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Some Useful Pedagogical Practices: Educational Neuroscience Perspective

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Abstract

We have reviewed the goals of education by approaching them from the direction of educational neuroscience; through education, we have to achieve transfer of learning in order to produce individuals who are better problem solvers and decision makers. To achieve this goal, learners will have to transform what they have learned explicitly into implicit memories and vice versa by attaching sense and meaning, ideally across multiple domain areas. Further, through education, we enhance learner consciousness and/or wisdom that give abilities to spontaneously recall retained memories readily, whenever necessary. A number of pedagogical practices that are useful in achieving the above goals are identified. When new contents are presented to learners, high-level, generalised concepts need to be emphasised; concepts are likely to penetrate through multiple domain areas and last longer in memory, thus helping learners to attach sense and meaning better. In order to reach out to multiple brain regions, inducing creativity, we need to get frontal lobes involved essentially, with an appropriate pace and form of presentation. The important task of motivating learners can be done by presenting learners with educational neuroscience facts that can be enlightening; even difficult content can be mastered by simply paying attention fully and through elaborate rehearsal; human brains have the feature of neural plasticity and neural networks can grow throughout the lifespan through effective learning. When setting assessment, we should focus on open-ended, novel and conceptual/generalised questions so that learners use their frontal lobes, engaging in a higher-order, divergent and/or inductive thinking process to provide answers.

Keywords: educational neuroscience, transfer of learning, sense and meaning, implicit and explicit learning, higher-order/divergent/inductive thinking, goals of education, pedagogical practices, visual-spatial learners, consciousness, creativity

1. Introduction

This paper identifies a number of useful pedagogical practices we can use as educators by approaching from the viewpoint of educational neuroscience, an emerging disciplinary area. The author is well aware of the reluctance of some educational practitioners to embrace the findings of neuroscience readily; however, we believe that there are more compelling reasons, as we discuss here, why we should be open to possible changes in our practices in the educational arena. The paper is organised into four main sections – sections 2 through to 5. In section 2, we introduce readers to some primarily neuroscience-based concepts that are closely related to learning. Some important, primarily learning-related concepts that can be viewed from the perspective of neuroscience are presented in section 3. Educational neuroscience concepts and information introduced to readers in sections 2 and 3 are used for the discussions in the subsequent sections. The section 4 reviews the goals of education by approaching them from the perspective of educational neuroscience. How the goals of education presented in section 4 can be achieved in teaching-learning environments and associated assessment is elaborated in section 5, the main, targeted section for practicing educators. A brief concluding summary follows in section 5.

2. Introduction to primarily neuroscience-based concepts that relate to learning

2.1 Basic structure of the human brain (Baars and Gage, 2010)

Mainly there are 3 layers of the brain, from bottom to top: the reptilian brain, mammalian brain and neocortex (MacLean, 1967). The reptilian brain is the oldest layer of the brain; it is composed of the brain stem, the structures that dominate in the brains of snakes and lizards. This part of the brain controls survival activities such as breathing, hart rate and balance. The mammalian brain is layered over the reptilian brain and consists of a system of brain parts called the limbic system. The constituents of the limbic system include amygdala, hippocampus and hypothalamus. The limbic system plays a major role in human emotions. The 3rd layer of the brain is the neocortex or primate brain, which is the most recent addition to our brain. It consists of wrinkled covering of cerebral hemispheres – the left and right. The neocortex plays a major role in cognitive, linguistic, motor, sensory and social abilities. It gives considerable flexibility in creativity in adapting to changing environments. The neocortex is densely interconnected with the limbic system and controls the expression of emotions.

The neocortex has 4 major lobes, namely, the frontal lobe, parietal lobe, temporal lobe and occipital lobe. One significant feature of the brain structure is brain localisation. That is, the brain is composed of a large number of functionally specialised regions (Luria, 1976; Geschwind, 1979; Edelman and Mountcastle, 1978). There are about 100 Brodmann areas, so to speak, now recognised in the neocortex. The 4 lobes of the neocortex and their processes are intricately intertwined with each other. Further, the neocortex, which is vital for cognitive functions, interacts constantly with major so called satellite organs such as the thalamus, basal ganglia, cerebellum, hippocampus and limbic regions.

