate their data and create another graph. Using that data, they will complete the remaining portions of their lab reports and discuss the validity of the experiment.

Students have widely varying abilities and pre-knowledge in the areas of lab reports and graphing. Some of my students are able to define terms such as independent variable, but have difficulty identifying it within a situation. Others cannot define the term or identify it without guided support. Similarly when creating graphs, each student is at a different level. An appropriate expectation for one of my autistic students would be to simply place data points and connect them on an otherwise completed graph, while one of my students with Attention Deficit Disorder needs only prompting about the required element of a graph. This is a perfect area to differentiate for each student. The science teachers in the building have created a lab report form, as well as a modified lab report form for students who struggle. The modified lab report form includes prompts, sentence starters, and explanations for each section of the report. For example, next to the section for "Dependent Variable" there is a hint: "what you measured at the end of the experiment." Prior to implementing this lesson, I will confer with the regular education science teacher and each student will have lab report and graphing worksheets tailored to their ability and instructional level. See the section on Lesson Plans and Appendix for more information regarding this activity.

To Increase Learning

Sleep

Teenagers require more sleep than people in other age groups--on average about 9 ¼ hours of sleep each night according to Mary Carskadon, Director of Chronobiology and Sleep Research at Brown University (2002). The PBS show Frontline aired an episode entitled Inside the Teenage Brain (2002). A ten minute chapter within this episode, available online, is entitled "From Zzzz's to A's" and analyzes research showing that a good night's sleep can improve a teen's ability to learn new skills.

Healthy Food

There has been much research about foods that may increase or inhibit brain function. There are two main ways that diet can affect the brain--by influencing its structure during periods of intense growth and by providing energy or energy efficiency. Green vegetables high in antioxidants such as spinach, broccoli, or asparagus may increase blood flow to the gray matter of the brain (BBC, 2009). One of the most publicized diets has been the beneficial effect of omega-3 fatty acids, most commonly found in fish oils. According to Dr. Richardson, "'Omega 3s can improve brain function at the very simplest level, by improving blood flow"' (BBC, 2009). A study of over 11,000 pregnant women found that "a greater intake of seafood during pregnancy was associated with greater pro-social behavior, better fine motor control and social development socials and higher verbal intelligence at 8 years of age" (Benton, 2008).

Fatty acids are also important in the development of myelin sheaths on neuronal axons. These sheaths provide a segmented cover to the axon allowing electrical stimuli to jump from one segment to the other, significantly speeding up communication of stimuli. On average, a stimulus is transmitted at 1 meter/second on unmyelinated axons in comparison to the much faster 100 meters/second on myelinated axons. The development of these sheaths is most important in pregnant women and young children because by two years of age, the brain is already about 80% of adult weight and a large extent of brain development has occurred (Benton, 2008).

In addition, fatty acids compose 20% of the receiving membrane at synaptic gaps. One theory is that these membranes, which hold the neurotransmitter ion channels, gain increased flexibility from the fatty composition allowing for a stronger communication of the electrical impulses of communication (BBC, 2009). More research needs to be done to support the benefits of eating a high Omega-3 diet for adults.

Breakfast and Eating Regularly

Studies have also shown that food deprivation at critical moments in development--the last trimester of pregnancy and the first few years of life--may have lasting negative consequences on cognitive function (Benton, 2008). A study involving children in Barbados who were malnourished for the first year of life found that 45% more had attentional deficits later in life compared with the control. Aggressive behavior was also more likely to be observed. Even in New York, research examining brain weight and socioeconomic status has shown that child brain weight is 15% lower in poor families (Benton, 2008). Low body weight is a predictive indicator of future cognitive ability and disease susceptibility throughout life.

Other studies have shown that healthy patterns of eating--eating breakfast, eating meals of lower glycemic index, and eating snacks--can positively affect cognitive functioning. The functions of the brain require an inordinate amount of energy resources. "Although the adult brain represents only 2% of body weight it is responsible for 20% of basal metabolic rate" (Benton, p.30). A child's brain is responsible for 44% of the basal metabolic rate and needs to be constantly supplied with glucose.

