Brain-Based and Constructivist Strategies for Teaching a "Science, Technology, and Society (STS)" Course

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Abstract

This paper describes the application of brain-based and constructivist learning strategies for teaching a "Science, Technology, and Society (STS)" course. Four professors who teach a "Science, Technology, and Society" course at DeVry University have combined their interdisciplinary backgrounds in engineering, psychology, history, anthropology and sociology, to develop brain-based and constructivist learning/teaching approaches that promote critical, analytical, and expert thinking in students. This STS course introduces students to the influences of technologies on society and explores the relationships between societies and technologies. There are essentially four objectives to this course: (1) developing a strong understanding of local and global forces and issues which affect people and societies, (2) guiding local/global societies to appropriate use of technology, (3) alerting societies to technological risks and failures, and (4) developing informed and encompassing personal decision-making and leadership and providing ways to solve problems in a technological world. It is anticipated that that by using brain-based and constructivist teaching strategies, educators can further promote in students everywhere, the future reality and urgency of technological social leadership to appropriately and responsibly help to develop our global community.

I. Introduction

The exponential growth of technology in the 20th century has made the relationship between life, society and economics more complex. The old economic model based on material assets is slowly being transformed to a new economic model – knowledge-based economy - based on the technological and intellectual capital of a nation.

The transition towards the new economic realities has also imposed a paradigm shift in the modes of teaching and learning. The education system is also being transformed from a "talk & chalk" model to a "lifelong learning" model. In this new knowledge-based economy, there are increased demands on students and educators. The fast rate of technological change is forcing learners to learn quickly and learn how to think and acquire new skills and competencies quickly. The "best practice" teaching strategies provide answers and solutions to cope with the new challenges in the domains of teaching and learning.

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II. Elements of "Best Practice" Teaching: Constructivism

During the past several decades, constructivism has gained popularity and advocacy as educators have searched for better ways to teach and learn. With traditional methods teachers have noted persistent shortfalls in students' understanding and a great deal of passive knowledge across all ages and grades, including the universities. According to the *Thesaurus of ERIC Descriptors,* [1] constructivism is a "viewpoint in learning theory which holds that individuals acquire knowledge by building it from innate capabilities interacting with the environment" (p. 64).

Constructivist teaching is based on recent research about the human brain and what is known about how learning occurs. It is an approach to teaching and learning based on the premise that cognition (learning) is the result of "mental construction." In other words, students learn by fitting new information together with what they already know. Constructivists believe that learning is affected by the context in which an idea is taught as well as by students' beliefs and attitudes.

Constructivism emphasizes the careful study of the processes by which students create and develop their ideas. Its educational applications lie in creating curricula that match (but also challenge) students' understanding, fostering further growth and development of the mind. Research has shown that active engagement in learning may lead to better retention, understanding and active use of knowledge. The collaborative or cooperative learning also seems to foster learning.[2] However, some educators point out to the limitations/drawbacks of the constructivist techniques.

1. Constructivist techniques often require more time than the traditional educational practices.
2. They can exert high cognitive demands on learners, and not all learners respond well to the challenge.
3. They can seem deceptive and manipulative.

Replacing traditional techniques with constructivist techniques could lead to problems for some learners. But using the constructivist techniques to support and to enhance the traditional methods could benefit all learners.

III. Elements of "Best practice teaching": Brain Based

Madeline Hunter [3] observes that we have learned more about the human brain and how it functions in the last two decades than we had learned from the beginning of time.
During the past 20 years, neuroscientists have amassed a wealth of knowledge on the brain and its development from birth to adulthood. And they are beginning to draw some solid conclusions about how the human brain grows and acquires a number of talents and abilities (see Table 1).

The recent findings in the field of neuroscience are transforming the process of learning from a speculative exercise towards an exact science. Non-invasive procedures such as magnetic resonance imaging (MRI) and positron emission tomography (PET) have provided a window on human brain (see Figure 1). As a result, scientists can actually see a thought occurring, fear erupting or a long buried memory enter into an individual's consciousness. Through these techniques, scientists can distinguish between neuronal group that are only one millimeter apart (30,000 neurons would fit on a pin-head).

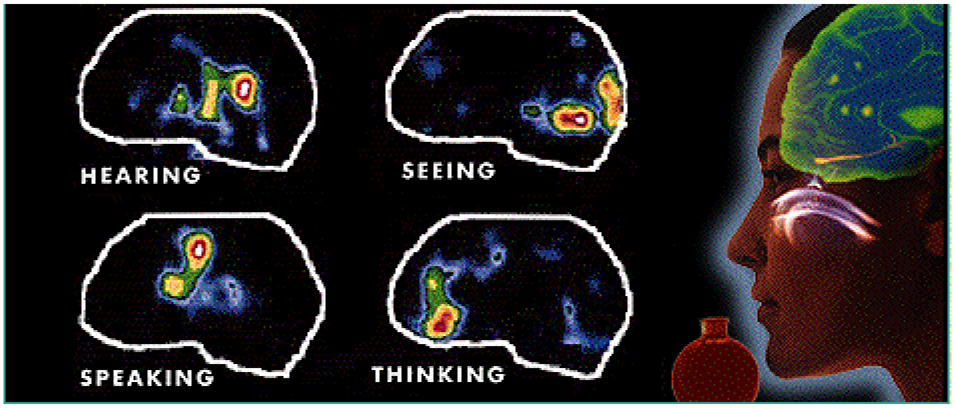


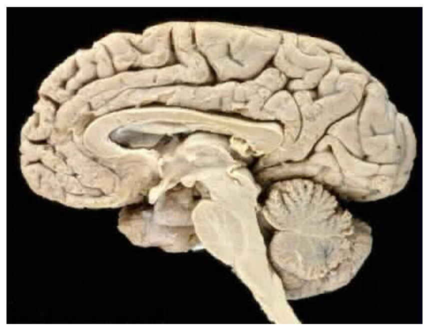
Figure 1: PET scan illustrating different tasks stimulating neural activity in distinct areas of brain.[4]