It is of special interest to know that frontal lobes are referred to as the organ of civilisation. The role the frontal lobes play in cognition is uniquely human and without their development civilisation could never have arisen (Fuster, 1997; Goldberg, 2001; Ingvar, 1985; Luria, 1966). They are crucial for all higher-order purposeful behaviours such as identifying the objective, projecting the goal, forging plans to reach it, organising the means by which such plans can be carried out and monitoring and judging the consequences. Further, frontal parts of the brain become active when resolving conflicting conditions. A correlation has also been identified between frontal activation and longer reaction time and sense of subjective effort. In summary, the frontal lobe, or more specifically the pre-frontal cortex (PFC), is used for human activities such as language, thought and executive control of higher-order processes and connect directly with every distinct functional unit of the brain (Nauta, 1972). This connectivity allows PFC to coordinate and integrate the functions of other brain structures.

2.2 Brain lateralisation

The ability of certain areas of the brain to perform unique functions is known as cerebral specialisation. If the activity is mainly limited to one hemisphere, it is called cerebral lateralisation. Research studies show that the right and left hemispheres of the brain have distinctly different functions that are not readily interchangeable (Sperry, 1966). The left hemisphere processes input in sequential and analytical manner, is time sensitive, generate spoken language, does arithmetic operations, recognise words and numbers (as words), active in constructing false memories, better at arousing attention to deal with outside stimuli. The right hemisphere processes inputs more holistically and abstractly, is space sensitive, interprets language through gestures, facial movements, emotions, and body language, does relational and mathematical operations, recognises faces, places, objects and music, more truthful in recall, put events in spatial patterns, better in internal processing, gathers information more from images than from words and look for visual patterns (Gazzaniga 1998a, 1998b; Gazzaniga, Ivry & Mangun, 2002; Semenza et al., 2006; Sweeney, 2009).

Further, the left and right hemispheres are found to be physically different. The left hemisphere has more grey matter, while the right hemisphere has more white. That is, the left hemisphere's more tightly packed neurons are better able to handle intense detailed work, while the right hemisphere's white matter contains neurons with longer axons that can connect with modules farther away. These long-range connections help the right hemisphere to come up with broad but rather vague concepts, explaining the association with creativity. However, one of the interesting features of the human brain is that it can integrate disparate activities taking place in specialised areas into a unifying whole. In fact, the 2 cerebral hemispheres are connected together by the largest fibre bundle in the brain known as corpus callosum.

Despite this significant revelation, it is widely observed and accepted that educational institutes are predominantly left-hemispheric oriented with emphasis on structured environments that run to specific time schedules, favouring facts and rules over patterns and predominantly following verbal instructions.

2.3 Types of memory

Human memory (Squire, 2004, 2009; Baars and Gage, 2010) can be defined as a lasting representation that is reflected in thought, experience, and/or behaviour. It can be divided in to 2 main types: explicit and implicit. Explicit memory refers to the memory with conscious awareness and the individual can declare its existence and comment on its content either verbally or non-verbally (Cohen & Squire, 1980; Ryle, 1949). Consequently, such memories are known as declarative memories. On the other hand, implicit memory is not accompanied by conscious awareness that one has a memory; the existence of implicit memory is inferred only from the effects it has on behaviour. Further, implicit memories may be retained without an intention to remember and accessed commonly by priming tasks (Banaji & Greenwald, 1995; Curran, 2001; Knowlton et al, 1996).

Explicit or declarative memory can be further divided into 2 types: episodic (autobiographical) memory and semantic memory (Tulving, 1972; 1985). Episodic memory refers to memories that have a specific source in time, space and life circumstances. In contrast, semantic memories involve facts (or high-level concepts and generalisations) about us, the world, and other knowledge that we share within a community and are independent of the spatial and temporal context in which they were acquired. Further, episodic memories are remembered consciously and susceptible to forgetting while semantic memories give a feeling of knowing rather than a fully conscious recollection and less susceptible to forgetting. Initially memories are episodic and context dependent and over time they are transformed into semantic memories (Penfield and Milner, 1958).

Another categorisation of human memory is the division into the 2 types referred to as working memory (Baddeley, 2000; Baddeley and Hitch, 1974; Cowan et al, 2005) and long-term memory (Dudai, 2004; LeDoux, 1996; Lees et al, 2000; McGaugh, 2000). Working memory is defined as the set of mental processes holding limited information in a temporarily accessible state in service of cognition. Prefrontal cortex (PFC) seems to play an important role in working memory processes and temporal and prefrontal regions of the cortex appear involve in working storage. Long-term memory, on the other hand can be large quantities of information stored in a more permanent or longer duration basis. The neocortex is believed to encode long-term memories by altering synaptic connections between billions of neurons. There are trillions of such synapses in the cortex and its satellite organs. Memories are believed to be unstable and vulnerable to interference in the early hours after they are formed, and after about a day, they appear to be consolidated or made more enduring (Hobson and Stickgold, 1995). This process of consolidation is thought to require protein synthesis and sleep and dreaming seem to support this process.

