

Neuroscience and the learning brain : From biology to psychology

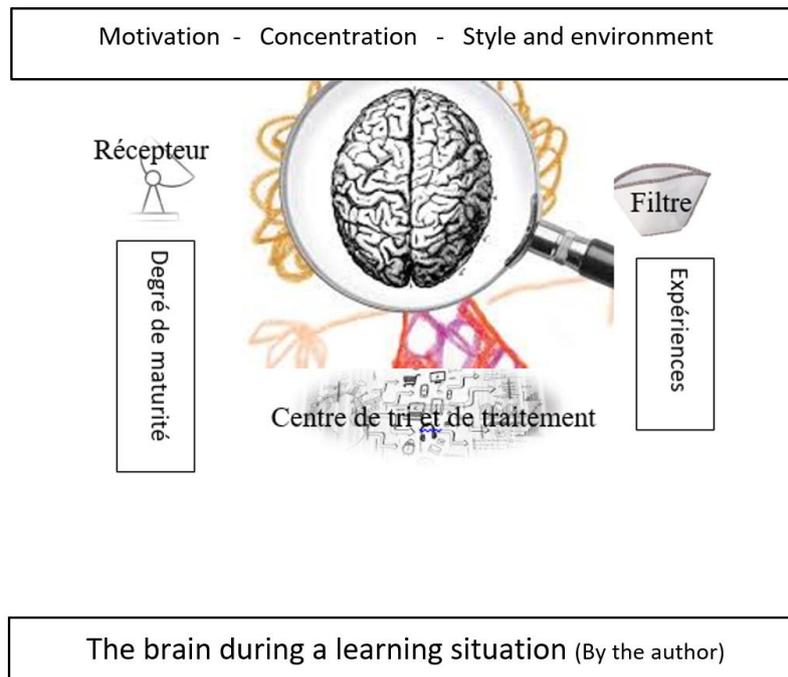
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ABSTRACT: Whether by using the most sophisticated scanning techniques or subtle psychological tests, experimenters were able to delve into the human brain and attempt to understand the way it learns. Research in neuroeducation focuses essentially on the teaching-learning activity by striving to produce, as far as possible, a precise comprehension of the cerebral mechanisms of cognition. The present article proposes a thoughtful reading of the act of learning in the light of the contributions of cognitive sciences and neuroeducation, passing essentially through biology and psychology.

KEYWORDS: learning, cognition, teaching, neuroeducation, brain.



1 INTRODUCTION

Whether by using the most sophisticated scanning techniques or subtle psychological tests, the experimenters were able to delve into the human brain and attempt to understand the way it learns.

Neuro-education consists of adapting teaching methods to capacities and mode of functioning of the brain as much as possible. An interdisciplinary field of research that combines neuroscience, psychology, anthropology, and education, neuro-education aims to create better ways of teaching.

Research in Neuroeducation uses findings on memory, learning, language, and other topics related to cognitive neuroscience (Philosophy, Psychology, Linguistics, Computer Science, Neuroscience) to instruct educators on the best teaching and learning strategies.

2 PROBLEM DEFINITION

In neuroscience, there is a growing number of research papers that invite educators and didactic specialists to consider the results of experiments on the active brain functioning to tailor their interventions in the classroom accordingly for better results. Learning brains are at the same time analogous and different, unique and similar, and this is where their richness and the difficulty for teachers lie.

Any attempt towards a pedagogical standardization can only lead to the dullness of those undergoing it. The interests and needs of individual and group students are so different that an intelligent and meaningful educational intervention must respect these differences that make them unique and full-fledged individuals. A pedagogy that addresses each student, rather than a group of students in a standardized manner, is the first step towards rationality. Actually, a classroom intervention that respects the individual is a necessity and a condition for educational practice success. It goes without saying that the task of teachers is far from being simple or easy. The equation to be solved is to reach the whole class by addressing each student.

3 THE BRAIN, THE PRINCIPAL ORGAN OF KNOWLEDGE

Personal characteristics determine the entire existence of the individual. These characteristics, which are a result of the joint actions of multiple factors of diverse nature, guide the relationship to the world as well as problem solving and relation to others.