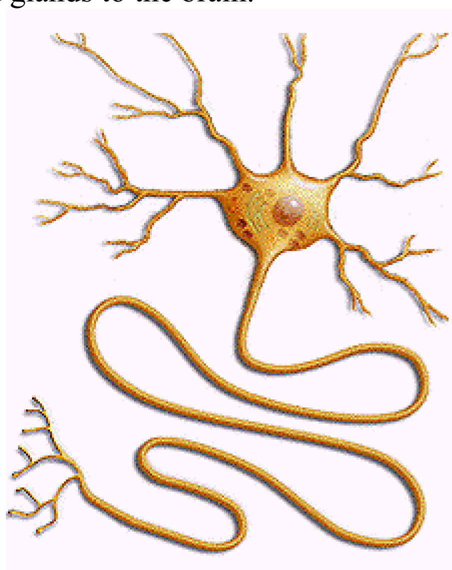
Brain has the ability to grow and change as it learns and experiences its environment. This property is called neuroplasticity. There is growing evidence that both the developing and the mature brain are structurally altered when learning takes place. These structural changes are believed to encode the learning in the brain. Recent brain research findings also suggest that classroom activities, which incorporate motivation, stimulating environment and critical thinking, promote development of the brain in the form of growth of new dendrites. [6] These findings suggest that brain is a dynamic organ, shaped to a great extent by experience. In order to become better teachers, educators have to: (a) understand how the brain learns: the process and the stimuli (environmental, emotional and physical), and (b) devise teaching strategies which enhance student learning.

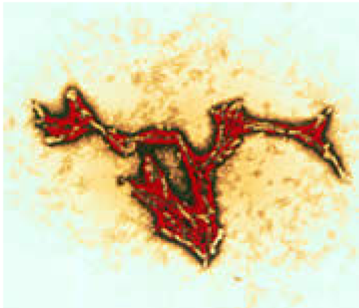
Educators have to refrain from monotonous and passive activities and should incorporate stimuli that promote learning in students with different learning styles. Motivational activities and stimulating environments promote dendrites to grow, and passive activities apparently do not cause dendrites to grow. Educators must also make sure that they teach students using stress-free teaching strategies and environment. Because the recent findings suggest that stress inhibits learning as it affects the formation of new memories and hinders higher order thinking. Over time stress results in inhibition of neuronal growth in the hippocampus. High levels of stress hormones (cortisol) transiently block hippocampal function, and over time can produce neuronal death (number of neurons in hippocampus is diminished). [7]

Research in neuroscience is advancing at an amazing pace, and literally hundreds of books and journal articles about the human brain have been published in last couple of years. With all this research, there still remains a wide gap between the human understanding of brain and the mind. Brain is extremely complex organ, and it still remains an undiscovered universe within human body. Researchers all over the globe are struggling to answer the key question: *how does a human brain transform itself into a mind?*

Table 1: Brain Facts

"The human brain is the most complex piece of machinery in the universe." Prof. Colin Blakemore, Oxford University	
Average Brain Weights (in grams) - Adult human - Newborn human - % brain of total body weight (150 pound human)	- 1,300 - 1,400 (about 3 pounds) - 350 – 400 - 2% 
Average brain width	140 mm
Average brain length	167 mm
Average brain height	93 mm
Electrical Activity	• EEG - beta wave frequency = 13 to 30 Hz (active & alert) • EEG - alpha wave frequency = 8 to 13 Hz (relaxation) • EEG - theta wave frequency = 4 to 7 Hz (early stages of sleep) • EEG - delta wave frequency = 0.5 to 4 Hz (occur during sleep)
Blood Supply	• % Brain utilization of total resting oxygen = 20% • % blood flow from heart to brain = 15-20% • Blood flow through whole brain (adult) = 750 ml/min • Time until unconsciousness after loss of blood supply to brain = 8-10 sec • Time until reflex loss after loss of blood supply to brain = 40-110 sec

Brain Chemicals	• Brain is a giant chemical factory • Neurotransmitters (50 have been identified so far), they determine: - Human behavior - Personality - perception
Basic Building Blocks	**Neurons:** Cells that specialize in communication. They exchange signals with each other and link sense organs, muscles and glands to the brain.  Each neuron is composed of three major parts: **Soma**: The Soma or cell body contains the nucleus and structure for keeping the cell alive. It is capable of receiving messages from nearby neurons. **Dendrite**: The dendrites are short, branching fibers that receive messages from nearby neurons. **Axon**: The axon is a single large fiber that conducts electro-chemical signals to other neurons, muscles and organs. Axons are usually only a fraction of an inch long in length, but longest can be over 3 feet in humans. [4] - Nerve impulses typically move from the dendrites to the soma and then travel down the axon Neurons are separated by a tiny gap (a few millionth of an inch across) called a synapse. - Neurotransmitters are stored and released at the end of the axon.

	- Protein called prions, replicate and strengthen connections with next-door neurons.  - Prions can flip between two different shapes; researchers believe that they might help in laying down memories.[5]
Types of Neurons	Neurons can be classified in three types: [4] **Sensory Neurons**: Also called efferent neurons, carry information from the senses to the central nervous systems. **Motor Neurons**: Also called efferent neurons, carry signals from the central nervous system to muscles and organs. **Interneurons**: transmit signals between neurons, most of the neurons in the body are Interneurons and found densely packed together in the brain and the spinal cord.
Average number of neurons in the brain	100 billion
Potential number of dendrites (neural branches) for a "typical" neuron	1,000 to 20,000
Potential number of dendrites for 100 billion neurons	100 billion neurons X 20,000 dendrites/neuron = 2,000 Trillion dendrites or neural branches.
Understanding of Brain (Old vs. Current)	**1970s - 80s**: Brain is a computer (Mental model for education: Memorization of facts). **1990s - 2005**: Brain is a complex network like Internet (Mental model for education: Guided experience for meaningful learning).

	Brain vs. Computer Network (Internet) Analogy: The IPv4 (Internet Protocol version 4) addressing scheme (uses 32-bit unique address to identify a device connected to the Internet), developed in 1980s, yields around 4 billion possible computer addresses. If the 32 bit address analogy is applied to identify memory entities in the 100 billion neurons with potential 2000 trillion dendrites, it yields almost an infinite number of memory locations in brain.
Key unanswered question in Brain research	How does a human brain transform itself into a mind?

Brain Research and Teaching/Learning

Caine and Caine [8] state that brain-compatible teaching is based on the following 12 principles:

1. The brain is a parallel processor.
2. Learning engages the entire physiology.
3. The search for meaning is innate.
4. The search for meaning occurs through "patterning."
5. Emotions are critical to patterning.
6. The brain processes parts and wholes.
7. Learning involves both focused attention and peripheral perception.
8. Learning always involves conscious and unconscious processes.
9. Brain has at least two different types of memory: a spatial memory system, and a set of systems for rote learning.
10. Humans understand and remember best when facts and skills are embedded in natural, spatial memory.
11. Learning is enhanced by challenge and inhibited by threat.
12. Each brain is unique.