2.4 Types of learning

Learning can be defined as the acquisition of lasting representations that involve a wide range of brain areas and activities (Baars and Gage, 2010). Very often, the unstated goal of learning is to turn explicit problem solving into the implicit kind. Similar to the way we discussed about explicit and implicit memories, learning can also be explicit or implicit. Explicit or declarative learning involves conscious learning while implicit (unconscious) learning (Berry and Dienes, 1993; Cleeremans, 1993) results as a side effect of conscious input. That is, even for implicit learning, conscious events guide the learning process. But there is no exclusively conscious learning as both, conscious and unconscious processes always go together. In a complete learning cycle, 3 phases can be identified: learning, retention and retrieval. Retention is generally viewed as unconscious, although it is shaped by conscious experiences. Explicit learning generally occurs when we pay attention to new information so that it becomes conscious. The brain begins learning as soon as it is placed in any novel environment. Simple novelty is enough to trigger attention and learning, including significant evoked potentials that sweep through the entire cortex. As soon as we experience or understand the new information with enough clarity, our brains are able to store it (Seitz & Watanabe, 2005). Sometime it may require repeated attention to new or difficult information in order for us to get a sense of clarity. Any new material may seem vague or hard to understand at first; however, when we spend time thinking about it or paying attention to it, a clearer sense of meaning tends to appear.

The brain takes more time to solve novel problems and voluntary actions become automatic with practice. As they do so, we tend to lose executive control over them. Cortical activity reduces when predictable voluntary action is practiced to the point of automaticity (Chein and Schneider, 2005; Coulthard et al, 2008; Langer and Imber, 1979; Raaijmakers and Shiffrin, 1992; Schneider, 2009; Shiffrin and Schneider, 1977). Once even very complex processes are learned, they seem to require less cortical activity.

The most of our learning is identified to be incidental (Eide & Eide, 2004), meaning that it occurs as a result of paying attention and becoming conscious of. That is, we do not deliberately memorise things all the time; memorising is only one way to make learning happen.

With our current practices, academic learning is mostly explicit with teachers pointing out the things to be learned and students doing their best to memorise them. However, most ordinary human learning is implicit (Bowers et al, 1990; James, 1890; Metcalfe, 1986; Yzerbyt et al, 1998). For example, social habits and language are mostly leant implicitly. Looking from another perspective, the most of our knowledge is tacit knowledge and the most of our learning takes place implicitly before it can be stated explicitly. Further, academic exams usually test associative recall (What is the capital of Australia?) rather than recognition tests. Associative recall tests give much lower estimates for accurate memories than recognition tests. That is, in associative recall, we expect more exact and specific answers than in recognition tests. Interestingly, these exact and specific answers are the ones that are likely to be forgotten soon (Tulving, 1972; 1985).

In the event of some emotional stimuli, there is evidence that unconscious learning takes place. That is, this gives much stronger evidence for implicit learning, in which some inferential process takes conscious input and encodes unconscious results. In other words, emotional learning results in implicit emotional memory that retains classically conditioned emotional relationships that cannot be voluntarily recollected or reported (Phelps and LeDoux, 2005; Panksepp, 1998). Psychological evidence shows that moderate levels of emotional arousal at the time of an event lead to better retention of explicit memories (Sylwester, 1998). That is, explicit memories are better consolidated by the reception of emotional stimuli by the amygdala.

Hebbian learning, named after neuropsychologist Donald Hebb, is summarised to “neurons that fire together wire together” (Hebb, 1949). It indicates that the more frequent certain synaptic connections are made the more likely they are to form lasting neural networks. In other words, synaptic connections that are rarely used will eventually die out (Diamond, 1996, 2001). This is a very simple idea on how we can explain the way learning takes place. In fact, it is observed that forming new synaptic connections or synaptogenesis (Huttenlocher et al, 1982; Huttenlocher, 1994) takes place throughout one’s lifespan, enabling a lifelong learning process. In other words, cortical plasticity lasts throughout the lifespan of a human being. However, in a changing, dynamic world, unlearning also has an important role to play. That is, we will have to let misconceptions or inaccurate knowledge to die out from our neural system. A similar concept known as neural Darwinism - survival of the fittest cells and synapses- is presented by Edelman (1989). In fact, human brains are identified to be selectionist rather than being instructionist, meaning that synaptic connections can grow by selecting new connections, not merely being restricted by an existing limited set of instructions as that happens in typical computers. In other words, human brains can be creative by learning new knowledge in the form of new synaptic connections that did not exist before.

