Learning, Emotion, and their Application for Teaching

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> The scientist's voice need not be the mere record of life as it is; scientific knowledge can be a pillar to help humans to endure and prevail.
>
> Antonio R. Damasio
> *Descartes' Error: Emotion, Reason and the Human Brain*

In 1994, after teaching at universities for 20 years, I was selected to participate on a retreat organized to improve the preparation of our students in the College of Science and Mathematics at Towson University. To ready myself, I read several papers on student learning and considered to be best practices in teaching university and college students. To my surprise, the lecture and laboratory method I had used was shown in many of these papers to be an ineffective way to ensure that students learned the material. This prompted me to continue learning about what works best to support student learning. The description below is a compendium of what I have learned about teaching during the last twelve years, integrating information about learning obtained from neurosciences research along with empirical evidence about teaching found in pedagogical literature.

When required to teach undergraduates, faculty members in higher education naturally choose to lecture because we remember this as being very effective method for our own learning. We emulate the best of our own university professors and model our teaching after theirs, using 60- to 90-minute lectures as a major component of disciplinary information delivery to students. Lecturing is effective for our own learning style because we are highly motivated sequential learners. A+ students (our learning cohort) learn in spite of poor quality teaching. Our intelligence, motivation and perseverance stimulate our thirst for knowledge and skill acquisition. Unfortunately, given its widespread use, lecturing is the least effective method for teaching the majority of student populations (McLeish 1968; Hartley and Davis 1978; King 1992; Ward and Bodner 1993; Dunn 1995; Bonwell and Eison 1999). At best, lecturing is effective for learning assessed with recognition tests (multiple choice, fill-in-the-blanks, etc), but works badly for understanding and retention (Halpern and Hackel 2003). The structural constraints of lecture halls and rigid schedules compound the problem when teaching non-linear and sometimes unmotivated learners. While economically effective for the institutions of higher education, lecture halls are not the best learning environment for students because they create physical barriers preventing students and faculty from engaging

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in active, collaborative and deep explorations of the subject matter.

Because we were trained in our disciplines but not trained to teach, we need to learn about effective teaching practices that result in learning (Shulman 1986, 1987). This calls for effective faculty development initiatives to promote faculty awareness and understanding of the best practices in teaching. Disregarding academics' natural curiosity to find how things work, most professional development initiatives introduce faculty members to a variety of teaching methods without providing them the opportunity to learn why they are effective. Also, faculty development is often devoid of the opportunity of continued contact with faculty peers in the form of faculty learning communities, which have been found to be most effective way to modify and sustain changes in faculty teaching practices (Cox 1995, 2001, 2003; Palmer 1998, 2002). In my experience as director of faculty development at Towson University, I found that neuroscience research information about how people learn can also be a powerful incentive to motivate faculty to use classroom strategies that have great potential to result in student learning (Bransford 2001).

Learning and Attention

For learning to occur, people must concentrate on the subject at hand and pay attention. Brain attention mechanisms are essential for learning because they limit sensory input to narrow ranges containing the potentially most useful information. The thalamus, a small nucleus deep within the brain, filters sensory information such as sound, tactile and visual inputs when we are paying attention to the subject at hand. It allows our attention to focus primarily and automatically within narrow ranges containing high contrast or emotional intensity (Crick 1995). A useful way to understand the importance of the filtering occurring during attention mechanisms is to consider that the chaotic mental environment of schizophrenics is the result of unfiltered sensory information reaching the cerebral cortex (Fishbach 1992).

An interesting experiment done at the University of Illinois illustrates this point. Two teams of four students each (black shirt and white shirt teams) passed basketballs to one another. Research subjects were to determine how many times the ball was held by the white shirt team. After 35 seconds of the exercise, a man dresses like a gorilla entered the room and thumped his chest. Only 50 percent of the experimental subjects saw the gorilla (Simons and Chabris, 2004). Our aim when teaching should be to create an environment that promotes student's concentration on the subject matter.

While lectures are typically 50 to 75 minutes long, studies show that the human brain is only able to pay attention for 10 to 20 minutes. An interesting study illustrating this point shows that students' average heart beat slows down after 20 minutes of lecture and continues decreasing to the end of lecture to a rate equivalent to drowsiness (Bligh 2000). This physiological effect regarding students' attention span is supported by pedagogical research on the subject. Bonwell and Eison (1999) showed that students are off task, not even thinking about lecture material for 50 percent of lecture periods. Hartley and Davis (1978) researched students' note-taking during lectures and found that students attention is highest during the first 10 minutes of the lecture, and then decreases after that. Therefore, lectures or information-intensive exercises that go beyond 10 to 20 minutes without pause are not effective because the learners' attention span has declined to a point where learning no longer occurs.