Based on these principles authors recommend that teachers should incorporate a variety of experiential learning strategies in order to promote learning. Cardellichio and Field [9] have suggested seven teaching strategies that encourage Neural Branching. They are:

1. Hypothetical thinking
2. Reversal
3. Application of different symbols
4. Analogy
5. Analysis of point of view
6. Completion
7. Web analysis

Cardellichio and Field [9] state that all these strategies are related to one another as they all provoke divergent thinking and thus extend students' neutral networks, and hence enhance student learning.

In order to incorporate brain-based learning and teaching strategies, educators have to understand how the brain learns: the process, the stimuli (environmental, emotional and physical). The human brain has about 100 billion neurons or nerve cells, and each neuron can generate 20,000 connections or dendrites, so the potential of total number of interconnections or development of mind is unlimited. The capacity of human brain is astonishing.[6,9]

Recent brain research findings suggest that classroom activities which incorporate motivation, stimulating environment and critical thinking promote development of the brain in form of growth of new dendrites. In this regard educators can use tools like multi-media, group exercises, Internet exercises, and group lab projects to enhance and support direct instruction. Educators can enhance student learning by conducting lectures in a friendly manner, so that nobody feels stress or is afraid to ask a question. No learning can take place in a tense environment.

IV. Technology, Society and Culture Objectives and Methodologies

Students at DeVry University are given the challenge and opportunity to guide and direct their technological knowledge into responsible awareness and choices for local/global solutions of problems and 21st Century urgent issues. All DeVry students must pass a senior-level inter-disciplinary capstone Humanities course entitled "Technology, Society and Culture". This course challenges students to realistically assess technological implications within the world stage and to bridge the gap between the developed world and the developing worlds. The course falls into the inter-disciplinary STS classification (a field known as Science, Technology and Society whose main focus is to explore the influences of technologies on society and the relationships between societies and technologies). The course emphasizes an integration of all their previous studies at DeVry in addition to professional group work, research, research presentations and technical reports, communication, critical thinking and analysis, solutions and applications of the moral and ethical dilemmas the use of technology sometimes presents. The course also identifies conditions that have promoted technological development and assesses the social, political, historic, environmental, ethical, cultural and economic effects of current technology and what technology might hold for the future on the local, national and international fronts. The challenge of this course include the interdisciplinary dimensions as well as the multi-cultural perspectives that are needed along with the dynamic of constantly changing current and relevant issues associated in the news which revolve around the ethical and responsible use of technology.

There are essentially four objectives to this course: (1) developing a strong understanding of local and global forces and issues which affect people and societies, (2) guiding local/global societies to appropriate use of technology, (3) alerting societies to technological risks and failures, and (4) developing informed and ethical personal decision-making and leadership and providing ways to solve problems in a technological world through such leadership. This course is very relevant in not only the interdisciplinary knowledge it encourages, but especially for our students who as future engineers cannot be blind to social issues and the implications of the technologies that they promote and use. Our future engineers must guide society to the appropriate uses of technology, alert society to technological failures, and provide a vision to society in helping to solve societal problems that are related to technology. In the future our engineers will be relied for knowledge with computer networks, wireless and optical networks, biotechnologies, biometrics, alternate energy technologies, no waste design engineering, biomedical applications, nano-technologies, genetics, knowledge of cultures and religions, globalization, and ethical decision making, just to name a few. With such urgencies of knowledge integration to fulfill the promises and needs of the engineering discipline, both technology and great social understanding are needed.[10]

Table 2 lists the examples of Brain-Based teaching strategies employed in the STS course. In order to promote critical and analytical thinking the following Constructivist and brain-based teaching approaches are primarily used in the STS course:

1. Collaborative Research Project "Third World Fair"
2. Heuristic Triangle Model
3. Flow Chart Modeling and Analysis
4. Case Study Integration

Table 2: Examples of Brain-Based Learning/Teaching Strategies Employed in the STS course

Characteristics of Brain-Based Learning/Teaching (Caine and Caine)	**Examples employed in STS Course**
1. The brain is a parallel processor	Examples/discussion of **conceptual** issues/realities which have positive/negative realities not previously considered or realized (e.g. impact of SUV's, cell phones, on-line gaming). All of our methods of case studies (CS), flow charts (FC), "Third World Fair (TWF), and The Heuristic Triangle Model (HM) approaches accomplish this.
2. Learning engages the entire physiology	Description of case studies, discussion of issues, debates, writing of papers, so that students get involved, take a stand, feel the emotion and realities; see viewpoints up close and real! This involving thinking, student's experiences, expertise, emotions, analysis/ synthesis, defense of positions, solving of problems, commitment to positions. Again this is accomplished with CS, FC, TWF and HM.
3. The search of meaning is innate.	ALWAYS trying to ask the question not only WHY are the responses/ issues what they are but HOW they relate to people – short-term, long term (e.g. Kyoto agreements). Science asks why – and STS is a social science that tries to examine cause and effect—the big WHY. All methods (CS, FC, TWF, and HM) get at this.
4. The search for meaning occurs through 'patterning'	If students have models, and processes such as case studies, flow charts, heuristic models – it give them frameworks and patterns of examination for analysis and synthesis which further spirals a continuous growth of more thinking, and depth of approaches. Applicable for all methods of CS, FC, TWF and HM.