2.5 Consciousness

Scientists have confirmed that consciousness can be defined and studied scientifically, contrary to the beliefs held otherwise, previously (Baars et al, 2003; Baars and Gage, 2010 Edelman, 1989, 1993, 2005, 2007; Edelman & Tononi, 2001; Koch, 1996; Palmer, 1999; Tononi & Edelman, 1998; Tulving, 2002). Consciousness results from neuronal interaction between thalamocortical systems; the neocortex is the main organ involved in it. The evolution of consciousness is understood to be the highest expression of the developed brain that parallels the evolution of the prefrontal cortex (PFC). Synonyms used for consciousness are awareness, explicit cognition and focal attention. Consciousness can be identified mainly in two levels – primary and higher-order consciousness. The former is concerned with perceptual world while the latter is related to abstractions and thought. Further consciousness involves with a range of contents: sensory perception, visual imagery, emotional feelings, inner speech, abstract concepts and action related ideas indicating the involvement of a number of brain regions, through an integrative view.

Of special interest to the phenomenon of consciousness is the theory developed by Giulio Tononi in the name of The Integrated Theory of Consciousness (Balduzzi & Tononi, 2008; Koch and Tononi, 2008; Tononi, 2008). It provides a new way to study consciousness using a rigorous scientific approach. The integrated theory of consciousness is a framework that is built on the notion that consciousness is a consequence of systems that have both a large amount of differentiated information that is also highly integrated. To summarise the idea, a computer may have a large quantity of memory (say 16 GB), but since these memory pieces are not integrated, computers do not have consciousness. Scientists have also been able to quantify the level of consciousness with a measure called neural complexity (C) (Edelman & Tononi, 2001). High values of C characterise conscious events and reflects the extent to which the dynamics of a neural system are both integrated and differentiated. Consciousness in humans can also be understood with the cognitive architecture known as the Global Workspace Theory (GWT) (Baars, 1988, 2002). The GWT proposes that momentarily dominant information is widely distributed in the brain. That is, the nervous system can be viewed as a massive distributed set of special-purpose networks. Consequently, coordination, control, and novel problem solving could take place by way of central information exchange. Conscious involvement of brain resources is particularly useful when novel information needs to be combined and integrated.

2.6 Attention

The word attention seems to imply the ability to direct cognitive resources to some event (Baars and Gage, 2010). It has a kind of pointing or directive sense. Selective attention implies a choice among a number of possible events. Consciousness seems to be the experience of an event after it has been selected by paying attention. We can decide voluntarily what to become conscious of or the selection can also be automatic if stimuli are intense, dynamic or biologically or personally important. In the real world, voluntary and automatic attentions are generally mixed. In summary, attention is defined as the ability to select information for cognitive purposes. This selection may be shaped by emotion (Zull, 2002), motivation and salience and is at least partly under executive control.

The term binocular rivalry is used to describe the process of selective attention in neuroscience (Logothetis, 1998; Tong et al, 1998). When 2 items are looked at the same time using one eye on each item using a pair of binoculars, at an instance of time we can only see one item properly or consciously. In other words, we cannot concentrate well on 2 things at the same time even though we see them both simultaneously. That is, when a person is given a task that requires in-depth, meaningful analysis of the material, memory under divided attention is much worse than memory under full attention. Deeper processing requires time to complete and divided attention limits the time allotted to encoding (Anderson et al, 2000; Fletcher et al, 1995). In learning, what we generally do is just pay attention to new material, even if it seems hard to understand. The biggest challenge is to pay continued attention to new and difficult information and to be patient enough to allow our brains to do wonder, ask questions, and ultimately comprehend any new material (Seitz & Watanabe, 2005).