In a learning situation, these characteristics concern both students and their teachers. Any similarity in the expression of personal character conceals an enriching dissimilarity for group management, problem-solving, and communication in the classroom, provided that the official leader knows how to make use of this dissimilarity in a positive way for significant learning.

Main organ of information processing, the brain is a receiver, a filter, and a sorting center of the information that is captured from the environment by the different senses. This nearly permanent work is performed in a quasi-automatic way by non-conscious circuits while consuming little mental energy. This capacity of the brain to process, sort, prioritize, and judge the transmitted information depends on its degree of maturity and previously acquired experiences. For this reason, there is a difference of appreciation between people facing the same circumstance. In other words, the received information by the brain determines its performance. Hence, the importance of language, or rather the importance of idiom in this treatment process. This activity is performed in a smooth way that the form of transmission of information (word, sentence, gesture, image, drawing, graphic, or any other form of representation) is clearly and well perceived. Besides, polysemy, lack of clarity, and ambiguity restrict the work of the brain, make it consume much energy, and may block or at least delay its operation, especially during its maturation phases. Challenge, as opposed to routine, stimulates the learning brain; however, too much or too little challenge could be detrimental to the learning brain. Proceeding by analogy, comparison, inference, deduction, and induction would better suit its functioning. Furthermore, placing the received information in its precise context is a necessary condition to provide it with its proper meaning.

As a genuine control tower, guided by its needs and acting as an aware thrifty, the adult brain controls the whole body by following several conscious and unconscious modalities to avoid exhaustion during knowledge management processes. Thus, its worker caterpillars, the neurons, disconnect when fatigue gains too much ground. That is what happens in the classroom for adolescents who are sleep-deprived, cognitively overloaded, or living under stress and who are unable to follow, process, or even understand the course.

The brain certainly has its limits and demands. Hence, the usefulness and importance for educational and pedagogical actors to know this organ, its maturational process, its mode of functioning, its preferences, and what harms it, that one may achieve meaningful schooling, improve pedagogical practices, and make learning activity a moment of pleasure and not a session of constraint or even torture.

3.1 THE BRAIN DURING A LEARNING SITUATION

The adult brain as a super saver has developed, during its long maturation process, highly automated strategies that consume the least amount of energy and are characterized by rapid execution since they are under the control of subcortical systems. The execution of these activities under the support of cortical areas would make them slow, costly, unsuitable to the

context, and could eventually lead to disastrous results. By doing so, the brain devotes its conscious part to tasks that are hardly automated, like reasoning, planning, problem-solving, or abstraction.

To reach this high-level of performance the brain had to work hard, as evidenced by the childhood journey from preschool to higher education. The implementation of these highly automated strategies requires laborious and very costly work for the conscious mind to achieve this result. Each newly learned skill at school (and even outside school) alerts the brain to mobilize attention, sensory and motor organs, working memory, long-term memory and its components, linguistic skills, mental mobility, in short, all motor and cognitive functions. Learning only can be achieved through hard work, continuous, voluntary, and conscious effort. To achieve positive results; the learning sequence has to be programmed to better arrange and order these cognitive functions regarding their relative importance to the requirements of the tasks to be performed. The learning brain is subject to neural constraints that must be taken into consideration to avoid being overwhelmed. Learning activity consumes energy, attention, memory, and executive functions, hence the need to understand that the implementation of delicate motor automatisms is required to master writing, and high-level language skills necessary for reading and expression require time. The needed duration to acquire these skills depends on brain differences among individuals. Learning situations in general, and schooling situations, in particular, require a very complex brain processing that not all learning brains can cope with, due to the lack of ability or maturational phase shift. Therefore, it is possible to encounter difficulties, delays, or even disorders that can become pathological during schooling. A pedagogical intervention armed with knowledge about the functioning of the learning brain would lead to opting for the most accessible tools and supports for clear and less ambiguous instructions, and the most attractive teaching situations that are free of malicious traps. It is under these conditions that learning would be a real moment of pleasure and joy to express oneself, transmit, communicate positively, exploit knowledge, and enrich personal experience and that of others.