A survey of research shows that cognitive ability improves when children eat breakfast. Specifically, better memory is associated with meals that release glucose slowly into the bloodstream. "A low GL (glycemic load) breakfast was associated with better memory, better sustained attention and spending more time on task" (Benton, 2008). The glycemic load is derived from the amount of carbohydrates in food and how the body processes the food. Foods that have a high glycemic load, such as sugary cereal, will cause the glucose level in the body to spike sharply, while foods with lower glycemic load, such as oatmeal or eggs, will have a more sustained impact because the glucose level in the body will rise and fall more gradually. Research has found

that the glucose spike from high GL foods can be remedied by a mid-morning snack. Students should be encouraged to eat a healthy breakfast and regular meals to improve and sustain their cognitive function.

Repetition/Lifelong Learning

People used to believe that the brain solidified and cemented in early childhood, preventing further growth and learning. Although younger brains do exhibit increased plasticity, recently published research has shown that the brains of the elderly also respond positively to mental exercises designed to boost reasoning and memory (Willis, Tennstedt, Marsiske; et. al., 2006). Thus, even over the summer months of school vacation, students can keep the brain active and healthy through reading and mind games.

A Quiet, Focused, Learning Environment

Today we live in a world of intensive and continuous stimulation. Laptops, smart phones, wireless Internet, text messages, and advertisements all compete for our attention. Even in the classroom, students are bombarded with auditory and visual stimuli, as well as distractions from their peers, or even a covert cell phone. With all of these competing stimuli, neurons in the brain's pre-frontal cortex--the brain's planning center--do have the ability to focus attention (Tierney, 2009). Although the brain is able to selectively focus, this effort is not without costs. As Desimone and Duncan (1995) found, "the ability to screen out irrelevant objects is not absolute" (p. 198).

Our visual systems are biased towards newer or novel stimuli, using information stored in the temporal lobe to provide context (Desimone & Duncan, 1995). According to Dr. Desimone, Director of the McGovern Institute for Brain Research at M.I.T., "'It takes a lot of your prefrontal brain power to force yourself not to process a strong input like a television commercial. If you're trying to read a book at the same time, you may not have the resources left to focus on the words"' (Tierney, 2009). Though some may be better at it than others, multitasking is essentially a myth. Students should be encouraged to have a quiet space devoted to studying with little other distracting stimuli so that students can focus the entirety of their cognitive resources on the academic tasks.

To Inhibit Learning

Alcohol

According to the National Institute on Alcohol Abuse and Alcoholism, there are 15.1 million individuals who abuse ethanol or are ethanol-dependent (Sircar et al., 2009). One of the most devastating effects of alcohol on the brain is Korsakov's Syndrome, which causes selective degeneration of mammilary bodies in the hypothalamus, leading to retrograde amnesia and confabulation. In Oliver Sack's "The Lost Mariner" within The Man Who Mistook His Wife for a Hat and Other Clinical Tales (1985), he recounts the story of Jimmie, who was trapped in the year 1945. While the ex-submarine radio operator remembered everything pre-1945 vividly, he was unable to recall his life afterwards and could not form new memories. He did not even recognize his aged brother. Jimmie had been in the Navy until 1965 and when he was released he began abusing alcohol until he had permanently destroyed his mammilary bodies to the point that ten years of his memory were erased and his ability to create new memories was destroyed.

Alcohol abuse is especially a serious concern in adolescence. According to the National Longitudinal Transition Study (NLTS), 54% of young adults with disabilities reported not having consumed alcohol in the last 30 days, as compared to 44% of young adults in the general population. Still, alcohol was the most frequent substance

abused for teens with disabilities, with 46% reporting some level of drinking in the past month (Hu et al. 2008). During adolescence the prefrontal cortex, limbic systems, and reward circuitry undergo active development and are more sensitive than fully adult brains. Research on rats has shown that "Ethanol-induced disruption of long-term potentiation (LTP) is more pronounced in hippocampal slices from periadolescent male rats than in adult male slices" (Sircar et al., 2009, p. 3). A similar study of teen alcohol users found that they had smaller left hippocampal volume, as compared to controls (Jacobus et al., 2009, p. 561). The hippocampus is particularly important to spatial learning such as navigating mazes, geometry, or manipulating figures mentally. Rats that have been given doses of ethanol and then placed in a water maze have been significantly slower at finding the resting platform than rats that have not been exposed to ethanol. More critically, rats exposed to ethanol long-term cannot form a memory of the location of the resting platform, showing the negative impact of long-term drinking on memory formation.