2.7 Automaticity

In general, the more predictable a sensorimotor skill becomes, the less of it will become conscious. The fading of conscious access to habitual skills is commonly called ‘automaticity’ and it goes along with a loss of precise voluntary control over habitual details (Baars and Gage, 2010, Chein and Schneider, 2005; Coulthard et al, 2008; Langer and Imber, 1979; Raaijmakers and Shiffrin, 1992; Schneider, 2009; Shiffrin and Schneider, 1977). Repetitive events tend to fade from consciousness unless they have special significance. That is, voluntary actions we are conscious with become automatic with practice. As they do so, we tend to lose executive control over them. In other words, effortful tasks show a wider spread of brain activity; the brain takes more time to solve novel problems and switching from one task to another seems to require additional mental resources beyond those involved in routine and automatic actions. The level of activity in cortex (at least) drops with practice and automaticity. It seems to indicate the recruitment of neuronal resources that are needed to work together to perform a task that is new or unpredictable.

3. Introduction to primarily learning-related concepts that can be viewed from neuroscience

3.1 Chunking

Chunking is a process in which working memory perceives or compresses a set of data as a single item as we perceive a set of letters as one word (Sousa, 2011). It appears to be an innate human characteristic related to our survival ability of seeking patterns in the environment (Feigenson & Halberda, 2004; Brady, Konkle & Alvarez, 2009). Chunking occurs in 2 ways. In one situation it is a deliberate and goal oriented process initiated by the learner such as learning a poem, increasing one line at a time. In other situations, it is more subtle, automatic and linked to perceptual processes as when we learn to read by increasing the number of words from a single word to two to a phrase and so on (Bor, Duncan, Wiseman & Owen, 2003). Since chunking allows us to deal with a few large blocks of information rather than a large number of small fragments, it gives us the ability to solve problems by accessing a large amount of relevant knowledge from long-term memory to be used in working memory. Further, chunking is more of an ability of organising our knowledge base for better use of limited working memory.

3.2 Sense and Meaning

When the survival and emotional elements are not present, transferring information from short-term memory to long-term memory requires other factors that need to be addressed (Sousa, 2011). One such important factor is whether sense and meaning are attached to the new learning from the perspective of the learner. When the content or new learning makes sense to the learner, he/she can attach previous learning to the new learning. In other words, the learner can understand new learning based on what he/she knows about the world or how it operates. On the other hand, when a meaning is attached to new learning, it is relevant to the learner and there is a purpose or motivation for the learner to learn it. If both sense and meaning are present, the likelihood of transferring from the short-term to long-term storage is very high. Then it is understood to have substantially more cerebral activity followed by dramatically improved retention (Maquire, Frith & Morris, 1999; Poppenk, Kohler & Moscovitch, 2010; Rittle-Johnson & Kmicikewycz, 2008). Of the 2 criteria, meaning has a greater impact on the probability that information will be stored in long-term memory. One way to attach meaning to new learning is helping students to make connections between subject areas by integrating curricular; it increases meaning and retention, especially when students recognise a future use of the new learning.

3.3 Transfer

The phenomenon known as transfer is one of the ultimate goals of teaching and learning. It encompasses the ability to learn in one situation and then use that learning, possibly in a modified or generalised form, in other situations (Sousa, 2011). Transfer is the key process involved in problem solving, creative thinking, and all other higher mental processes of inventions and artistic products. Transfer can be described as a two part process – transfer during learning and transfer of learning. In the former, the effects the past learning have on the acquisition and processing of new learning are highlighted, while in the latter, the degree to which the learner becomes capable of applying new learning to future situations is presented. Further, transfer can be categorised as positive and negative transfers; in positive transfer, past learning helps the learner with new learning, while past learning interferes with the learners understanding of new learning in negative transfer. We can see here a close relationship between the concepts of making sense and meaning and transfer; the more the learner makes sense and meaning the better the function of transfer that takes place.

One way educators achieve successful transfer is by introducing integrated thematic units. Factors that affect the transfer process include the context and degree of original learning and critical attributes of a concept taught (Hunter, 2004). In relation to the first factor, it is important to understand that if something is worth teaching, it needs to be taught well, while the second factor highlights the need to emphasise on unique characteristics of the concepts learned. Further, it is understood that significant and efficient transfer occurs only if we teach to achieve it (Hunter, 2004; Mestre, 2002; Perkins and Saloman, 1988). The proper and frequent use of transfer greatly enhances the constructivist approach (Brooks & Brooks, 1999) to learning, and vice versa.