4 SUBJECTIVITY AND LEARNING

The development of self-awareness (intrasubjective consciousness) plays a role in everyday life just as much as the development of social skills that are crucial to living in society between others (intersubjective consciousness). Any delay, dysfunction, or disorder affecting the development of the subjective dimension makes the person vulnerable and exposed to the risk of endangering his or her future social being. Understanding, management, control of feelings, emotions, and affections are as essential to life as analyzing and understanding the feelings, reactions, and behaviors of others. Any defect in these functions would jeopardize the person's integration and adaptation to the group, community, or society and would reduce the opportunities to be operational, active, and recognized in the social environment, in other words, this would be the royal road to marginalization and exclusion.

4.1 INTRA-SUBJECTIVITY: SELF-DIRECTED LEARNING

The construction of the intra-subjective dimension depends on the development of the function of understanding, of judging personal motivations, of clear-sightedness on feelings, of the estimation of strengths and weaknesses, of the precision of goals and programming actions accordingly. The development of this dimension is a prerequisite for the establishment of capacities of self-evaluation, metacognition, discipline, and concentration. Besides, it provides a good starting point for a well-constructed personality allowing openness to others, cooperating, and coexisting with them.

Neurobiologically, intra-subjective construction and its expression demand active and sustained involvement of the right brain, amygdala, and dopamine. At school, the intra-subjective dimension determines both affective aspects, including emotions, feelings, motivation, and cognitive functions, in addition to self-image. The relevance of learning with respect to previously set objectives, and personal performance and efficiency are specified, reviewed, and corrected. The intra-subjective dimension has a link to the progressive construction of reasonable decision-making capacity. When a child, pupil, or student faces a problematic situation, he or she gradually learns to analyze, balance, assume, evaluate and judge the elements of this situation, initially with hesitation, energy expenditure, and many errors before reaching efficiency and automation of processes. A problematic situation is any confrontation with a dilemma that can test intelligence, moral sense, responsibility, and liability. That means that there are strong links between intra-subjectivity and intersubjectivity and that the transition from intra-subjective to intersubjective aspects (or the inverse) is the result of a laborious, conscious and unconscious learning process within which the teacher can play a crucial role from preschool to university. Indeed, the teacher can play the role of an inducer and initiator of extrinsic motivation. By setting up a social climate and a well-equipped surrounding, that is favorable and conducive to attract the attention of learners, the teacher can maintain students attention as long as possible while respecting their psychological characteristics, getting them to focus on the task, to invest themselves in it and to seek success (satisfaction and reward at the same time). A favorable learning climate must respect certain conditions such as the precision of expectations from learners, positive feedback communication that may encourage them, the implementation of attractive,

non-routine, or monotonous didactic situations that constitute realistic challenges respecting the intellectual level of the student.

4.2 INTERSUBJECTIVITY: LEARNING WITHIN A GROUP

The intersubjective dimension of personality is associated with the right hemisphere. Neurons and neurotransmitters are predominantly involved in the process of construction, development, and consolidation of this dimension. Analyzing and understanding the actions of others, and social interactions in general, require the intervention of serotonin and oxytocin. These biological components constitute a mandatory condition for the implementation of the intersubjective dynamics that include formal and non-formal learning and school and extra-curricular activities. The construction of the personality's intersubjective dimension passes through contact, cooperation, solidarity, conflict, adversity, the search of a compromise between intra-subjectivity and the demands of group life with the help of conformism, the identification of common points, and anchors to relationships in both, real and virtual life. Emotions are deeply involved in this process of living in a group (family, team, band, school, etcetera) and of building and developing intersubjectivity. The role of the brain and precisely, of the insula (a cerebral structure in the temporal lobe) in changing attitudes and opinions in line with the group that the person belongs to is evident. To avoid marginalization or exclusion from the group, the individual opts for conformity to the dominant ideas and behaviors in the group and thus gives in to social pressures. Living in a community also involves the constitution of mindset, opinions, and judgments about others. The formation of judgments about others depends on perceiving, decoding, interpreting, and understanding emotions. This operation, carried out rapidly by the adult brain (the amygdala), barely exceeding a tenth of a second, is built up gradually from a young age and depends on subjective emotional experience in interaction with the cultural environment. This judgment may get distorted, manipulated, and subject to the effects of social pressure and conformity. For example, many people agree that people who are elegant and beautiful have intelligence, ambition, attractiveness, positivity, balance, and social skills. These conditional judgments have a considerable impact on all areas where evaluation is required: justice, education, and employment. Moreover, verbal and non-verbal language plays a crucial role in intersubjective relationships. Enunciated speech occupies a small place compared to prosodic traits and body language. If the person can choose words consciously and deliberately, non-conscious components could be contradictory and disguise the explicit element of verbal interaction. The possible contradiction between speech, on the one hand, and thoughts and affections, on the other hand, is detectable by any participant coming from the same cultural context. Intersubjective relationships must be genuine and free of disharmony and contradictions between communication components for effectiveness reasons. This authenticity is particularly essential in schooling because it can have effects on the future of learners and their integration into the school culture. The teacher has at his (or her) disposal a set of language tools that can make learning pleasant, enjoyable, and inclusive.

