Teaching Implications of Information Processing Theory and Evaluation Approach of learning Strategies using LVQ Neural Network

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Abstract: - In terms of information processing model, learning represents the process of gathering information, and organizing it into mental schemata. Information-processing theory has definite educational implications for students with learning and behavior problems. Teachers with a greater understanding of the theory and how it is formed to, select learning strategies in order to improve the retention and retrieval of learning. But it must also be taken into consideration that the learning environment has specific effects on academic achievement. Socialization alters the levels of stress, confidence, and even the content knowledge. Social support provides encouragement, stress reduction, feedback, and communication factors which enable learning. Furthermore, an evaluation of 4 learning strategies attempted via a well-formed LVQ Neural Network.

Key-Words: - information processing, memory, matacognition, learning strategies, general education classroom, learning, behavioral problems and neural networks.

1. Introduction

While behaviorists talk about learning as the result of the interactions between an organism and its environment or changes in responses, the cognitive approach focuses on the knowledge which guides those responses. Cognitive learning theory focuses on what happens in the mind, and views learning as changes in the learner's cognitive structure.

The rapid proliferation of computers has encouraged the use of computer model to explain learning. Information-processing theory, one of the dominant cognitive theories since 1970, attempts to describe how sensory input is perceived, transformed, reduced, elaborated, stored, retrieved and used. In terms of information processing model, learning represents the process of gathering information, and organizing it into mental schemata (organized structures of stereotypic knowledge). Learning is defined as the process of acquiring new information; while memory is defined as the persistence of learning that can be assessed at a later time.

2. The information-processing theory

At a first glance, the gathering and storage of information may seem less efficient as a learning system compared to the behaviorist notion of associations between stimuli and responses. But learning through information gathering has an advantage: flexibility. For example, if your route to home is represented by a mental map of the city, not fixed series of responses, you can take an alternative route when traffic is bad. This is an effective behavior and depends on remembering information at the right time.

The information processing approach has led to a model of memory which is based on a computer analogy. By the late 1960s Atkinson and Shiffrin [1] proposed the most influential model of memory (see figure 1). It was assumed that information came in from the environment, was processed by a series of temporary sensory memory systems (a part of the process of perception), and then fed into a limited capacity short-term store. This was assumed to act as a working memory. That is, a system for holding information and allowing it to be used to perform a wide range of cognitive tasks, including transfer into and retrieval from long-term memory.

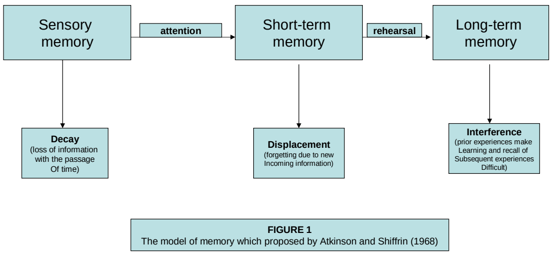

Fig. 1: The model of memory proposed by Atkinson and Shiffrin (1968). According to this model, information is processed in a sequence of steps. Memory is regarded as having three separate stages: sensory memory, short-term memory and long term-memory.

The first of the three categories of memory, the sensory memory (visual and verbal), has a high capacity of information, but a very short life of just a few milliseconds. The information quickly fades unless we actively attend to it and perceive it.

Since we are bombarded by sensory stimuli, we must selectively focus on those elements which are likely to be most significant. This selection occurs through the process of attention. Attention is important because it selects the information which becomes available to memory. We cannot make material meaningful, organize it, associate it, or visualize it if we do not get it in the first place.

Unlike sensory memory that has short duration and high capacity, short-term memory (STM), has a longer duration and a limited capacity (5-9 meaningful items or chunks, see figure 2) based on continual rehearsal (manipulating the stimulus information in order to code the information for long-term memory). STM can be thought of as activated memory (working memory), necessary for feeding information into and out of the long-term memory.