Female adolescents may be at a higher risk. Studies have shown that ninth-grade girls drink as much or more than boys and a higher percentage of them binge drink. Females with alcohol-use disorder have smaller pre-frontal cortex as compared to their male counterparts (Sircar et al., 2009). As mentioned above, the pre-frontal cortex is involved in personality expression, decision-making and moderating appropriate social behavior and is at a critical period of development during adolescence.

Smoking

Although the nicotine in cigarettes is a stimulant and thus does not alone produce the cognitive impairments of alcohol, alcohol and smoking are some of the most commonly co-abused substances. According to the NLTS, one in five young adults with disabilities reported smoking daily in the past 30 days. These levels of smoking are concurrent with levels reported for teens without disabilities (Hu et al. 2008). Initially, the nicotine provided by smoking and alcohol counteracts the others' negative cognitive effects. Quickly though, tolerance develops, requiring more and more of the substance to provoke the same response. As a result, users begin consuming more and more of a substance. Trying to quit either smoking or drinking produces withdrawal, which has significant negative learning and cognitive effects. As a result, co-abuse of cigarettes and alcohol produces a spiral of addiction that can negatively impact learning (Drug Week, 2007).

Marijuana

Students frequently hear the negative messages surround illicit drug use. Do they truly understand the impact? According to Jacobus et al. (2009), "nearly half of 12 th graders have tried marijuana and 6% use daily" (p. 559). Marijuana is also a component in 120,000 emergency room visits--15% involving adolescents--and over 30% of juvenile arrests test positive for marijuana (National Institute of Justice, 2002). The NLTS found that overall "the majority of young adults with disabilities (83 percent) reported not using any illegal drugs in the past 30 days. Young adults in the general population were more likely than those with disabilities to report the use of any illegal drugs (28 percent vs. 16 percent)" (Hu et al., 2008). Certain categories of disability, such as emotional disturbance and to a lesser extent learning disability, reported higher levels of use in all areas of the study.

Studies of adult marijuana use have shown that for most marijuana users, after 28 days of abstinence the negative cognitive effects--slower psychomotor speed, poorer executive functioning and manual dexterity--have disappeared (Jacobus et al., 2009). But during adolescence, the brain is in a crucial period of neurological development, namely in the prefrontal and temporal cortices. The brain increases its myelination, the fatty sheaths covering the axons, which make the conduction of communications more rapid. It also reduces and

strengthens the synaptic connections in the brain, prioritizing those used most frequently. Adolescent marijuana users performed worse on tests of attention, problem-solving tasks, nonverbal memory and learning (Jacobus et al., 2009). Studies involving adults with early (before age 17) onset and heavier marijuana usage performed especially poorly on the above measures. While adolescent users were able to regain cognitive functioning with abstinence, cognitive disadvantages were more likely to appear and continue, even after a month of abstinence (Jacobus et al., 2009). Overall, Jacobus et al. (2009) found that "adolescent marijuana users may be at increased risk for impairments in neurocognitive functioning, which may lead to negative consequences in school (e.g., trouble retaining information), impaired driving, and risky decision-making" (p. 561). Similarly to alcohol, female users may be at a higher risk for neurocognitive effects from marijuana due to interactions between different hormone and receptors in their brains.

Brain Injury: Seat belts and helmets

Every day more than 100 Americans are killed in motor vehicle crashes, and many more who survive have significant brain damage (Cohen & Einav, 2003). In 1984, New York was the first US state to mandate the wearing of seatbelts. Seatbelt use significantly reduces the number of fatalities of the occupants of cars involved in accidents (Cohen & Einav).