5. Emotions are critical to patterning	Involvement involves emotions towards the new understanding and also the issues themselves. When students are involved in an interdisciplinary course, they are challenged and using their own selves, old and new knowledge, experiences and emotions. All methods encourage such involvement.
6. The brain processes part and wholes.	This is the whole concept of STS. It is vital to examine the wholes that connect to parts – not just parts or wholes. The purpose of STS is to connect the dots and bring the parts and wholes together such as in flow charts, case studies, "Third World Fair": and "The Heuristic Triangle Model".
7. Learning involves both focused attention and peripheral perception	The flow of focus must see relationships and that involves not only the foci but also the connectives – the implications and peripheral effects. This is demonstrated in CS, FC, TWF and HM.
8. Learning always involves conscious and unconscious processes	This means you develop new perspectives and understandings, new epiphanies or transformative thinking. In order for new perspectives to occur one must alter old assumptions, some of these are unconscious as well as conscious. Sharing of multi-perspectives and realities in STS class as well as different types of class involvement activities of group work, problem solving and model development target examinations of assumptions. These processes are exemplified in CS, FC, TWF and HM.
9. The brain has at least two different types of memory: a spatial memory system and a set of systems of rote learning.	The many planes of examination in STS from global to local and their connection on issues (e.g. oil consumption) incorporates many different arenas of interdisciplinary knowledge involving abstractions, theoretical examination and applications. It however also involves the practical aspects of good student performance and applications which integrate that learning. The four applications of CS, FC, TWF and HM do both.
10. Humans understand and remember best when facts and skills are embedded in natural, spatial memory	As stated above the four methods (CS, FC, TWF, HM) provide an anchor to BOTH abstraction and reality.
11. Learning is enhanced by challenge and inhibited by threat	In our STS course, we engage in dynamic interchanges of different views and perspectives which involves all students individually and in group approaches. As educators, we make sure that the atmosphere is supportive, fascinating, challenging, but never threatening – a safe haven for controversy and many perspectives. Again the four methods of CS, FC, TWF, HM support this.
12. Each brain is unique	Understanding the many learning styles, individual perspectives, experiences that students bring to the forum, is

	part of the richness of the class and the discourse that supports both individuality and learning. The four methods of CS, FC, TWF and HM also focus/enhance that individuality using its uniqueness as part of the vital forum of the class.

V. Collaborative Research Project "Third World Fair"

In this Constructivist teaching methodology, student act as consultants/researchers for advising a technological solution to existing problems in the third world. There are two parts to the "Third World Fair" project. First, students form groups where they will remain throughout the exercise and they select a nation generally regarded to be a member of the Third World. Students are then assigned to provide answers to over two dozen questions designed to give them a statistical snapshot of their chosen countries. Some of them are fairly basic, such as population statistics, life expectancy, infant mortality, rural-urban spread, per capita income, and gross domestic product. Others are a bit more challenging, such the percentage of GDP spent on defense, the number of universities, the extent of the highway and railway system, and so on. Many of the answers can be found on line, although students must show they have taken advantage of more traditional sources. The other question requires them to specify a technology (or technologies) that could be employed for the solution of an existing problem/issue in the developing country.

The first stage of the Third World Fair concludes with half-hour presentations, as the teams share their findings with the class. Each member of the team must play a role in the presentation, and the use of some for of instructional technology is required. A written report must also be presented to the instructor for evaluation.

Stage Two of the Third World Fair builds on the collected data and the proposed technology. The team must now try to convince their classmates, now decision makers of the country the team has been researching, to invest in the technology the team feels will improve the quality of life for its residents. The second presentation begins with a brief recapitulation of the information developed earlier, to serve as a bridge to the technology they will unveil. The real focus is the technology; why it will work, how it will work and how much it will cost. As stated before, these must be appropriate technologies which are currently in existence and meet the cost, infrastructure, maintenance and environmental criteria. The teams must touch on all of these issues during the presentation, a process which demonstrates the extent of critical thinking given to the project, as well as the level of burden sharing, as each group member usually handles one of the assigned areas. The results are usually very creative, but rarely far-fetched.
At the conclusion of the presentation, each team must discuss what they think may be the moral or ethical implications implicit in the deployment of the proposed technology. It would be easy to say that when faced with the problems of the Third World, no technology, regardless of its dangers would be rejected. However, at this stage of the project students are not that easily rushed to such a judgment. They tend to be a bit more thoughtful regarding the selection of the technology, and demonstrate during a mandatory question and answer period a sharpened sense of critical thinking as to why they proposed what they did.

In the two stages of the Third World Fair, there are ingredients of both Constructivist and Brain-Based learning at work. The student's foundation of knowledge is both complemented and challenged by the research required. The active engagement in a project of this nature tends to reinforce retention, and could lead to a more active used of learning. In addition, the collaborative approach taken in completing the assignment fosters a positive stress-free learning environment, in which critical thinking can hopefully flourish.

VI. Heuristic Triangle Model

A second approach to encourage integration of central viewpoints so that problems and solutions are discussed from different philosophies and disciplines and seen as inter-relating is a model to relate to in discussion of most issues and problems. This approach is termed the "heuristic triangle technological" model (see Figure 2) where humanity, ecological, and ethical area interdependencies for balance and decision making are modeled as part of technical assessment and decision making. This begins as a heuristic teaching device but hopefully carries through in becoming habit in decision making considerations. Interdependencies in approaches provide important inter-relating perspectives that are not simplistic in nature and therefore encourage short term and long term perspectives, non-isolatory or non-reductionist thinking and involve (1) the moral, humanistic-cultural side, (2) the ecological view as well as (3) the technological development impact. Such an inter-dependency view therefore evolves as a developing moral assessment and approach for understanding and decision making rather than a more one-planed fix-it solution of some technical effect.