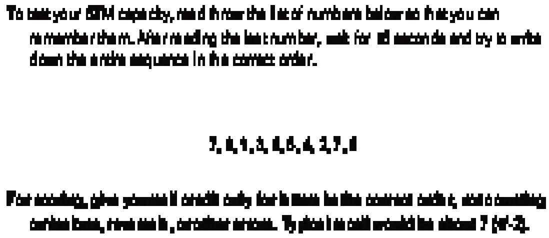

Fig. 2: A test of short-term memory. To test your short-memory, follow the instructions in the box.

The last part of the model is the long-term memory (LTM). The term LTM is reserved for memory of experiences and knowledge that occurred at some point in time prior to the immediate past or near present. In a computer, LTM would be analogous to a storage device such as a hard disc. LTM can be divided in two types, *declarative memory* and *nondeclarative memory*. Declarative memory (or conscious memory) describes the remembering of facts, names, objects, and can be further divided into *episodic memory* (autobiographical, memory for personal experience) and *semantic memory* (the memory for facts and verbal information). Nondeclarative memory (or implicit memory) describes the memories that can be recalled without conscious effort and can be divided into *procedural memory* (memory for performing learned skills and tasks), *associative learning* (or classical conditioning, where memory is a process of forming ties between a stimulus and a response), and *nonassociative learning* (a learning whereby the individual responds to things without conscious attention) (see figure 3).

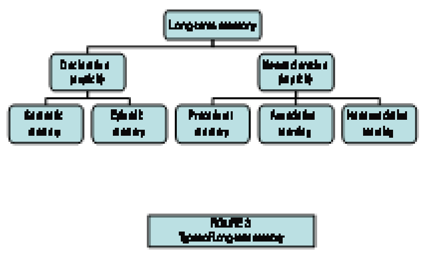

Fig.3: Many psychologists believe that long-term memory can be divided into two major types, declarative memory and nondeclarative memory. Declarative memory can be further divided into episodic memory and semantic memory. .

We have to say that the figure 1 presents a simplified model depicting the sequence of stages in which information is acquired. Although the figure implies that each activity is relatively separate, these processes are highly interactive. Also this processing system is controlled by executive functioning, which assists the learner in coordinating, monitoring, and determining which strategies the learner should employ for effective learning [2].

LTM and STM are two different processing systems. In order to answer the questions what sort of processing takes place in STM and how this relates to what is retained in LTM, Baddeley and Hitch (1974), proposed a three-part model of working memory [3]. The three-component model contains a *central executive* control system which is an attentional control system that regulates two subsidiary slave systems: one is the *phonological* (or *articulatory*) *loop* while the other is the *visuo-spatial sketchpad* (see figure 4).

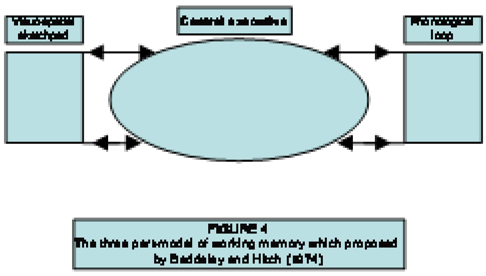

Fig. 4: Baddeley and Hitch (1974) proposed a three-part working memory system that contains a central executive control system that regulates two subsidiary slave systems: the phonological loop and the visuo-spatial sketchpad.

The phonological loop is thought to be responsible for coding acoustic information in memory. The visuo-spatial sketchpad is thought to be responsible for coding visual-spatial codes in working memory. At the center of the model is the *central executive system*, a control center that presides over the interactions between the two slave systems and LTM. In recent years an additional component of the *episodic buffer* has been proposed from Baddeley [4]. A component responsible for integrating information from the subcomponents of working memory and long-term memory. This is assumed to link the component of working memory with LTM and to be the basis of conscious awareness. The four-part model suggests that auditory and visual rehearsal occurring during learning increase the working memory's interactions with LTM, raising the probability it will be stored.