To illustrate this point, students should be exposed to a guest speaker who has survived a severe car accident and read testimonials from other teens, such as Angela Moehring's (Jayaraman, 2005). Angela, at age 20, was out late socializing with friends. On the way home the driver got into an accident and Angela, not wearing her seatbelt, was thrown from the car. She sustained a brain injury to her frontal and temporal lobes, as well as broken ribs and jaw, while all other occupants of the car were wearing their seatbelts and were uninjured. Her injuries have affected her speech, memory, and adult decision-making abilities. She is currently functioning cognitively as a middle schooler (Jayaraman). Other testimonials similar to Angela's are easy to locate online.

New Hampshire is currently the only state in the country that does not have a mandatory adult seat belt law, with a recent bill defeated in the Senate in June 2009. Wearing a seat belt is an easy way to prevent head injuries sustained during car accidents. As another CAPT preparation activity embedded in this unit, students will complete an interdisciplinary writing activity. In a five-paragraph essay students will take a position as to whether or not New Hampshire should pass a mandatory seat belt law. It will require students to synthesize the information they have learned in the unit, as well as in their social studies classes. Their essay should take a clear position, support that position with three details including from the two sources, and should logically and clearly express their ideas. A complete lesson plan is incorporated in the Lesson Plans section.

Classroom Activities

Lesson 1: How Fast Do You React?: Introduction & Lab Report

Grade: High School

Goal: To increase understanding of factors surrounding brain reaction time. Given a research situation, write a lab report in the correct form.

Objectives

Students will identify the independent, dependent, and control variables.
Given a research situation, students will develop an appropriate problem statement and hypothesis.
Students will write a correct, specific, and accurate lab procedure

Standards

D INQ.1	Formulate a testable hypothesis and demonstrate logical connections between the scientific concepts guiding the hypothesis and the design of the experiment.
D INQ.2	Design and conduct appropriate types of scientific investigations to answer different questions.
D INQ.3	Identify independent and dependent variables, including those that are kept constant and those used as controls.

Materials: Computer with Internet access and adobe flash, whiteboard/screen, overhead projector, lab report worksheet

Procedure

1. Introduce the issue of reaction time with a bellwork assignment quick write: What things change how fast you react/do something? (Hint: think about school or sports). Students complete this activity during the first 5 minutes of class.
2. Introduce a mini-lab to explore how fast we react to different situations.
3. Using the overhead projector, navigate to the website with the plug-in application that will measure reaction rate. (http://serendip.brynmawr.edu/bb/reaction/reaction.html). Explain that we are going to be testing everyone's reaction time in the different situations. Walk the students through the steps for each case.
4. Distribute a lab report handout, giving students who need additional help the modified version.
5. Review the components of a lab report: hypothesis, problem statement, independent variable, dependent variable, control variables, and procedure.
6. Using the lab report hand out, have students complete the hypothesis, problem statement, independent variable, dependent variable, control variables and procedure of this lab. They may work in small groups. Circulate to answer questions, prompt, and ensure all students comprehend the task.

Expected Outcomes

Students will hand in partially completed lab report forms at the end of class.

Completed sections include hypothesis, problem statement, independent variable, dependent variable, control variables, and procedure. They will be prepared to actually complete the mini-lab and collect the data during the following class session.

Lesson 2: How Fast Do You React?: Measuring and Graphing Reaction Time

Grade: High School

Goal: To increase understanding of factors surrounding brain reaction time. To create an accurate graph from data.

Objectives

Students will graph data, using equal intervals, labeled graph and a title.
Students will evaluate data, validity, and write a conclusion to lab report.

Standards

D INQ.1 Use appropriate tools and techniques to make observations and gather data.
D INQ.2 Assess the reliability of the data that was generated in the investigation.

Materials: Computers with internet access and adobe flash, graph paper, rulers, whiteboard, overhead, calculators.