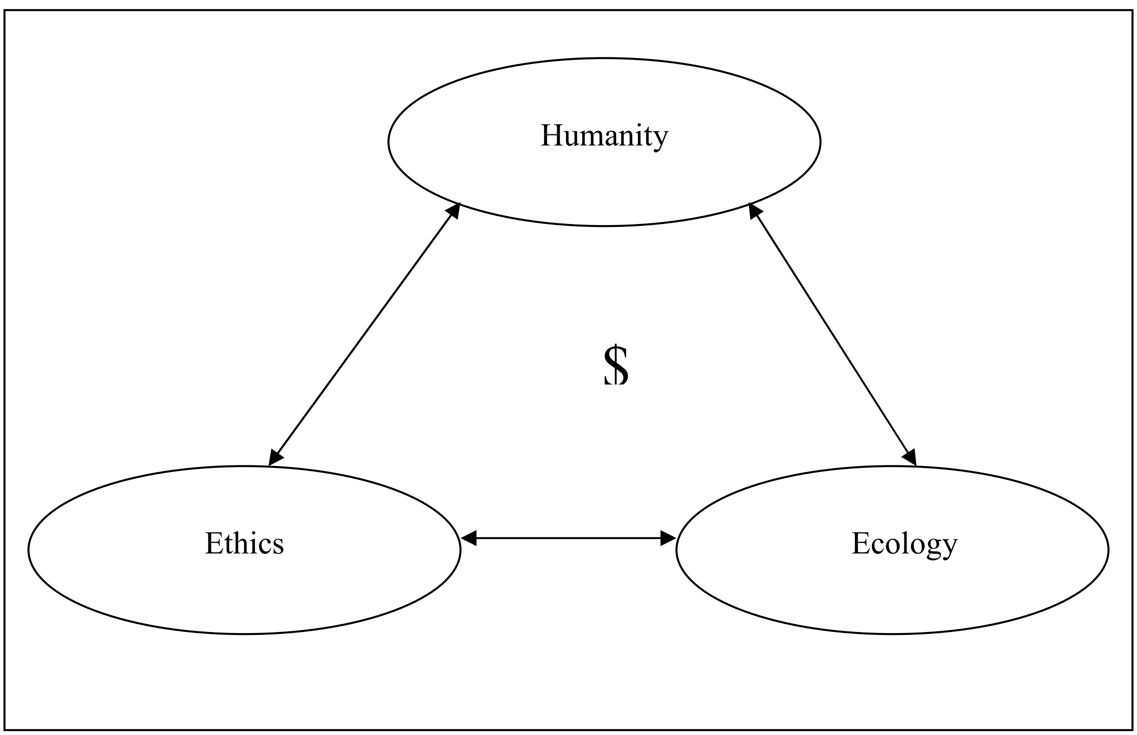


Figure 2. "Heuristic triangle technological" model for decision making.

The Heuristic Triangle Model, aside from modeling interdependencies and giving an assessment framework for understanding priorities and implications of technological decision making, also supports brain-based teaching/learning approaches. Heuristic modeling builds from conceptual abstractions which create mental projections, constructions and involvements which are reality based but provide the versatility of manipulation of ideas within a framework. Caine and Caine [8] stated that brain-based teaching/learning is founded on 12 principles. Heuristic modeling (HM) utilizes these 12 principles in the following ways:

1. The brain is a parallel processor: HM provides a parallel conceptualization so that ideas can be offered and manipulated within this conceptual world to build relationships and implications. For example, examination of the effect of world fossil fuel use and emissions, takes on a framed and focused discussion of the inter-relations, priorities and global/local problems of the issue.
2. Learning engages the entire physiology: HM involves the emotions, attitudes, experience of student's own perspectives as students engage in their own modeling and thinking. From this student modeling, many different and often passionate inter-relationships and approaches are created which demonstrate student views and ownership. Discussion and reconciliation of these ideas involve not only individual student immersion but also class immersion in the discussion and resolution of the many ideas.
3. The search for meaning is innate: HM seeks to determine implications of actions and relationships. Therefore the focus is not in the item itself but in the consequences of this pattern or these patterns – examination of the significance of differences which is the base of understanding meaning.
4. The search for meaning occurs through 'patterning': As stated above, HM provides frameworks, patterning so that implications can be drawn from the differing patterns.
5. Emotions are critical to patterning: HM encourages ownership and understanding which are tied to individual perspectives. Emotions and ownership are part of dealing with individual perspectives, assumptions and the building of new perspectives.
6. The brain processes parts and wholes: As discussed the purpose of HM is to connect specifics to larger realizations and consequences so that patterns and connections of parts and whole actions are made. For example, discussions of cloning bring many specific parts and actions to future wholes of new realizations of new humanity, health, characteristics of humanity, power, etc.).
7. Learning involves both focused attention and peripheral perception: HM draws connections between the focused item and its many implications and peripherals.
8. Learning always involves conscious and unconscious processes: Part of the success of HM is the epiphanies, new perspectives and realizations that are drawn out from new realizations. This also means uncovering old assumptions to understand and deal with the new perspectives which means learning is occurring.
9. The brain has at least two different types of memory: a spatial memory system and a set of systems for rote learning: HM is not only a realization, idea-expansive tool, but it is also a reference point to use in remembering and in studying reference which involves a more rote-type use such as references for analysis, synthesis, discussion and writing ideas.

10. Humans understand and remember best when facts and skills are embedded in natural, spatial memory: HM provides natural references of real events couched in conceptual, spatial memory.
11. Learning is enhanced by challenge and inhibited by threat: The open discussion of individual modeling and class reaction to these models provides a fertile environment for academic exchange, challenge, and inspiration, but a safe haven environment is always maintained for mutual respect and positive learning. For example, discussion of globalization brings many issues of ethics, power, loyalties, many nationalistic viewpoints become passionate. All viewpoints are never threatened by encouraged.
12. Each brain is unique: The HM approach encourages individualization, but also a community where these ideas are brought together. This approach provides for all learning styles and individual expertise, experience and perspectives. It brings us together into a community of thinkers, planners, and learners.

Technological advancements or new technologies are at the peak of the heuristic triangle model because they represent impetus for change and economic growth! Technological development is the core and catalyst for national economic development, global trade and commerce. Such a lack of the developing world's nationally owned technological products, industry and flow of products to global markets becomes a primary cause of the developing worlds' accompanying lack of economic growth and stability. This economic wide gap is indicated by the generalized statistic that the GNP of the highest countries of the developed world is more than 36 times that of the lowest GNP countries of the developing world, along with the realization of appallingly low GNP averages per capita in general in the countries in the developing world.

The paucity of economic stability and growth, of course, leads to basic quality of life problems and humanitarian considerations. In the developed world, even with our magical production of "techno-wonders", the humanitarian side is not a priority when considering the impact or economic profits of a pervading technology. Take, for example, the considerations of the positive and negative impacts of any technology on individual, family, societal life, quality of life issues (such as the cell phone, the Internet, television, etc.) Such value considerations generally become ignored and subverted in favor of the "get rich" or "must have" tactics and strategies. In the developing world humanitarian problems are even more exaggerated, where with little or poorly distributed economic stability and growth, the basic quality of life collapses to intrinsic problems of illiteracy, poverty, social injustice, corruption, lack of resources, poor health care, political and military feudal rule. It turns out that if, indeed, the humanitarian aspects were considered as an important component of technological and economic growth, our technological decisions would begin to have a denominator of great and grave importance and societal relevance. This humanitarian denominator brings to the glitz of the technological growth numerator a balance, reality, and direction of the importance of technology for the support of decision-making of "where and how" society wants to direct technology's impact. The consideration of the impact on society and their humanitarian various values brings important direction and context to the blinding, profit-making directions of technological growth. Such a perspective puts society and individual value priorities and context back into the driver's seat of society, determining a more considered and humanitarian technological growth direction rather than the dominating mercenary perspective.