One rationalization given by faculty for lecturing is that they must "cover the content" of the course. McLeash (1968) has shown that students forget most of what was said in a lecture as soon as they leave the lecture hall. It does not seem to matter how well the professor covers the material in lecture; what matters is how students internalize the subject matter on their own. McKeachy (1999) has shown that at the end of the course student involvement during classroom time, such as in class discussions, is far superior to lectures for student retention of information, transfer of knowledge to new situations and the development of problem-solving abilities. Thus, care should be given to designing activities in which students participate in collaborative group activities or dialogue that will allow active processing of the information imparted in the lecture.

Learning and Memory

Humans are evolutionarily programmed for learning. Learning involves physical changes in the brain, specifically, modification of the strength of connections between neurons. At the cellular level, neurons occupied in learning a specific problem are linked to one another in a network. Neuroscience research shows that learning involves the strengthening of neuronal networks, which are chains of neurons carrying related information and firing at the same time. Neuroscientists are fond of saying that "what wires together fires together," meaning that coordinated firing of neurons processing the same information is crucial to learning (Hebb 1949; Edelman 1989, 1992; Malenka and Nichol 1999; Malenka 2003; Malenka and Bear 2004).

Once attention has been established, learning also requires the presence of intact memory. While we are thinking about a complex problem, we must be able to hold the discrete elements of the problem in the hippocampus, "the table top" of our brain, in a process called short-term memory. Short-term memory (lasting from minutes to weeks) holds only up to six units of foreground information at a time (Miller 1956). This is a good lesson to learn for those among us who like to crowd large amounts of facts in our lectures. Long-term memories (lasting from weeks to years) are the result of transcription of genes and protein synthesis to create new synapses or strengthen those existing between the involved neurons.

Ultimately, a clear understanding of memory and learning requires us to study them at the cellular and molecular level. Although the study of learning in humans has not yet reached the molecular level, it would be very surprising if such mechanism is not also operational in humans. Indeed, our understanding of how the brain works was first discovered in mollusks and rodents and other animal models (Ramón y Cajal 1909).

In the words of Nobel Prize winner, Erik Kandel, in learning, "a dialogue is established between genes and the synapse" (Kandel and Hawkins 1992; Albertini et al. 1994; Kandel 2000; Kandel 2001). For more than two decades, Kandel and his co-workers have carried out studies of the sea slug Aplysia to understand the molecular correlates of learning. Short- and long-time memory formation share an evolutionarily conserved molecular switch called CREB (cyclic AMP-response element binding protein) to initiate the process. In the 1990s, these researchers snipped out a set of the slug's neurons involved in memory storage. They found that adding a CREB-disrupting compound halts the molecular long-term memory process. This sign of CREB's involvement in memory launched a series of studies that deciphered the memory process in sea slugs and in organisms that are capable of forming more complex types of long-term memories such as mice, rats, and primates (Milner et al. 1998; Squire and Kandel 1998; Mayford and Kandel 1999). In a simplified way we can say that the process of creating lasting memories begins when the neuron's endings, or dendrites, receive signals. The electrochemical signals generated during nerve transmission induce reactions involving a protein (protein Kinase A), which in turn activates CREB in the nucleus. The jump-started CREB protein activates genes in the cell's DNA. These genes are transcribed into messenger RNA which is used as a blueprint to produce proteins that secure a memory (Steward and Barker 1992; Sullivan 2003).

In practical terms, the process of establishing long-term memories requires time-on-task by the learner. Repetition of the concepts being studied by our students using different sensory modalities will cement the learning not only by insuring stronger connections among neurons, but also forming new ones that ensure recollection of the concepts, thus building higher level learning (Bloom 1956).

Recent studies show that older adults can learn as effectively as the young because memory consolidation in the learning process continues during our entire life span. Happily for those of us beyond middle age, the brain is quite plastic, showing growth in areas of use even in older adults (Maguire et al. 2000). New information regarding the ability of neurons to divide in the hippocampus (site of memory) is an unexpected and exiting new development that informs us of our continued capacity to produce neurons in the adult brain (Eriksson et al. 1998; Gould et al. 1999).