The specific processes in the information-processing system (i.e, attention, working memory and long-term memory) are coordinated by the *executive functioning* or *matacognition* (see figure 5), [5]. Matacognition is considered to have two components [6]:

1. An awareness of what skills, strategies, and resources are needed to perform a cognitive task
2. The ability to use shelf-regulatory strategies to monitor the thinking process and to undertake fix-up strategies when processing is not done smoothly.

Terms associated with Executive Functions

- Abstract reasoning
- Anticipation
- Attentional control
- Behavioral initiation
- Behavioral regulation
- Common sense
- Concept formation
- Creativity
- Estimation
- Fluency
- Goal setting
- Hypothesis generating
- Inhibition of impulsiveness
- Mental flexibility
- Organization
- Planning problem solving
- Rule learning
- Self-control
- Self-monitoring
- Set formation and maintenance
- Set shifting
- Working memory

FIGURE 5
Source: Adapted from (Baron, 2004, p. 134)

Fig. 5: There are many terms that researchers use to describe executive functioning.

3. Information processing theory and neurodevelopmental disorders

Students with learning and behavior problems have learning disabilities (they have trouble with processing, organizing, and applying information), emotional and behavioral problems (withdrawal, aggressiveness…) and, mild cognitive disabilities (they have difficulty meeting the cognitive and social demands of the general education classroom). These students have many learning needs. They have reading problems (decoding words, and comprehension), writing difficulties (written expression, handwriting, and spelling), mathematic difficulties, and difficulty in performing learning skills that could help them learn easier (attention, memory, reasoning, metacognitive skills, and motivation) (see figure 6).

Fig. 6: Students with learning and/or behavior disabilities have a range of learning and emotional problems. These problems can be divided into three categories: no academic, academic and interpersonal/intrapersonal problems.

Working memory has been an extremely influential concept that in the last 20 years has guided empirical investigations of developmental disorders. Dyslexia, arithmetic learning disability, specific language impairment, developmental coordination disorder, attention deficit hyperactivity disorder, autism, Down, and Williams syndromes appear to indicate deficits in this part of the memory system [7]. In addition, evidence from studies that have specifically investigated the central executive functioning of children with learning and behavior disabilities, seems to indicate deficits in this part of the memory system [8].

4. Teaching implications and applications of the information-processing model

Information-processing theory has definite educational implications for students with learning and behavior problems. The teacher who knows the theory can modify his/her teaching and learning environment to facilitate directing a student's attention and perception of the incoming information, make suggestions about students using metacognitive strategies, teach skills to stay active in working memory and ways to storage the information in LTM.

School-based interventions for ADHD include a range of modifications to the classroom environment, academic tasks, in-class consequences, home based programs, and self-management interventions. Compelling evidence exists that ADHD comprises a deficit in the development of behavioral inhibition. The inhibitory deficit that characterizes ADHD disrupts the formation and execution of the next 4 executive functions [9]:

1. *Nonverbal working memory* (the ability to maintain internal representations of sensory-motor information)
2. *Verbal working memory* (the internal representation of speech)
3. *Self-regulation of affect/motivation/arousal* (the ability to delay or modulate emotional reactions elicited by stimulus events), and
4. *Reconstitution* (refers to the verbal and nonverbal analysis/synthesis skills that contribute to the flexibility and creativity necessary for planning solutions) (see figure 7)

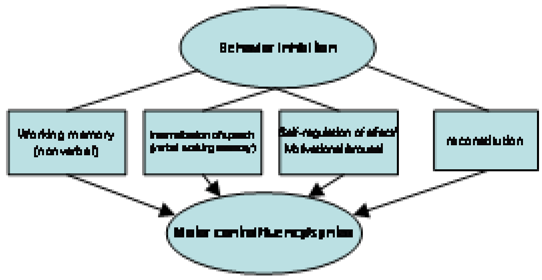

Fig. 7: Compelling evidence exists that ADHD comprises a deficit in the development of behavioral inhibition. The inhibitory deficit that characterizes ADHD disrupts the formation and execution of the next 4 executive functions: Nonverbal working memory, Verbal working memory, Self-regulation of affect/motivation/arousal, and Reconstitution.