3.4 Rehearsal

Rehearsal is a critical component in learning that helps the transfer of information from working memory to long-term storage. There are two major factors associated with the process of rehearsal – the amount of time devoted to rehearsal and the type of rehearsal (Sousa, 2011). The amount of time devoted to rehearsal can be found in two stages, either initial or secondary rehearsal. Initial rehearsal occurs when information first enters working memory (when sense and meaning are attached). Several studies showed that during longer rehearsals, which may even take place at a secondary stage, the amount of activity in the frontal lobe determined whether items were stored or forgotten (Buckner, Kelley & Petersen, 1999; Wagner et al., 1998).

Another categorisation of the task of practicing or rehearsal is whether it is massed practice or distributed practice. Practicing new learning during time periods that are very close together is called massed practice; immediate memory is involved greatly here. Some example situations are mentally rehearsing a new phone number, cramming for an exam and trying a different example of applying new learning in a short period of time. In distributed practice, more sustained practice over time is done or introduce a spacing effect, which is the key to retention, as in the case of secondary rehearsal (Seabrook, Brown & Solity, 2005; Metcalfe, Kornell & Son, 2007; Carpenter, Pashler & Cepeda, 2009; Hunter, 2004). A spiral curriculum in which key concepts are revised at regular intervals is a method we can use to engage learners in distributed practice.

The type of rehearsal can also be either rote or elaborative rehearsal. When the learner has to remember information exactly the way it entered the working memory, it is termed as rote rehearsal. Some examples are when a poem, telephone number, or multiplication table is remembered. Elaborative rehearsal takes place when new learning is associated with prior learning to form new connections. The assignment of sense and meaning to new learning can occur only if the learner has adequate time to process and reprocess (rehearsal) it. When learners get very little time for elaborative rehearsal, they have no option but to resort more frequently to rote rehearsal.

3.5 Wait Times

The wait-time described here in terms of teaching and learning is the period of teacher silence that follows the posing of a question to the learner cohort before the first student is called on for a response. Studies reveal that higher wait times (about 5 seconds) showed improved learning outcomes (Rowe, 1974; (Sousa, 2011)), providing more higher-order responses. Further, the same researcher also noted that constant longer wait-times resulted in positive changes in the behaviour of teachers by giving them an inclination to use more higher-order questioning.

3.6 Learner Motivation

The longer an item being learnt is processed (or rehearsed) in working memory, the greater the probability that sense and meaning may be found and, therefore, the retention in long-term memory will occur (Sousa, 2011). Recent research studies have validated the long-standing belief that motivation is the key to the amount of attention and time devoted to a learning situation. Focus and learning takes place at the highest possible level when the learner is intrinsically motivated (Walker, Greene & Mansell, 2006; Wigfield & Eccles, 2002). Extrinsic motivators can only be of value to get students started on a learning topic before they can move toward intrinsic rewards.

Researchers have identified a number of practices that can be used to motivate learners (Diamond & Hopson, 1998; Hunter, 2004; Moore, 2005). Teachers can relate the new item being learnt to as many past learning networks as possible, including as many real world examples. Giving timely feedback on learner thinking is another such practice we can use to motivate learners to continue processing, make corrective actions until the completion of successful learning. Further, we can try to introduce and maintain an appropriate level of concern in order for the learners to have a helpful anxiety level, rather than crossing the boundary to a harmful anxiety level. When a helpful anxiety level is maintained, it develops a desire for learners to do well while a harmful anxiety level will threaten learners to keep away from engagement.

Another important fact that contributes towards the level learner motivation is emotional status of the learner. Recent studies reaffirm that as learners generate positive emotions, their scope of attention broadens and critical thinking skills are enhanced. In contrast, neutral and negative emotions narrow the scope of attention and thinking (Fredrickson & Branigan, 2005; Zenasni & Lubart, 2011). Emotions affect learning in two distinct ways: the emotional status of the environment in which learning occurs (implicit memory) and the degree to which emotions are associated with the learning content (explicit memory). When students feel positive about their learning environment, such as the presences of a non-authoritative, friendly facilitator, a biochemical called endorphins is released in the brain. Endorphins produce a feeling of euphoria and stimulate the frontal lobes. Consequently, the learning experience is made more pleasurable and successful. Conversely, if students are stressed and have a negative feeling about the learning environment, a hormone called cortisol is released. Cortisol travels throughout the brain and body and activates defence behaviours, such as fight or flight. As a result, the frontal lobe activity is reduced to focus on the cause of stress and how to deal with it (Kuhlmann, Kirschbaum & Woolf, 2005; Tollenaar, Elzinga, Spinhoven & Everaerd, 2009)