Experienced and Novice Learners

The development of imaging techniques has allowed scientists to observe the brain in action in specific cognitive tasks at the moment the task is taking place. For example we can now observe the areas of the brain responsible for speech, face recognition, and decision making (among many others) lighting up in brain scans. One of the interesting findings gained through brain imaging is that experience seems to change the way we process information in learning. Experts size up situations when processing complex information of their expertise by identifying relationships and patterns among elements of a problem or issue that novices do not recognize (Bransford 1999). Additionally, experts use less energy than novices in solving problems, because they use fewer neurons to solve a given problem. In a way, experts engage in "chunking," a process of combining related elements into a unit. Reasoning like a good physicist, historian, or physiologist involves more than logical thinking. Specific knowledge, both conceptual and methodological, is used to frame the expert's reasoning. In contrast, novices most often fail in reaching quick solutions to complex problems, not because they are not using logical reasoning, but because their thinking is not enhanced by the same methodological and conceptual framework already known by the experts (Bunce 2001; Rickey and Stacey 2000).

Research shows that novices use significantly larger areas of their brains to process information and, therefore, are using more energy and effort to think and to understand (Presenti 2001). Studies show that the brain areas used in a new task are often different than those used in the same task after is learned. For example, once a person has learned to read (Eden 2000; Shaywits et al. 2004) or a new language (Raichle 1996) images in the brain show different and smaller brain areas being used after learning has occurred.

To help our teaching practice, we must remember that as we become more proficient about a certain topic we "chunk" related information, freeing more space for new information in the hippocampus (Bransford et al. 1999). Multiple repetition of a concept or skill creates an easier processing of the same information in the future. We learn to link-related tasks or concepts as we become more sophisticated learners (La Berge and Samuels 1974; Schneider and Shiffrin 1985; Anderson 1982). Once we understand a concept's many component parts, we can use the entire conceptual thread as one "chunk" to be placed on our tabletop.

Excellent teachers "chunk" subject matter elements in their lectures and also in outlines that cover the material. Faculty need to keep in mind that their students are novices learning the material. They have not yet developed the ability to "chunk" related information into discrete blocks that can be called upon as units when trying to understand complex concepts.

Learning while Dreaming

Dreaming may be part of a mechanism our brain uses in memory consolidation of newly learned material. Neuroscience research has shown that memory processing occurs in humans during rapid eye movement sleep (REM). Subjects denied REM sleep are unable to remember previously learned information such as observed patterns (Karni et al. 1994). Interestingly, experiments carried out in rats have shown that gene zif-268, which is associated with learning, is selectively upgraded during REM sleep (Ribeiro et al. 1999). Therefore, sleep appears to be an evolutionarily conserved mechanism to promote learning.

Experiments carried out by Maquet and his coworkers (2002), have shown that human subjects who are asked to detect texture differences were affected by sleep in attaining memory consolidation. With four training sessions the same day, performance worsened unless the subjects napped. After a single training session, subjects' performance improved after the first night's sleep. The improvement was significant if the subjects were allowed to sleep during the first part of the night (non-REM sleep), but it was optimal if the subjects are allowed to sleep and dream (REM sleep).

Participants in studies of dream activity have been shown to produce elaborate story telling of newly learned material. Human interactions occurring at the same time the material is being learned (such as in collaborative learning) add to the story telling of our dreams (Bloom 1956; Mentakowski et al. 2000). Physiologically, if the material taught previously is brought back again in the next class period and discussed again, chances are high that that material will consolidate in the hippocampus (short-term memory) and in various areas of the cortex for future recall, insuring that a deeper and higher level learning occurs.

Making Sense in Learning and Constructivism

In spite of the overused analogies about the brain being like a computer, human memory is less precise but more adaptive and inventive than computer memory. Our brain tends to complete partial information by creating images that fill in missing parts of images to complete a known entity or structure (Crick 1995). Our innate need to make sense can sometimes make us fill in details in pictures that are not correct because our brains don't have the accuracy of a computerized database (Bransford et al. 1999; Svinichi 1994). We have evolved to make meaning and to fill in missing parts of a story we are creating about a given phenomenon. People learn by putting together a "construct" of disparate segments of a certain concept and by comparing this construct with previous knowledge about the concept being learned. Pedagogical research calls this process, "constructivist theory" (Perry 1981). The learner constructs an understanding of the concept based on the sensory information provided. Then the learner superimposes this "construct" on previous memories of related experiences or phenomena (Svinicki 1994). Something that cannot be reconstructed by the learner's mind cannot be said to have been learned at all (Leamson 2000).