Procedure

1. Hand out a recording grid for students to record each trial and their average speed for each of the four cases. Each student will complete 5 trials of each case, for a total of 20 trials.
2. Set half of the students on a computer, while the other half watch. Go to the website (http://serendip.brynmawr.edu/bb/reaction/reaction.html). It should take approximately 5-10 minutes for the students to complete the task. Circulate, answering questions and ensuring that students are recording their data. Swap and have the other half of the students complete the task. A full-size regular education class should complete this activity in a computer lab or using a class set of laptops.
3. After students have completed their data, regroup and aggregate your data as a class. On the board record individual averages for each case. Pass out calculators and have each student calculate the class average for each case.
4. Record the class averages for each case on the board and have students record them on their worksheets.
5. Distribute graph paper with preprinted axes and the necessary components of a graph: equal scale on axes, title, labels for axes. Differentiate and scaffold support in the graphing activity based on student ability.

6. Students will create two graphs of the data: one of their personal reaction times for each case, and one of the class aggregated and averaged data. Graphs must include all of the necessary components.

Expected Outcomes

After using this interactive flash program, students should have an average reaction time for each of the four cases. Typically, the reaction times should increase with each case (1-4) so that a graph with a positive correlation will be produced.

Follow-up

In following lessons, students will complete the unfinished sections of their lab reports--results, conclusion, and validity discussion. The teacher will reviews and correct the first portion of the lab reports. Possible validity questions include: Which data set is more reliable and valid, your data or the class data? Explain why?

Lesson 3: Interdisciplinary Writing: Should there be a mandatory seat belt law?

Grade: High School

Goal: To increase student knowledge of seat belt laws and student ability to support a position with evidence.

Objectives

Students will write a five-paragraph essay supporting a position.
Students will develop 3 supporting reasons for their position, using concrete details from the text.

Standards

Social Studies Content Standard 7: Students will explain that political systems emanate from the need of humans for order, leading to compromise and the establishment of authority. b. Analyze and evaluate the advantages and disadvantages of limited and unlimited government

Language Arts Content Standard 1: Students will read and respond in individual, literal, critical and evaluative ways to literary, informational and persuasive texts.

b. Examine the fit between the text and prior knowledge by reconciling differences, extracting clues or evidence, making inferences, drawing conclusions, predicting events, inferring motives and generalizing beyond the text

Materials: white-lined paper, rulers, whiteboard, editorial in response to mandatory seat belt law from UnionLeader.com or other New Hampshire news source, a testimonial article from a person who did not wear a seat belt and sustained a significant brain injury.

Introduction

In earlier lessons and in their regular education classes, students have been exposed to the interdisciplinary writing format from the CAPT test. In Social Studies classes, students learn the role of state government in relationship to the federal government. Throughout this unit, students have learned information about brain function and how to improve their cognitive abilities and how to negatively impact their abilities. Students will independently synthesize this information, as well as primary texts to choose a position on mandatory adult seat belt law in New Hampshire.

Procedure

1. Provide students with background information surrounding mandatory seat belt laws in different states. New Hampshire is currently the only state in the country without a mandatory seat belt law.
2. Given what they have learned about brain function, students must choose a position and write an essay in response to the question: Should New Hampshire adopt a mandatory adult seat belt law?
3. Review the steps for writing an interdisciplinary response: Read the question, read the two texts, choose a position, highlight or underline supporting details from the text, create an outline, write the five paragraph essay.
4. Pass out materials and allow students time to complete task.

Expected Outcomes

After reading the statements from both sides of the issue, students will produce an essay answering the question: Should New Hampshire adopt a mandatory adult seat belt law? Students will support their positions using specific details from the two articles.

Follow-Up

After students complete their essays, arrange a class discussion, with proponents and opponents seated on opposite sides of the room. Using their essays, have them engage in a discussion of the topic. A panel of outside teachers could even be brought in to assess which side did a better job arguing and supporting their position. A similar issue could easily be used in a further lesson involving motorcycle helmet laws.