The third major area of the interdependence of technological growth triangle is the impact of ecology and natural resources. Since the 70's, Rachel Carson's *Silent Spring*, and the resulting ecological movement, ecological consciousness has grown. But with over 50,000 species becoming extinct each year (Rainforest action network, 2004); threatening air and water pollution; significant loss of fish, topsoil, forest resources; increasing problems of waste accumulation; and population growth rates (with their needs) soaring at exponential rates of about 1 billion new people every 15 years; resource sustainability has to be an accompanying design for any pattern of technological growth. So far, such real considerations elude national policies, multi-national-corporations, and do not remain an important priority – perhaps a low level consideration of the decision-making process at best. Making sure that thought and decision-making include ecological basic design is part of a necessary 21st Century ideology if we are going to maintain high technological and economic growth on a planetary scale with any form of humanitarian concerns. It is technologically feasible to even try to attain zero-waste technologies as a reality for this century if such a priority is enacted.

The three areas of technology and technological growth, humanitarian concerns and values, and ecology and natural resources are, therefore, three MACRO interdependent areas that must be part of any technological considerations. These three areas - a metaphor of juggling three equally important balls in the world technological arena simultaneously - becomes the juggling act that must be learned and integrated for the 21st Century of technological growth. If one or more of these balls are dropped, so goes the directions of the problems of the world. In the center of the heuristic model is the indisputable dollar sign and ethics. – these are the engines and energy which drive the three macro concepts. For without making all of these considerations economically feasible - none of them will happen. Also within the center, is the model of ethics. For without ethical considerations and applications of all these areas, success for the future of the world and the planetary community is less likely to achieve the positive combined synergy of our humanitarian needs and potential. Ethics should be a higher consideration than the monetary concerns, but, of course, that is an ideal highest standard that may elude us in practicality. It is however, we believe, sufficient to make ethics of equal dimension to the monetary concept (but no less so) in the dynamics which energize the synergy of technological growth, human values, and planetary ecological balance.

The heuristic triangle (of technological growth, human values and planetary ecological balance) model for technological growth and analysis is a very important teaching and decision-making tool for students and their future roles in technological leadership. As future managers, researchers, employees and consumers of technology, and most importantly as determiners of the new directions of technology, students need to approach decision making from many different perspectives and disciplines. But in addition to considerations from an interdisciplinary view, the triangle model imposes equal consideration for ALL technological considerations on these three signal fronts that imposes ethical and humane considerations for all uses and growth of technologies. This is one of the important goals of a Science, Technology and Society course. In class, discussions of cloning, stem-cell research, genome therapy, and nanotechnology, etc. ALWAYS take on such multidimensional writing, discussion. Readings are used from many different areas and fronts, but discussion then in the end always gets to these three macro areas. Such an approach underscores the importance of multi-level intercultural considerations and avoidance of simplistic answers and reductionist thinking. This heuristic technological model integration becomes a habit in student's thinking and problem-solving and provides inspiration for their future local and global technological directions and development.

VII. Use of Flow Charts

A third approach to provide conceptualization and examination of complex technological and societal applications is the utilization of flow charts for analysis, modeling and problem-solving. Flow charts are logical maps that enable students to use problem-solving strategies in order to understand cognitively, ethically and technologically the various options available correlating to technological and social issues.

In class, the flow charts are used after completion of a reading assignment and as an analytical tool with the case studies. Students can also draw their own flow charts to illustrate a technological problem/issue with their potential solutions and consequences.

This conceptualization presents patterns of expert thinking, connections, and priorities, which further bring out the need for the reality-based discussion and awareness of the issues. Flow charts can be used in many fascinating other ways – such as the analysis of other people's points of view and the ability to contrast these viewpoints and project where the viewpoints lead along with their technological and other implications. Mapping the conceptual connections between technology and its impact on society is the core of the course of "Technology, Society and Culture" and this approach helps the connections to become concrete so they have to be acknowledged and must be dealt with.

The use of flow charts is a dynamic approach that provides a visual mapping of a problem, its implications on society and potential solutions. The use of flow charts also supports Bloom's taxonomy (Professor Benjamin Bloom of the University of Chicago and co-workers who met from 1948 to 1953 devised six major steps or levels to learning: knowledge, comprehension, application, analysis, synthesis, and evaluation). Bloom's Taxonomy encourages a learner to de-emphasize the acts of remembering and reporting knowledge, and focuses on applying and translating information into new forms by applying that information to new contexts and domains by the processes of analysis, synthesis and evaluation.[11] The use of flow charts also support the brain-compatible teaching principles outlined by Caine and Caine. [8]

The following are some examples of the use of flow charts to teach students the implications of technology on society.

- Chernobyl: Nuclear power at what price? (Figure 3)
- Agent Orange (Figure 4)
- The Challenger (Figure 5)