Recent research reveals that students are more likely to gain greater understanding and pleasure from learning when allowed to transform the learning into creative thoughts and products. It is understood that our success as a species can, to a certain extent, be attributed to the brain's persistent interest in novelty; that is, we as human beings like to see changes occurring within ourselves, more specifically the neural networks we possess, and in the environment. Conversely, if an environment contains mainly predictable or repeated stimuli, the brain's interest and attention on the task at hand is lowered and attempts are made within for novel sensation. As a result, we can make learners pay more attention by enabling them to make new connections between new knowledge introduced and past learning or knowledge. That is if we enable the process of transfer appropriately by allowing learners to make sense and meaning of the new knowledge, learners will be more motivated to engage in the learning process.

3.7 Creativity

Most definitions of creativity appear to have the notion of thinking outside the box. It essentially refers to using divergent thinking to probe deeply and broadly, and to find alternative solutions to problems that were not previously considered (Sousa, 2011). Although creativity comes naturally to some individuals, there is increasing evidence and understanding that it can be taught in the classroom. Such teaching essentially requires restricting the common instructional approach that revolves predominantly around convergent thinking; in these environments, finding one correct solution to a problem is the norm and memorisation prevails over deeper and broader understanding.

Neuroscientists suggest that creative thinking involves communication among many brain regions that do not normally interact during non-creative thinking. Although there is no single brain area that is responsible for creativity, most creative activities involve the brain's frontal lobe, which connects many brain regions together (Heilman, Nadeau & Beversdorf, 2003; Chavez-Eakle, Graff-Guerrero, Garcia-Reyna, Vaugier & Cruz-Fuentes, 2007; Fink, Benedek, Grabner, Staudt & Neubauer, 2007). Further, it has been observed that when more complex problems are processed, different parts of the brain are activated (Cole, Bagic, Kass &

Schneider, 2010; Kelly, Hester, Foxe, Shpaner & Garavan, 2006); it indicates that when more complex problems are solved, a higher level of creativity is used.

Research studies show that the areas of the brain responsible for inhibition and self-regulation are much less activated during a creative activity than during a purely memorised activity; instead, the activity in the brain areas associated with individuality and self-expression is increased during a creative task (Limb & Braun, 2008). It gives us the understanding that when we turn off the brain areas involving inhibition and self-regulation, it leads to less focussed attention and spontaneous and creative behaviour.

3.8 Complexity and Difficulty Levels

Blooms Taxonomy is one of the most popular models used for evaluating the level of learning for a number of years (Sousa, 2011). The original model of Bloom's Taxonomy (Bloom, Engelhart, Furst, Hill & Krathwohl, 1956) had 6 complexity levels, namely, Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. It held that the 6 levels were cumulative – a lower level needs to be satisfied before moving to a higher level. A revised model was presented in 2001 (Anderson et al., 2001) retaining all of the 6 levels. In the revised taxonomy, names of all levels were changed to verb form, 3 levels renamed and 2 were interchanged to a classification of Remember, Understand, Apply, Analyse, Evaluate and Create. In contrast to the original model, the strict hierarchy in the 2001 revision has been loosened to allow levels to overlap one another.

Recent neuroscience studies have found different cerebral regions were involved in solving problems of logic and sequence (deductive reasoning) than in solving open-ended problems with multiple answers (inductive reasoning) (Jausovec & Jausovec, 2000; Mihov, Denzler & Forster, 2010; Parsons & Osherson, 2001). These evidences weaken Bloom's initial notion that one type of thinking is dependent on the prior activation of lower level thinking. Cognitive psychologists have observed that, more specifically, the thinking skills at the upper levels were a lot more fluid than Bloom's rigid hierarchy suggested.

Cognitive psychologists have generally divided thought into 2 categories: convergent, lower-order thinking and divergent, higher-order thinking. The lower 3 levels of Bloom's Taxonomy describe a convergent thinking process whereby the learner recalls and focuses what is known and comprehended to solve problems through application. The upper 3 levels of the Taxonomy describe a divergent thinking process in which the learner come up with new insights and discoveries or relationships that were not part of the original information. Recent research studies show that elaborative rehearsal, involving higher-order thinking skills, engages the brain's frontal lobe. Further, they indicate that different parts of the brain are involved as more complex problem-solving tasks are handled (Cole, Bagic, Kass & Schneider, 2010; Kelly, Hester, Foxe, Shpaner & Garavan, 2006).