Therefore, the professor (the expert) must ensure that the correct concept has been constructed by the student's brain. The creative urge of human beings should not be suppressed by demanding endless recitation of facts, which can be easily obtained by consulting existing and readily available information. Restricting the framework for disciplinary material being studied should also be avoided because, by becoming too prescriptive, we block students from creating their own frameworks and schema that are the basis of deep learning. Rather, these creative impulses should be supported and encouraged to progress through an active and cooperative learning framework (Chickering and Gamson 1987).

Additionally, our brain organizes bits of related information into categories, which has been hypothesized by Miller (2000) to be stored in parallel regions of the cerebral cortex. The connections between these parallel regions correspond to neurons arranged in vertical neuronal columns in the cortex, which have been extensively observed in histological and physiological studies since the beginning of 20th century (Ramón y Cajal 1909). On the other hand, connections between columns have not been characterized as well. Faculty members can utilize this information from neuroscience research to design learning experiences for their students by asking them to compare the characteristics of a given issue before asking them to contrast the characteristics.

Affect and Learning

As shown in extensive literature (only a small number of which is shown in the following references), collaborative learning is a very powerful tool to promote student learning (Goodsell et al. 1992; Smith and MacGregor 1992; Bosworth 1994; Gibbs 1994; Emerson et al. 1994; Miller et al. 1994; Bykerk-Kauffman 1995; Cooper 1995; Dougherty et al. 1995; Mathews et al. 1995; Cooper 1996; Malacinski and Zell 1996; Stetson 1966; Zell and Malacinsky 1994). Meta analyses of collaborative learning strongly support the effectiveness of this method in the classroom to promote deep learning, retention, and transference of information to novel situations (Johnson et al. 1981; Springer et al. 1999; Bowen 2000).

I suspect that that the efficacy of the collaborative learning methodology probably depends on the social interactions among individuals involved in the learning. These social learning groups probably provide emotional contexts that focus the cognitive process and strengthen long-term memory. We already know that learning opportunities can be optimized to get students more deeply engaged in learning by drawing on and expanding on what they already know (Silverman et al. 2000; Sivinicki 1994). In a collaborative setting, ideally students should be able to think, articulate thoughts and be open to constructive challenge and debate.

Neuroscientists are providing evidence that emotion is intimately linked to cognition and learning (Damasio 1994, 1999, 2003). A group of researchers has shown that subjects remember emotionally laden film clips much longer that neutral ones. The amygdala, a part of the limbic system (a center of emotion processing in the brain), is highly active when subjects are viewing scary film clips (McGaugh et al. 1996). Research has shown that human attention and memory are focused automatically and primarily within narrow ranges that contain high contrast or emotional intensity (Bransford et al. 1999; Kandel and Hawkins 1992). Apparently, emotion laden information is immediately and preferentially processed by areas of the brain carrying on cognitive tasks.

Additionally, humans are highly attentive to faces when scoping the environment. For instance, one study followed the path of observers' eyes looking at pictures and found that the majority of their time was spent looking at faces (Kanwisher 2001). Our species has evolved very sensitive detectors for recognizing emotional states in others. For instance, Damasio (1994) has shown that we have two distinct and specific areas in the human brain that can accurately control and discern a genuine, emotionally evoked smile from a forced smile. Emotional smiles are controlled and perceived by the limbic system, which includes the hippocampus. The hippocampus is also the control site for short-term memory and thus, many memory and learning pathways are shared at this level. In contrast, forced smiles, as when we are posing for a photograph—called a "Pan American smile" by one researcher thinking about the forced smiles of a flight attendant (Dolan et al. 1996)—are controlled by an area in the parietal lobe that controls muscle movements and not a part of the limbic system. Thus, any learning situation framed in a positive or negative emotional state and processed in the frontal lobe as a "feeling" has a greater potential to be stored in long-term memory in cortical neurons (Damasio 1994, 1999, 2003).

Our ability to remember faces was probably evolutionarily conserved because it was extremely important for our species' survival. Currently, losing this ability can have the disastrous consequences of memory and cognitive failures experienced by people suffering from prosapognosia, the inability to recognize familiar faces (Bodamer 1947). This inability to process familiar faces is also expressed in autistic patients (DeFrancesco 2001). In our Neolithic past, it was essential for our survival that we quickly detect those who were friendly from those who could do us harm. Our brains have not changed very much since that time, and those survival strategies may serve us now in our learning processes (Mithen 1996). It is interesting that educational research shows that student evaluations of the instructors at the end of the semester correlate significantly and strongly with student evaluations provided three minutes after the instructor enters their classroom (Seldin 1999). A possible explanation for this fact is that students quickly assess the professors' personal investment in students' success as learners. Learning is an intensely cognitive and emotional experience centered in the frontal cortex but focused by the limbic system, which is the site that controls emotion (Silverman and Casazza 2000; Sylwester 1995).