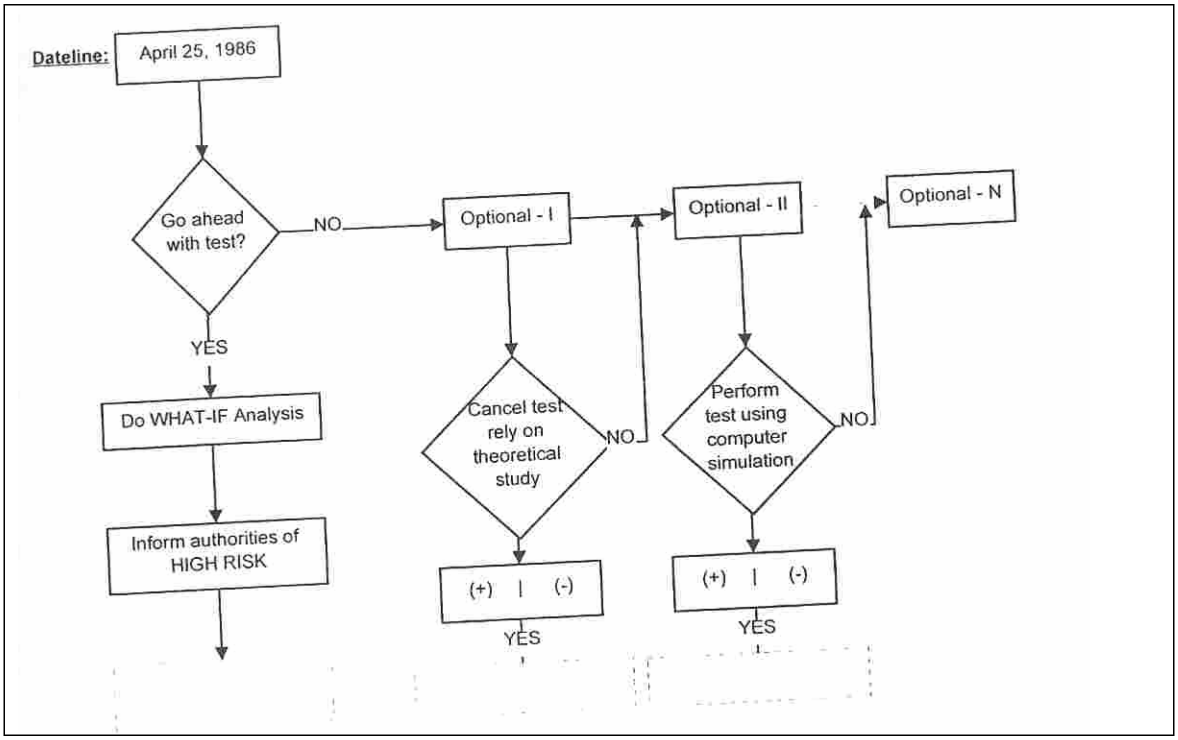


Figure 3. Flowchart for Chernobyl: Nuclear price at what price?

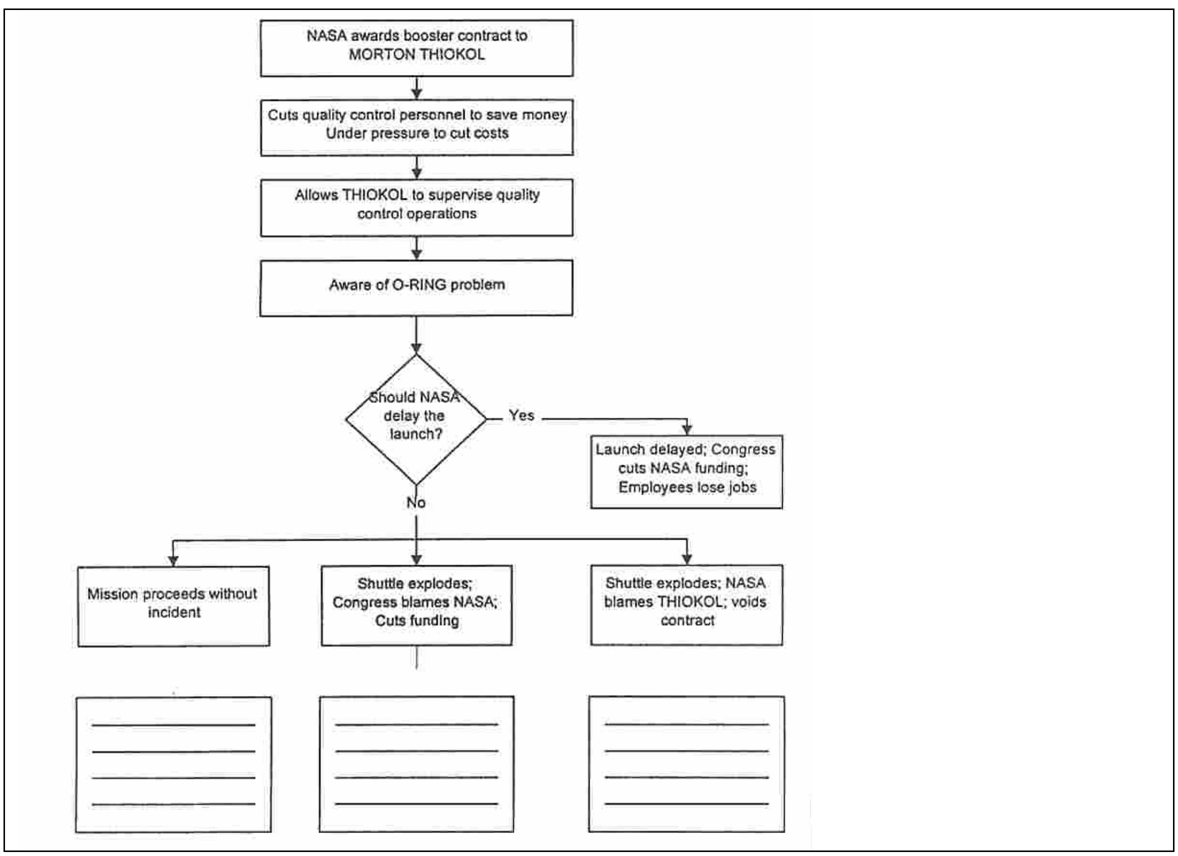


Figure 4. Flowchart for Challenger case study.