In addition to its euphoric effect, reducing stress and creating intersubjective bonds (sharing and contagion of laughter), humor promotes learning and memorization. Humor sense, a part of the words of mind as Freud described it, is not only limited to telling funny stories or making jokes but can be a crucial technique for classroom practice at different times and phases of the course. Kind humor, and not squeaky, dark or sarcastic humor, can unlock many difficult situations, attract attention, awaken or initiate the class, and play down difficulties and mistakes. Not everyone has a sense of humor either in production or in comprehension because of its tight connection with other dimensions of personality and their development. Nevertheless, for those who master humor, or at least have a sense of it, it can be an essential tool for intersubjective links establishing because the modalities of humor are rich, multiple and varied and involve several cerebral zones. Therefore, it involves high-level cognitive activities that depend on the prefrontal lobe.

In short, intersubjectivity occupies a predominant place in the schooling area because training, learning, and openness take place through interactions, with the help of the cerebral structure and its components. Opting for diversity and dynamics of verbal and non-verbal communication and promoting positive emotions constitute an indispensable factor for academic results enhancement. The size of the group moderates this diversity, which is an inevitable part of the puzzle, as is the effect of the less well-trained, though decisive, teacher. Some teachers do better with certain groups and have difficulty managing others within the same institution. Similarly, some groups learn better with some teachers and almost nothing with others even though they have the same professional profile. Nor group neither individual learners are the same. Girls have very different attitudes towards school in comparison to boys. Likewise, learners with difficulties do not place the same importance on learning as learners who are comfortable with learning. Therefore, it is necessary to set up clear rules and codes that are accepted by everybody to promote the construction and development of intersubjectivity in the school environment as elsewhere. Interaction between the different dimensions of the environment within which the learner evolves determines his (or her) sociability.

5 THE BASICS AND PRINCIPLES OF NEURO-PEDAGOGICAL LEARNING

Neuropedagogy is based on a set of general rules and norms, that can guide classroom work, issued from the results of research on brain functioning. This practice of making a stand by objection has been applied in active pedagogy, from Decroly to Montessori via Freinet or Makarenko; each school of thought specifies the bases, lays down the rules, and determines the principles to respect in classroom practice. Neuro-pedagogy draws its theoretical references from cognitive sciences, this field of study tries to adapt its findings to the reality of the classroom and to the act of putting activities into the teaching-learning process. These sciences stipulate that all learning involves some fundamentals such as attention, active engagement, feedback, and consolidation.

5.1 LEARNING BASICS

1- Attention, a complex cerebral activity, incorporates an operation of information selection from the environment according to the internal state of the subject matter. Selection is necessarily exclusive because it proceeds by elimination to retain only the selected elements and concentrate on them for an in-depth examination. Far from being a simple operation, the attention mechanism consists of three consecutive and serial subsystems, namely: alert, guidance, and executive control.

The attention of the learner is a must; there can be no learning without attracting the attention of the person to be taught. It is necessary to mention that learning while being distracted is an illusion (the case of using a smartphone in the classroom). The brain cannot perform two learning activities at the same time because its conscious mode of operation is strictly serial. The prefrontal cortex makes choices and can only pay attention and focus on one activity at a time. Hence, the importance of contextualizing scenarios in the classroom and the teacher's effect in alerting the learner, capturing his (or her) attention, and getting the learner to focus actively on the task.