Resources

Teacher Resource Websites

°¤ University of Washington, Digital Anatomist Project (http://da.biostr.washington.edu/da.html)

This website includes images of the brain, as well as digital representations. There are anatomy quizzes, as well as a puzzle game.

°¤ Bryn Mawr University, Serendip, Interactive Learning Environment (http://serendip.brynmawr.edu/bb/kinser/Home1.html)

This website includes comparative photos of animal brains, as well as brain cross-sections.

°¤ BBC Science & Nature-Human Body and Mind (http://www.bbc.co.uk/science/humanbody/)

This website includes images, and interactive brain map, as well as psychological brain interactives.

°¤ Frontline: Inside the Teenage Brain (http://www.pbs.org/wgbh/pages/frontline/shows/teenbrain/)

PBS TV special exploring brain details and needs specific to teenagers.

°¤ Neuroscience for Kids (http://faculty.washington.edu/chudler/chgames.html)

Website of brain games to engage students in interesting aspects of brain function.

Annotated Bibliography

Addiction medicine: Nicotine-alcohol interaction impacts learning, could have implications for addiction treatment. (2007, November 23). Drug Week, 1658. This article discusses the cyclical and negative interactions between nicotine and alcohol co-abuse and its affect on learning.

BBC. (2009, June 26). Human Body and Mind. Retrieved June 27, 2009, from BBC: http://www.bbc.co.uk/science/humanbody/mind/. A interactive website on anatomy, as well as the functions of the brain and psychological functions.

BBC News. (2000, March 14). Taxi drivers' brains "grow" on the job. BBC News World Edition, Retrieved June 29, 2009, from http://news.bbc.co.uk/2/hi/science/nature/677048.stm. Article describing how the hippocampus of long-term cab drivers actually increased in size, in theory due to the extreme spatial memory requirements of their job.

Benton, D. (2008). The influence of children's diet on their cognition and behavior. European Journal of Nutrition, 47, 25-37. This article explores the research basis for the influence on diet on the cognitive development of children.

Bransford, J. D., Brown, A.L., & Cocking, R. R. (Ed.). (1999). How people learn: Brain, mind, experience, and school. Washington, D.C.: National Academy Press. This book is a comprehensive exploration of how the brain functions in school environments.

Carle, E. (1998). Hello red fox. New York: Simon & Schuster Children's Publishing. Children's book involving simultaneous contrast after-images.

Chudler, E.H. (2008). Neuroscience for Kids. Retrieved April 5, 2009, from Brain Games Web site: http://faculty.washington.edu/chudler/chgames.html. Website of brain games to engage students in interesting aspects of brain

function.

Cohen, A., & Einav, L. (2003, November). The effects of mandatory seat belt laws on driving behavior and traffic fatalities. The Review of Economics and Statistics, 85, 828-843. Article describing the impact mandatory seat belt laws have in decreasing the number of auto accident fatalities.

Deakin Psychology Department, (2006, July 17). Phineas Gage Information. Retrieved June 27, 2009, from Deakin University: http://www.deakin.edu.au/hmnbs/psychology/gagepage/. Internet site developed to comprehensively review the case of Phineas Gage (1823-1860), a railroad worker who sustained a severe injury to his frontal lobe and consequently suffered personality changes.

Dellorto, D. (2009, May, 04). Toddler brain difference linked to autism. CNN.com, Retrieved May 07, 2009, from http://www.cnn.com/2009/HEALTH/05/04/autism.brain.amygdala/. This CNN article highlights recent research that identifies an anatomical difference between a normal and autistic brain. The enlarged amygdala in 2-year-old autistic children may be critical in diagnosing autism earlier.

Desimone, R. & Duncan, J. (1995). Neural mechanisms of selective visual attention. Annual Review of Neuroscience, 18, 193-222. This research explores the brain's efforts to select between competing stimuli.

Gallagher, W. (2009). Rapt: Attention and the focused life. New York, NY: Penguin Group. This book explores the brain's negotiation of stimuli and provides examples of using the brain's ability to focus as a key to success.