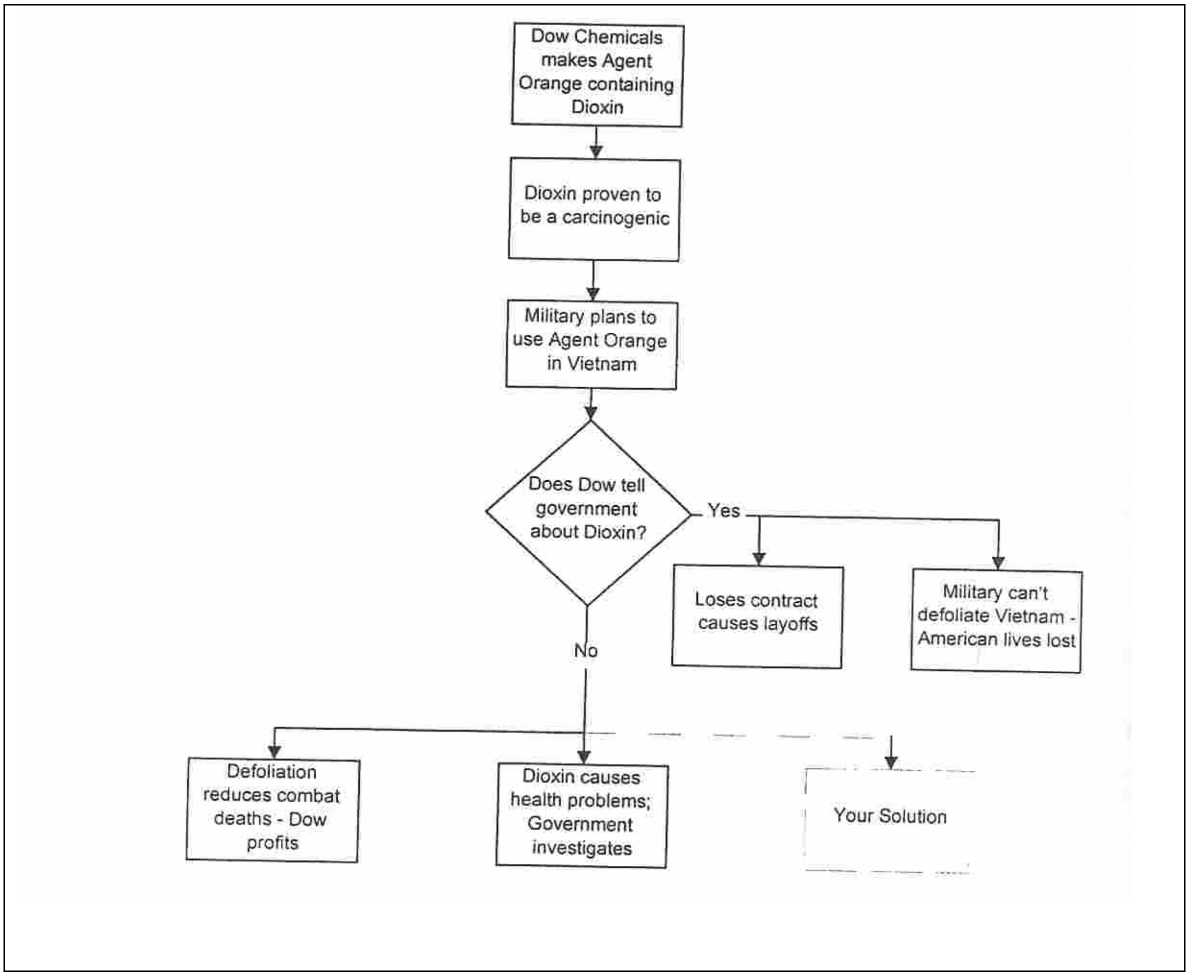


Figure 5. Flowchart for Agent Orange case study.

VIII. Case study Integration

A fourth approach employed for brain-based and constructivist teaching/learning strategies is the case study integration. The objective that fuels the case study framework is to encourage a deeper analysis of information into categories that ignite student interest. The diverse categorical presentation of the implications of technology pushes students to get out of their comfort level and into processing information in focused, new ways. Case studies take students beyond information memorization and instead mandate creative, analytic, and evaluative thinking. This process creates formats in which more students can attach their personal learning styles and interests to the concepts presented.

Cases that are given to the students are similar to those used with flowcharts (Chernobyl, Exxon Valdez. Challenger, Three Mile Island, Agent Orange, Yucca Mt., asbestosis in Libby Montana, genetically modified foods). Students are asked to research the case and fill out a flowchart that will provide them with a linear map that guides their written and oral presentation. The focus is to use critical thinking skills to create potential, viable, solutions to the problems presented in the case. The case study integration focuses on two methodologies: Intergenerational justice, and the power of one.

1. Intergenerational justice: How do actions of today impact lives of tomorrow? STS course prepares students to make ethical decisions that could potentially make positive impacts now, while influencing generations of the future. This ethical impact concept could be construed as too global, but in this course it is narrowed to issues and practices that students can understand, integrate, and relate to. The goal is to cognitively remove students from their cocoon of technological immersion and immediate personal gain, to understanding how the ethical use of technology can improve and impact the world for future generations in positive ways.

2. The power of one: One person can make a difference. Teaching this course from an ethical base using practical and process oriented formats to reinforce the power of one and intergenerational justice helps students understand current and future global issues and immediate personal decisions. Students are asked to identify and evaluate technologies (e.g. stem cell research, Internet use, medical treatments) and their impact on society (e.g. better health, effective information faster, longer life spans). It is important for students to understand how the use of technology impacts all at personal, community, regional, national and international levels.

The case studies contain both positive and negative societal impacts. They integrate real life events that encourage students to create effective, reality-based solutions. Case analysis provides a voice to perceptions about themselves, technology and the world around them. Students learn to identify problems and speak from the perspective of individuals who lived through the case events. This identification creates awareness and understanding of global problems that might have otherwise been misunderstood or even ignored.

IX. Conclusion

Four constructivist and brain-based methodologies of Third World Fair, Heurist Triangle Model, Use of Flow Charts, and Case Study Integration provide concrete tools and approaches to teaching a challenging, encompassing, perspective-changing class. We find that the utilization of such methodologies ground students in multi-dimensions of the realities of global inequities and social and technological responsibilities. It is our hope that in the sharing of these methodologies we can further promote in students everywhere, the future reality and urgency of technological social leadership to appropriately and responsibly help to develop our global community.

REFERENCES

1. Houston, J.E. (Ed.). (1995). *Thesaurus of ERIC descriptors* (13th ed.). Phoenix, AZ: Orynx Press.

2. Shapiro, G (2000). *Leadership for constructivist schools*. Lanham, MD: The Scarecrow Press, Inc.

3. Hunter, M. (1994). *Enhancing Teaching*. New York: Macmillan.

4. Hilton, J., and Perdue, C. (2000). *Mind Matters CD-ROM*. Upper Saddle River, NJ: Prentice Hall

5. Pearson, H. (2003, December 3). Prion proteins may store memories. *Nature*. Available online: http://www.nature.com/news/2003/031229/pf/031229-2_pf.html

6. Rose, C., and Nichol., M., (1997). *Accelerated Learning for the 21st Century*. Delacorte Press: New York.

7. Rimmele ,U. A Primer on Emotions and Learning. Available online: http://www.oecd.org/document/12/0,2340,fr_2649_20616271_33813516_1_1_1_1,00.html

8. Caine, R.N., & Caine, G. (1991). *Making connections: Teaching and the human brain.* Alexandria, VA: Association for Supervision and Curriculum Development, 80-87.

9. Cardellicho and Field (1997). Seven Strategies That Encourage Neural Branching. *Educational Leadership*. March, 33-36.

10. Eichler, B., Hjorth, L., Khan, A., & Morello, J., (2004). *Third World Studies: Giving First World Students A Real World Experience*, Presented at 30th Annual Third World Conference, Chicago, Illinois, March 3-6, 2004.

11. Bloom, B. (Ed.). (1956) *Taxonomy of educational objectives: The classification of educational goals*. New York: McKay.

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