The behavior of children with ADHD tends to be unplanned, unreasoned, and emotional, seemingly lacking organization, purpose, and intend. The procedures based on cognitive self-instructional methods are not sufficiently powerful to influence the symptomatology of ADHD. The children with ADHD are unlikely to master control of their behavior by self-directed private speech, and thus require control by others (a limitation of the information processing model). A number of general principles that apply to the classroom management of children with ADHD stemming from this model are the following [10]:

i. Rules and instructions provided to students with ADHD must be clear, brief, and often delivered through more visible and external modes of presentation than is required for the management of typical children
ii. Consequences must be delivered immediately and, more frequently (not just more swiftly) to children with ADHD, in view of their motivational deficits

iii. The type of the consequences used for children must often be of higher magnitude, or more powerful, than that needed to manage the behavior of typical children

iv. An appropriate and often richer degree of incentives must be provided within a setting or task to reinforce appropriate behavior before punishment can be implemented

v. The reinforcers or particular rewards that are employed must be changed or rotated more frequently for children with ADHD than for typical children, given the penchant of the former for more rapid habituations or satiation to response to consequence.

vi. Anticipation is the key with the children with ADHD (the teachers must be more mindful of planning ahead in managing children with this disorder)

vii. Children with ADHD must be held more publicly accountable for their behavior and goal attainment than typical children

viii. Behavioral interventions, while successful, only work during implementation, and even then require continued monitoring and modification over time for maximal effectiveness.

A classroom-based intervention is guided by research and theory in cognitive psychology, and consists of the following seven core principles that aim to prevent task failures due to working memory overload [11]:

1. Recognize the warning signs of working memory failures
   i. incomplete recall (the child remembers the first few words in the sentence and forgets the rest)
   ii. failure to follow instructions
   iii. place-keeping errors (often lose track of what he has done)
   iv. task abandonment

2. Monitor the child in order to provide effective support
   i. Look out for warning signs of working memory overload (incomplete recall, failing to follow instructions…)
   ii. ask the child what he or she is doing, and what he or she intends to do next

3. Evaluate the working demands of learning activities
   i. excessive length (because working memory is limited in capacity, modify the activities) – content that is unfamiliar and not meaningful (low meaningfulness and high unpredictability place heavy demands on working memory)
   ii. a demanding mental processing activity (the working memory capacity is directly affected by whether or not the child is also engaged in another mental activity that demands attention).

4. Reduce working memory loads
   i. reduce the amount of material
   ii. increase the meaningfulness and familiarity of material
   iii. simplify mental processing (the working memory demands of a task can be reduced by making the processing element less demanding)
   iv. restructure complex tasks (break down multi-step tasks into separate independent steps)

5. Be prepared to repeat

6. Encourage the use of memory aids
   i. writing aids (for example spelling aids include wall charts, flash cards placed in view of the child…)
   ii. Use Mathematical aids (unifix blocks, number lines, fingers…)
   iii. Apply Audio recording devices Computer software (Computer programs are helpful because students can get error correction while using them and allow students to continually move upward into areas of increasing challenge)

7. Develop the child's use of strategies for supporting memory
   i. Request help (the teacher encourages the pupils to ask for help)
   ii. Rehearsal (repeating a limited amount of verbal material, either silently or aloud)
   iii. Using long term memory: chunking strategy, acronyms (NOW for the National Organization for Woman), and acrostics (Bless My Dear Aunt Suzy for operations in their proper order Brackets, Multiplication, Division, Addition, Subtraction).
   iv. Place keeping and organizational strategies (metacognition, break tasks down into their component parts a treat each part as a separate task to be completed before starting the next one).