Gardner, H. (1993). Frames of mind: Theory of multiple intelligences. New York, NY: Basic Books. Educational theory book that stresses that educators should recognize and value the various intelligences that we all possess in different distributions.

Growing up different. (2001). Scientific American Frontiers. Retrieved March 7, 2009, from Scientific American Frontiers: Growing Up Different Web site: http://www.pbs.org/saf/1205/index.html

PBS TV special on growing up with different disabilities.

Hart, B. L., Hart, L. A., & Pinter-Wollman, N. (2008). Large brains and cognition: Where do elephants fit in? Neuroscience and Biobehavioral Reviews, 32, 86-98. This article explores the cognitive capacity of elephants given that they, like humans, are large mammals with large brains and needy offspring.

Holdrege, C. (2001, Spring). Elephantine intelligence. The Nature Institute In Context, Retrieved June 29, 2009, from http://www.natureinstitute.org/pub/ic/ic5/elephant.htm. Article describing anatomical differences between human and elephant brains and potential evolutionary reasons behind these differences.

Inside the teenage brain. (2002). Frontline. Retrieved March 8, 2009, from Frontline: Inside the Teenage Brain Web site: http://www.pbs.org/wgbh/pages/frontline/shows/teenbrain/

PBS TV special exploring brain details and needs specific to teenagers.

Inside the teenage brain: Interview with Mary Carskadon. (2002). Frontline, Retrieved May 23, 2009, from http://www.pbs.org/wgbh/pages/frontline/shows/teenbrain/interviews/carskadon.html. Interview with the director of Chronobiology and Sleep Research at Brown University regarding teenage sleep requirements and the effect on the teenage brain.

Jacobus, J., Bava, S., Cohen-Zion, M., Mahmood, O., & Tapert, S.F. (2009). Functional consequences of marijuana use in adolescents. Pharmacology, Biochemistry and Behavior, 92, 559-565. This article reviews neuropsychological studies involving the cognitive impact of marijuana use.

Jayaraman, P. (2005, May). Coming back from a Brain Injury: A traumatic brain injury survivor tells her story. The Southern Health Magazine, Retrieved June 29, 2009, from http://www.southernillinoisan.com/articles/2009/04/05/health/doc49c1580ef374c306648886.txt This testimonial article describes how the poor decision not to wear a seat belt has entirely changed a teen's life after she sustained terrible head injuries in a car accident.

Johansson, B. B. & Pavel V. B. (2002). Neuronal plasticity and dendritic spines: Effect of environmental enrichment on intact and postschemic rat brain. Journal of Cerebral Blood Flow & Metabolism, 22, 89-96. This article explains the results of experiments comparing the influence of environmental enrichment on rat brains. Results indicate that housing rats in an enriched environment significantly increases dendritic spines density in all cortical layers.

Kimball, J. W. (2006, December 17). Long term potentiation. Retrieved June 7, 2009, from: http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/L/LTP.html. This website, created by the writer of high school biology textbooks, explains the basis for learning and memory at the neuron level.

Kolb, B. (1995). Brain plasticity and behavior. Hillsdale, NY: Lawrence Erlboum. A book on brain plasticity and flexibility, including information on the positive effects of an enriched environment.

McIntosh, H. (1998). New technologies advance studies of autism. APA Online, 29, Retrieved April 2, 2009, from http://www.apa.org/monitor/nov98/study.html. Article describing how fMRI technology is facilitating autism research.

National Institute of Justice. (2002). Preliminary data on drug use & related matters among adult arrestees & juvenile detainees. Washington, DC: US Department of

Justice. A report from the Department of Justice with data on teens, illegal activity, and drug involvement.

Prensky, M. (2001). Digital natives digital immigrants. On the Horizon, 9, 1-6. An article arguing that students have developed as natives in the digital age, requiring teaching style and content to adapt to address their needs and learning styles.

Sacks, O. (2007, September 24). The abyss: Music and amnesia. The New Yorker, Retrieved June 29, 2009, from http://www.newyorker.com/reporting/2007/09/24/070924fa_fact_sacks. Article describes the circumstances surrounding musician Clive Wearing's amnesia. Due to herpes encephalitis, Wearing has a memory span of only a few seconds.