Executive control plays an inhibiting role in both behavioral and cognitive levels in relation to pre-scientific or common sense representations. Indeed, cognitive control and inhibition are linked in a way to constitute the brain discipline. Learning does not only mean adding or acquiring new knowledge but also blocking automated behaviors, habits, temptations, distractions, strategies, and misrepresentations to be able to adapt to the demands of a new or unprecedented situation. Moreover, research on conservation in the Piagetian theory presented by Houdé and others (2011) showed that, contrary to the students who did not accomplish the number conservation test, cerebral areas (the right ventrolateral prefrontal cortex), which are related to inhibition, were activated for those who passed the conservation test successfully. This study, which presented the results of previous research (Joliot et al., 2009; Leroux et al., 2006; Leroux et al., 2009; and Bull, Espy, Wiebe, Sheffield & Nelson, 2011) in the same sense, also demonstrated significant activation of intraparietal furrows for students who completed the task successfully.

This cerebral zone is also involved in the semantic and symbolic processing of numbers. In other words, students who have developed number conservation skills in the Piagetian sense activate the intraparietal sulcus required for the understanding of numbers, in addition to the ventrolateral prefrontal cortex associated with the development of inhibition. It would seem that these results mean that the acquisition of numbers conservation function demands the ability to inhibit perceptual, intuitive, and erroneous responses (Bjorklund & Harnishfeger, 1990; Dempster & Brainerd, 1995; Houdé, 2000). The consequences for school learning are consistent with the importance given to the development of inhibition capacity among students since their integration of educational institutions. Indeed, research by Lubin and others (2012) focused on the development of this capacity for mathematics and spelling in the primary cycle (6 to 11 years old students). These researchers provided students with tools that enable cognitive control of errors after identifying repeated errors during the learning of certain notions in mathematics and language. The results of this research highlighted the importance and relevance of learning with inhibition by teaching students to inhibit some strategies or wrong answers, compared to conventional learning activities that are unable to help students to overcome mistakes that have been made repeatedly for generations.

2- Passivity cannot lead to meaningful learning. Hence, the need for active engagement. Confronting learners with a difficulty or a challenge by creating an imbalance or a contradiction in their knowledge is a way among others to mobilize them. The teacher should amaze learners, disturb their conviction, demand explanations to move them from common knowledge to scientific knowledge, from a mythical-magical thought to logico-philosophical thinking. The learning brain is at its optimal performance and activation when faced with a reasonable challenge that can even involve sustained effort. To maintain attention and commitment, the balance between the abilities of learners and the demands of the situation on the one hand, and the progression of motor, cognitive and metacognitive challenges, on the other hand, are mandatory.

3- The attentive and committed learner can not be the sole judge of his actions and activity. An external witness is essential to estimate performance, which is the result of analysis of the situation, the mental elaboration of the response, and finally,

the implementation of the answer. Introspection plays a significant role in the evaluation of the results and the situation. For this reason, introspection must be trained beforehand. Knowledge of the outcome or feedback is essential to evaluate, reframe, revise, and review performance. Therefore, the error is constitutive of learning and an evidence of the learner's activity; those who do not make mistakes are those who are passive and do not learn. Teaching based on simple transmission does not involve the same brain areas as teaching that is driven by comprehension. The latter way of teaching encourages the learning brain to make hypotheses (which may be erroneous), to prepare its response accordingly, and to execute it. The learner's feedback allows him to compare his performance with the appropriate response, to revise his hypothesis partly or totally according to the perceived gap between the two. To respond to a problem situation, the brain functions cyclically and serially: Hypothesis, execution, feedback, evaluation, and a new hypothesis. Teachers need to integrate a positive representation of error in their intervention since it is fundamental to meaningful learning and to point out the mistake in an unequivocal manner and without contempt, mockery, or desolation making it a vector of progress by overcoming its fertile and fertilizing pitfalls.