We believe that the strategy instruction refers to the process of helping children become shelf-regulated learners, individuals who have knowledge of how to learn as well as knowledge of how to effectively use what they have learned. Such self-regulation requires that the students play an active role and monitor closely the effects they take and decisions they make while learning. This involves the metacognition. Metacognition is process of <<thinking about thinking>> and students who meet metacognitive standards [12]:

i. know strategies, including when to use them and why they are helpful, and initiate action based on this knowledge
ii. know academic success is the result of smart effort and put this knowledge to work
iii. know how to monitor and use strategies flexibly and take initiative to apply this knowledge
iv. know a lot of important ideas related to content areas and use this knowledge to generate and recall other important ideas
v. know how the mind works with respect to thinking and learning and use this knowledge to maximize learning
vi. know that applying knowledge and strategies is more important than biology and take action to use these knowledge and strategy assets to overcome any perceived deficits
vii. know the importance of active involvement and reflectivity and put this knowledge into work so as to set and protect goals and apply strategies
viii. Know themselves as learners and what works for them and initiate actions based on this knowledge.

Learning strategies are techniques, which enable students to learn to solve problems and complete tasks independently. These strategies cover many areas (reading comprehension, note-taking, math problem solving, and written expression) and four of them [13, 14, 15, 16] are summarized in the next table (see Table 1).

POSSE ([illegible]) (A reading comprehension strategy) P Predict ideas O Organize the ideas S Search for the structure S Summarize the main ideas E Evaluate your understanding	CALL UP ([illegible]) (A note taking strategy) C Copy from board or transparency A Add details L Listen and write the question L Listen and right the answer U Utilize the text P Put in your own word
POWER ([illegible]) (A writing strategy) P Planning O Organizing W Writing E Editing R Revising	DRAW ([illegible]) (A math problem solving strategy) D Discover the sign (what operation to perform) R Read the problem (aloud) A Answer, or draw, and check W Write the answer

Table 1: There is a growing research base of learning strategies that work for students who have learning problems. In this table there are four examples of successful learning strategies.

5. Evaluation of strategies via Neural Network

In the table 1 the most successful learning Strategies are transformed in a numeric representation, in which each strategic factor obtain a value. The range of this value is between 0 and 2. Thus, we formed the following values:

P_1 Predict ideas [0,1,2]
O_1 Organize the ideas [0,1,2]
S_1 Search for the structure [0,1,2]
S_2 Summarize the main ideas [0,1,2]
E_1 Evaluate your understanding[0,1,2]
C_1 Copy from board or transparency
A_1 Add details [0,1,2]
L_1 Listen and write the question [0,1,2]
L_2 Listen and right the answer [0,1,2]
U_1 Utilize the text [0,1,2]
P_1 Put in your own word [0,1,2]
P_2 Planning [0,1,2]
O_2 Organizing [0,1,2]
W_1 Writing [0,1,2]
E_2 Editing [0,1,2]
R_1 Revising
D_1 Discover the sign (what operation to perform) [0,1,2]
R_2 Read the problem (aloud) [0,1,2]
A_2 Answer, or draw, and check [0,1,2]
W_2 Write the answer [0,1,2]

In this way, a vector dimensionality 1x20 is constructed V=[P1, O1, S 1, S2, E1, C1, A1, L1, L2, U1, P1, P2, O2,, W1, E2, R1, D1, R2, A2, W2] and three (3) categories are selected, the categories poor, fair and excellent. These are called A, B and C. As A category was selected the class of vectors in which the sum of the elements was ranged between 0 and 12, in the same way the B category the score was ranged between 13 and 25 and finally the C category is ranged between 26 and 40. For example, as A category considers the following vector [0,1,1,1,0,2,0,0,0,0,0,0,0,0,0,0,0,0,0,0] and as an ideal vector which is belong in class C considers the vector: [2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2]

The final step of the proposed method is to use the estimated strategic parameter vectors as feature vectors, in order to train and then to test an artificial neural network classifier.
The neural network selected and employed in our work is the Learning Vector Quantizer (LVQ).