Sacks, O. (1985). The man who mistook his wife for a hat and other clinical tales. New York, NY: Touchstone. Sacks recounts clinical stories of patients afflicted with various neurological disorders and the effects of lost memories or fantastic perceptions.

Serendip. (2001, July 2). Time to think?: Making observations. Retrieved May 24, 2009, from Brain and Behavior Web site: http://serendip.brynmawr.edu/bb/reaction/reaction.html. Website with a shockwave plug-in activity measuring brain reaction time when given increasingly complex activities.

Sircar, R., Basak, A. K., & Sircar, D. (2009, April). Repeated ethanol exposure affects the acquisition of spatial memory in adolescent female rats. Behavioural Brain Research, 202, 225-231. This study explores the effects of ethanol on the acquisition of spatial memory in adolescent female rats. Results indicate that ethanol negatively affects spatial learning.

Small, G.W. (2008). iBrain: Surviving the technological alteration of the modern mind. New York, NY: Collins Living. This book analyzes the effects of technology on the modern brain.

Sousa, D.A. (2005). How the brain learns. Thousand Oaks, CA: Corwin Press.

The book describes the functioning of the brain in a learning environment.

Sousa, D.A. (2007). How the special needs brain learns. Thousand Oaks, CA: Corwin Press. This book describes the functioning of a disabled brain in a learning environment.

Tierney, J. (2009, May 5). Ear plugs to lasers: The science of concentration. The New York Times. This article is a book review of Rapt, a book exploring the science of concentration and focus.

Time. (2007, July 30). BBC. Retrieved April 5, 2009, from BBC Four: Daytime Documentaries Time Web site: http://www.bbc.co.uk/bbcfour/documentaries/features/time1.shtml

Video clips of Clive Wearing, a man who has a 30 second memory span due to damage to his temporal lobe.

Yu, J., Huang, T., & Newman, L. (2008, March). Facts from the National Longitudinal Transition Study 2. U.S. Department of Health and Human Services, Institute of Education Sciences, National Center for Special Education Research. This fact sheet from a longer longitudinal study summarizes statistics about substance abuse among young adults with disabilities. It compares rates of alcohol, smoking, and marijuana use between young adults and young adults with disabilities and usage rates among the different disabilities.

Vendantam, S. Short mental workouts may slow decline of aging minds, study finds. (2006, Dec 20). Washington Post, p. A01. Newspaper article reviewing a study published showing the positive effects of brain drills and mental games on the daily functioning of the elderly.

Volkmar F.R., Greenough W.T. (1972). Rearing complexity affects branching of dendrites in the visual cortex of the rate. Science, 176, 1445-1447. Article discusses the positive effects of an enriched environment on complexity of dendritic branching.

Willis, S. L., Tennstedt, S.L., & Marsiske, M., et. al. (2006). Long-term effects of cognitive training on everyday functional outcomes in older adults. JAMA, 296 (23), 2805-2814. Results of a study conducted to evaluate the effects of mind exercises on daily functional living in elderly patients. Results found that the mental exercises improved both cognitive, as well as functional living abilities.

Appendix A

Name: _____

How Fast Are You?

Directions:

1) Type in the following website address: http://serendip.brynmawr.edu/bb/reaction/reaction.html
2) Do five trials for each of the four cases, recording each of your trials, and your average speed for each case.

Case 1: Act

Trial	Reaction Time (milliseconds)
1	
2	
3	
4	
5	
Average Time	

Case 2: Think, Act

Trial	Reaction Time (milliseconds)
1	
2	
3	
4	
5	
Average Time	

Case 3: Read, Think, Act

Trial	Reaction Time (milliseconds)
1	
2	
3	
4	
5	
Average Time	

Case 4: Read, Think-Negate, Act

Trial	Reaction Time (milliseconds)
1	
2	
3	
4	
5	
Average Time	

Class Averages

Case	Avg. Reaction Time (milliseconds)
1	
2	
3	
4	