4- Automate and strengthen acquired knowledge: Repetition is the watchword of all learning that seeks efficiency, speed, and energy saving. It is repetition that leads to automation, which means the release of the prefrontal cortex from the total support of the automated activity. Gradually and at the time of getting the appropriate answer, the posterior areas of the brain, as well as subcortical centers, take over (at least) the executive part of the response, leaving the prefrontal cortex to decide whether to start or stop the operation. Nevertheless, if the learner does not perform the previous steps correctly and automates an inappropriate response, as a result of the insufficient engagement, poorly executed control, and non sufficient or inexistent feedback, an unlearning phase would be required to progress. The unlearning of already automated erroneous responses involves the inhibitory control that reactivates the prefrontal cortex, which is essential to bring out the automatism of the sub-cortical and posterior centers of the brain for further processing by new neuronal circuits before their consolidation. Brain imaging studies carried out on the subject have shown that the change of reasoning mode, face to a problem situation involving a switch from an automated but erroneous approach to a new and more appropriate one, is supported at the cerebral level by the transition of the activated areas from the brain posterior part to the prefrontal cortex. The correction of already automated errors is quite costly on the cognitive level and takes more time because it is the result of a pricey dislocation of the circuits established during the first automation and the establishment of new neuronal milestones matching the recent response. From the academic perspective, this means that the teacher has to spend a little more time on error detection and correction if he wants to achieve intelligent learning.

5.2 LEARNING PRINCIPLES

1ST PRINCIPLE: LEARNING INVOLVES THE WHOLE BEING

Learning involves the whole being. The brain receives information to be processed through the senses. Hence, the importance of making the body eager to learn, to give, and to receive. The importance of physical activity in improving learning is evident since physical exercise that precedes a demanding intellectual task makes the brain more alert. A balanced diet benefits learning. Both undernutrition and malnourishment are at the detriment of learning ability; a diet that is too rich in carbohydrates is harmful to the learner. Besides, mistreatment, over-pressure, insecurity, and non-recognition force the brain to search for defense strategies that consume too much energy and take up too much time from learning and understanding. Long-term stress, anxiety, or threats do not only reduce the ability to understand and learn but more seriously, they affect the brain structure and functioning mode.

2ND PRINCIPLE: CO-LEARNING IS A MUST

Learning on a solitary basis is both uncommon and expensive. The learner imitates, observes, receives knowledge, evaluates it, and compares it to his pre-acquired notions. Interaction is essential for intelligent and meaningful learning. The environment of learning influences the significance of learned concepts and contributes to the building of a better acceptance of others and their differences.

3RD PRINCIPLE: LEARNING MUST BE MEANINGFUL

Setting learning goals to help learners set their own goals is essential and increases motivation and commitment. Blind learning and passivity disempower, demotivate, and make the learner feel like a puppet or a pawn.

4TH PRINCIPLE: THE LEARNING ACTIVITY MUST PRESENT THE NEW INFORMATION AFTER THE OLD ONE

New notions are better perceived when linked with concepts that are already stored and stamped in memory. This linking facilitates the act of structuring and reorganizing the connections that the brain undertakes each time confronted with new knowledge and prevents the brain from being completely confused and disoriented.

5TH PRINCIPLE: LEARNING MUST BE FUN

Giving the desire and the joy of learning motivates the learner, encourages active engagement, and pushes back fatigue for a considerable time. Creating a welcoming, caring, and equitable climate where all participants have proper treatment enhances motivation, values efforts without making fun of mistakes, and maintains self-esteem. Learning with pleasure and happiness does not mean being lax but simply being strict without being rude.

6TH PRINCIPLE: LEARNING REQUIRES SUSTAINED ATTENTION

Attention is a necessary but not sufficient condition for learning because alone, it cannot guarantee understanding. The ability of the student to stay focused depends on several factors like age. Each age has attention abilities and concentration duration that increase with age. Hence, the need to switch moments of teaching with moments of relaxation (humor). The construction of knowledge is a complex and laborious work, and one of the roles of the teacher is to be a facilitator to knowledge development.

7TH PRINCIPLE: ERROR-FREE LEARNING IS A RED HERRING

Chasing mistakes by considering them as a failure or punishing them leads to passive, uninteresting, and boring learning that is without sense or value. A learner who makes a mistake is a learner who tries hard, and the error informs the teacher on the process and mechanisms of understanding much more than the correct answer that is a muted response to the question. Making a mistake leads to a re-examination of the process of interpretation, then to reflection and metacognition.