To summarize, learning produces substantial physiological changes that can be measured in the laboratory down to the molecular level. In practice, I suggest that these changes can also be perceived immediately by experienced observers situated close to the learner through changes in facial expression, body language, and subtle changes in the color of the skin. Teaching professors talk about reading "Aha" moments in their students' faces when they finally understand a difficult concept. Such changes are probably used to advantage by experienced teachers, and they can be learned by the novice teacher to diagnose the level of understanding experienced by their students.

One's genetic learning program is constrained by culture and educational history. Collaborative learning can allow interchange of concepts and the sharing of prior knowledge or misconceptions in a manner that a single individual might not have considered. In this instructional approach, students become the main agents of learning. Students take more initiative for learning, but do so in conjunction with other students to make learning socially interactive rather than the one-way transfer of prepackaged information in lecture-based or computer-based instruction (Hansen and Stephens 2000).

Inspiration in Teaching and Learning

If the burden of learning is directly on the student, as shown by neuroscience and pedagogical research, what then is the role of the teacher? The teaching professor has an important role which cannot be duplicated by computers or simulations. "Hands-on- teaching" that does not actively and collaboratively engage students in a learning situation is not enough to produce learning, as evidenced by the failure of those of us teaching science laboratories. Our students go through the mechanical motions of the exercises but display profoundly deficient understanding of the concepts that the laboratory activity is designed to elicit. The difficult role of the teaching professor is to select and focus on the most important disciplinary material for students to learn and to design active and cooperative learning opportunities that promote students effective and long-lasting constructs of the subject being studied.

Another important role of the teacher is to inspire and motivate students to become cognitively engaged in the learning process. The inspirational and motivational role of the faculty member has a basis in our social nature that has made us successful survivors in our evolutionary history. We have areas in the hippocampus of our brains that have evolved to route emotionally laden experiences directly to the frontal lobe cortex where higher order thinking and planning take place (Damasio 1994, 1997, 2003). Placing newly acquired disciplinary material into a context that makes sense to the learner facilitates connections between the material being learned, previous experiences, and understandings of similar concepts, resulting in the re-articulation of this material. Thus, the student is constructing his/her own knowledge based on interactions with a group of learners and an empathetic teacher, allowing his/her newly acquired concept a greater chance to be remembered.

Some faculty members frequently express the misconception that expert knowledge in one's discipline and publication-rich involvement in research are sufficient to support excellent teaching by the mere fact that they possess cutting edge information in their field. This misconception, hard to eradicate, as are all misconceptions, is not supported by the pedagogical literature. The structure and activities of lectures and study groups work must be carefully designed so that the social and emotional contexts are appropriate for promoting social interaction and deeper learning. This can occur only when we back up our disciplinary knowledge with understanding use of the best practices provided to us by the accumulated body of knowledge regarding teaching and learning (Angelo 1993; Bloom 1953; Brophy 1992; Caprio 1996; Chickering and Gamson 1987; Hansen and Stephens 2000). Disciplinary knowledge exists separately and independently from the pedagogical knowledge needed to cause student learning. Only expert teaching professors have acquired both disciplinary and pedagogical knowledge to prepare them to support student learning in their own discipline.

Many of the subjects we teach are complex and are difficult to categorize or reduce to their lowest common denominator (King 1992). Reduction of the material covered is not the same as simplification of the material if it does not inform sufficiently. The lack of rigor inherent in such practice results in the *McDonaldization* of higher education. Extending the metaphor, mass produced foods are clean, expedient, efficient, and affordable, but they do not constitute a wholesome, nutritionally balanced meal. Oversimplification of disciplinary material results in slick and superficial renditions: clean, efficient, and affordable, but not necessarily effective or lasting.

Besides being experts in their fields and knowledgeable of pedagogical best practices, teaching professors must care deeply for their students. Important and inspiring work from professional educators, such as Parker Palmer, Stephen Brookfield, and Louis Schmier, among others, informs faculty members on the importance of the holistic and individual rapport created between teacher and student as essential in learning. Students may be novices on the material we are teaching them, but their evolutionary history makes them experts in evaluating our commitment to their learning. I believe interpretations of the role of affect in consciousness and learning are important elements that explain the effectiveness of cooperative learning and the lasting effectiveness of the few beloved professors we all remember.

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