LVQ was proposed by Kohonen [18], as a supervised extension of the more general family of unsupervised classifiers named Self-Organizing Maps (SOMs). The training of LVQ is a two step procedure. In the first step, initial positions of the class representatives (or codebook vectors) are determined in the r-dimensional space using standard clustering algorithms such as the K-Means or the LBG algorithm, with a given number of classes. In the second step, class representative positions are iteratively updated so that the total classification error of the training set of vectors is minimized. To this end, codebook vectors are directed towards the data vectors of the same class and distanced from the data vectors of different classes. A euclidean distance measure is used for calculating distances. Specifically, every time a member of the training set, feature vector ti, is incorrectly classified, the two codebook vectors involved (correct rc(i-1) and incorrect rw(i-1)) are updated as follows:

$rc(i) = rc(i-1) + a(i) [ti - rc(i-1)],$

$rw(i) = rw(i-1) - a(i) [ti - rw(i-1)].$

The rate of the update, or learning rate, a, controls the speed of convergence and is a descending function of "time" or iteration index (i).

The class separating surfaces obtained in this way are nearly optimal in the bayesian sense. Different rules applied when "moving" (updating) class representatives during the training iteration produce different versions of the LVQ training algorithm. The version employed here, namely LVQ1, is chosen for its properties of quick convergence and robustness of the class representatives positions over extended learning periods.

Thus, we constructed a well-formed LVQ network which is used to classify the feature vectors (model order p = 20) is shown in Fig. 6. Input vectors of dimensionality 20 x 1 are weighted and fed to the first layer of neurons, known as the competitive layer. These neurons compete for inputs in a "greedy" way; hence the layer name. Four (4) such neurons form the competitive layer in our case. The output of the competitive layer, which is in fact a grouping of the inputs into subclasses, is fed to the second linear layer, which groups subclasses into target classes. The weights connecting the two layers take on binary values of zero or one, indicating mere class membership and not actual weighting. Two target classes exist here, the class of interest (A or B or C or D, respectively) and class X, serving as the "complement" or "denial" of the class of interest. Therefore, the linear layer consists of two (2) neurons, which group the four subclasses into two target classes. An analogous architecture with six (6) competitive neurons is used with the bilinear feature vectors whose dimensionality is 20 x 1. The learning rate used in the training process is in the order of 10-3. Training iterations are terminated when either the classification error falls below 10-2 or a maximum number of 3000 epochs is reached.

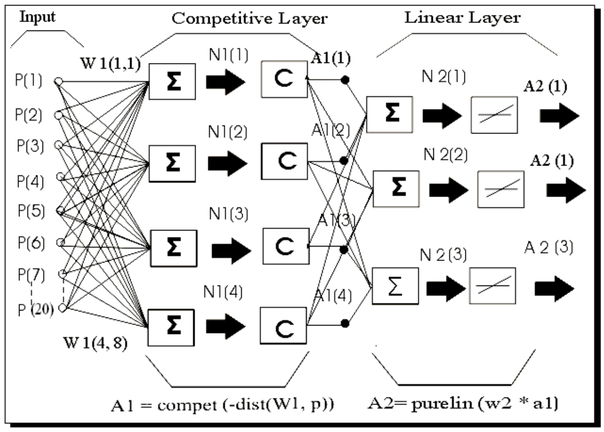

Fig. 6 A*rchitecture of the LVQ neural network employed for the classification for AR input vectors of dimensionality 20.*

The usability of this proposal is focused in the evaluation procedure of the selected strategies. In particular, this procedure is divided into two steps. In the first step we train three groups of 60 vectors, 20 per category (A, B and D).

In the second step we test many paradigms which extracted using ADHD method. For this reason, if it is possible to evaluate with a sophisticate way the progress of each child according the training score of LVQ and the possible ascension of category for example from category A to category B.