8TH PRINCIPLE: THE LEARNING PROCESS MUST ENGAGE THE LEARNER IN THE ACTIVITY

Passivity cannot lead to the construction of meaningful knowledge since the students obtain significant learning when they feel that they are the actors of their learning activity and not subjects or receptors of few notions that are sometimes disjointed. The brain is at its best when confronted with challenges, variety, real problems, or at least realistic and contextualized problems. It prefers the procedural to the declarative, variable to routine, unpredictable to customary; otherwise, it stalls and disconnects.

9TH PRINCIPLE: EACH PERSON IS UNIQUE

Each brain evolves at its own pace. The rhythm of development (biology), experience (psychology), and knowledge (learning) of each cerebral system is different. Consequently, knowledge is distinct, and preferences influence the attitude towards learning.

10TH PRINCIPLE: "EMOTIONS ARE THE BASIS OF EVERY LEARNING"¹

Learning with pleasure and happiness and giving the joy of learning is the foundation for meaningful and sustainable knowledge. These delights are considered as pure pleasures provided by science just as the thrill of solving a mathematical problem, the amusement of studying, aesthetic pleasure, and the entertainment of thinking among others. Positive emotions, encouragement, active listening, and acceptance of difference put the brain in a state of thirst, and hunger for learning. On the other hand, negative emotions, bullying, physical or verbal humiliation are hurtful to the brain and consequently to cognitive

¹ Platon.

processes such as learning and memory. Likewise, the sentiments of the teachers, and their effects on the quality and effectiveness of the intervention, availability, and ability to interact positively with learners, must be taken into consideration.

11TH PRINCIPLE: REPETITION IS MANDATORY FOR LEARNING

Without repetition, it would be difficult for the learning brain to perceive the nuances of speech, to follow the reasoning, to capture the multiple aspects of an exposed experience of reality, to establish links between notions, concepts, and meanings, and to develop reasoning skills and understanding of the world. Repetition stimulates and activates memorization. Without repetition, it would be impossible to achieve the automation that frees the cortical centers of new learning, and without it; memorization would be impossible, and students must repeat learning activities each time. Given the number of repetitions, the capacity of assimilation, and integration of content and procedures are not the same and cannot be the same for each learning brain. Trying to submit all the students to the rules and put them under the same compactor would be damaging to the whole class.

6 CONCLUSION

Intelligent learning is a complex process that is carried out by each learner in his (or her) own way; successful learning requires, among other things, knowledge of the mechanisms and involved steps and not the expected results that may appear or give the illusion of being the same for all learners. Today's school places importance on the outcome of understanding more than on the process behind this understanding. Awareness of the importance of the learning pathway and considering it in the teacher's pedagogical and didactic approach could encourage the teacher to change his attitudes, his intervention, and his evaluation. It is essential for the learner to be supported in his efforts to understand and to validate the results of this process in a clear, rigorous yet gentle manner, which is a condition to help him progress at his own pace. The learner's development needs to be in front of a strict, rigorous, firm, fair, and above all, caring and not unpleasant teacher. Emotional processes have as much importance as cognitive processes in learning and development. Therefore, the school must make available and offer an ecosystem that is operationally rich, organized, demanding, and positive in its perception of error, but also welcoming, caring, and emotionally balanced to learners. The school has to stimulate the will to learn, to direct executive control in order to trigger the biological system of healthy learning. By choosing ways to awaken, involve, and surprise learners when necessary, without stigmatizing, or paralyzing their efforts by provoking feelings of powerlessness and repugnance towards the activity, it is possible to renew the success of the school and mobilize it for society.

The learning brain does not like routine; on the opposite, the learning brain is at its best in new and reasonably challenging situations. Surprising and astonishing the learning brain can trigger a set of questions about oneself and the world and thus initiate the learning process. In fact, as Jobert and Thievenaz (2014) pointed out, "it is through the experience of astonishment that human beings 'wake up startled' and discover that other ways of thinking and acting are possible, or that they will have to change something to adapt to the changes and demands of the situation." Astonishment can be an excellent trigger for a learning process or even an independent research process in response to a problematic or a new context.

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