6. Discussion

The proliferation of computers has encouraged the use of the computer to explain the brain functions (learning, memory…). The information processing model is a metaphor which is borrowed from computer science, as reflected in terms like input, processing and output. But there are problems and limitations with such analogy. The model represents learning and remembering as a mechanistic and not as a biochemical process. The brain is fallible, forgets, and stores the information different from a computer (the brain stores sequences of patterns and recalling only one piece of the pattern can activate the whole). In addition, in the human brain there are connections between cognition and emotion, between motivation and actions which have been largely ignored in the cognitive approach.

On the other hand, the information processing model proposed by Atkinson and Shiffrin provides a helpful framework for thinking about memory. Teachers with a greater understanding of the theory and how it is formed can select learning strategies in order to improve the retention and retrieval of learning.

In addition, the model also predicts the participation of different brain structures in each stage of processing. For example verbal short-term memory is supported by structures in the side part of the left hemisphere of the brain; visuo-spatial short-term memory is located in the right hemisphere (the opposite side of the brain from verbal short-term memory). The central executive part of working memory is located in the front regions of both the left and the right hemispheres of the brain. (See Table 2).

Structure	Possible role in memory
Temporal lobe, hippocampus and surrounding structures	•Transfer of information from STM to LTM •Management of declarative memories
Diencephalon, thalamus and mammillary bodies	•Transfer of information from STM to LTM
Association cortex	•Semantic memory •Encoding LTM •Retrieval of LTM
Prefrontal cortex	•Episodic memory •STM
Basal ganglia	•Procedural memory

Table 2: Brain structures and their roles in memory

Anyone, parents, educators, psychologists, should know how the brain changes in order to implement their learning strategies in a better way. We must try to improve the cognition of all learners, from those with impaired learning to the gifted. We also have to think about how we can maximize the potential of any growing child. Brains have different vulnerabilities and different opportunities at each age and we have to discover the risks and strategies for intervention in order to create opportunities for positive change in the brain.

The research suggests that focused types of learning experiences such as skill building can benefit the brain. If the rest of the environment stays the same but the subject acquires a particular skill that's new to the brain, the brain is still likely to change, but the changes will be narrow and less global. The ability to modify the brain on purpose can happen because of neuroplasticity, the capacity that allows for region specific changes in brain's structure, mapping, or functioning. The human brain is organized around being responsive to the surrounding environment. Learning is a biological change and good teaching begets learning, teachers are <<brain changers>>.

Learning is socially constructed, and occurs during social interactions. Learning is a social event and teacher needs to consider that students bring to learning their own culture, background knowledge and language.

A strategy for accommodating students with special needs in the general education classroom is the INCLUDE strategy [17]. This strategy is based on the assumption that student success is the result of the interaction between the student and the classroom environment and gives a systematic way of matching the learning needs of students, classroom demands or expectations of the teacher, and reasonable accommodations that can help when gaps exist.

The INCLUDE strategy follows seven steps:

a. **I**dentify environmental, curricular, and instructional classroom demands
b. **N**ote student learning strengths and need
c. **C**heck for potential areas of student success
d. **L**ook for potential problem areas
e. **U**se information gathered to brainstorm instructional adaptations
f. **D**ecide which adaptations to implement
g. **E**valuate student progress.

Social dynamics can change the entire process of learning. The social climate links to the classrooms physical and environmental characteristics have specific effects on academic achievement, both individually and together. Socialization alters the levels of stress, confidence, and even the content knowledge. Social support provides widespread encouragement, stress reduction, feedback, and a sense of community that enables learning. Reciprocal teaching, learning strategies, flexible grouping (pairs, triads…), and promoting student responsibility for the protection of learning and safety rights in the classroom, can improve social skills and when students have better social skills, there are fewer classroom discipline problems and more effective instruction is likely. Finally, the use of the LVQ neural network ¶opens new horizons in a new approach of the evaluation of these strategies and as a further research is proposed the experimentation of this method using multiplies cases.

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