It is interesting to note that constructivist teachers, more specifically, ask open-ended questions and continually encourage students to analyse, evaluate and create (Brooks and Brooks, 1999). That is, it appears that teachers, who constantly use the upper levels of Bloom's revised taxonomy, are essentially demonstrating constructivist behaviours. However, we observe schooling still demands mostly the processing levels of convergent thinking. Common pedagogical practices and assessment focus on content acquisition through rote rehearsal, rather than on processes of analysis, synthesis and evaluation. Repeating the exact answers becomes more important than the processes used to get the answer.

In relation to Bloom's Taxonomy, the terms complexity and difficulty are used to describe different mental operations. However, often we find them being used synonymously. In Boom's Taxonomy, we say, there are 6 levels of complexity. Complexity describes the thought process or a level of thought that the brain uses to deal with information. Difficulty on the other hand refers the amount of effort, and possibly time, that the learner must expend, usually within a single level of complexity, while engage in learning. It is worth realising that a certain learning activity can become increasingly difficult without becoming more complex.

It has been observed that if teachers understand and follow the revised Bloom's Taxonomy correctly, all members of a learner cohort, irrespective of individual differences, can be sent through a process of higher-order learning. One way to make this practically possible is to review the curriculum and remove the topics of the least importance in order to gain the time needed for practicing at higher levels. Another approach is to integrate the new concepts with previously taught material and connect them to appropriate concepts in the other curriculum areas; here we are essentially using the process of transfer more appropriately in the teaching-learning context.

3.9 Types of Problem Solving/Decision Making

Individuals need to become better decision makers and problem solvers through education. In schools or colleges, we are usually given a problem or question and we must find or write the correct answer (Baars and Gage, 2010). Usually only one correct answer exists to these questions or problems. For example, balancing a check book and remembering the capital city of a country are similar tasks. By finding the correct solution, we engage in veridical decision-making. However, apart from high school exams, college tests and factual and computational trivia, most decisions we make in our everyday lives do not have intrinsically correct solutions. That is, the decisions we make are not always objective, rather they are, in most cases, subjective. What career path to make, what location to visit in the vacation are some such example decisions we make in ambiguous situations. By making a decision or choice, we engage in adaptive decision-making. Further, our best neural system performance is not for the exact symbol sequences that conventional computers handle so well. Rather, our brains are exceptionally good at dealing with complex, ill-defined, and novel challenges, the kinds that people have to deal with in real world. That is, humans are exceptionally flexible in adapting to new conditions.

The choices we make are not inherent in the situations at hand. There are complex interplay between the properties of the situations and our own individual properties, aspirations, doubts, and histories. The prefrontal cortex (PFC) is central to such decision-making or evaluation. Finding solutions for deterministic situations often is accomplished algorithmically or following a number of steps routinely. These tasks are increasingly delegated to various devices such as calculators, computers and the like. However, making judgments, in the absence of inherently correct solutions, remain, at least for now, a uniquely human territory. Thus, through education an individual must develop the capacity to have the flexibility to adopt different perspectives on the same situation at different times. The organism must be able to disambiguate the same situation in multiple different ways and to have the capacity to switch between them at will. Frontal lobes of the brain hemispheres play an important role in dealing with these ambiguous situations.

It appears that goals of and approaches to science education have shifted recently. Science usually works from a third person perspective. This means that researchers adopt an objective point of view, seeing all evidence as a physical object. Even human beings are seen as objects. Recently, scientists interested in consciousness have begun arguing for an additional way of conducting and approaching science that appreciates and accepts data gathered from first person perspective, i.e. phenomenological data from introspection or self-report. In second person perspective, the other person is viewed as a subject rather than an object, as someone who has mental states (Baron-Cohen, 1995; Frith and Frith, 1999).

4. Reflecting on Goals of Education Taking into Consideration the Findings from Educational Neuroscience

Broadly, the main goal of education is to develop human beings to become better problem solvers and decision makers who achieve a deeper perception of reality through enhanced creativity and wisdom. Wisdom is understood here as an advanced from of creativity (Claxton, 2008) that penetrates into knowledge of multiple domain areas. From the basis of neuroscience, enhancing wisdom implies enhancing consciousness. As presented in the Integrated Theory of Consciousness (see section 2.5), we can understand consciousness as the integration of a large number of differentiated information or brain regions that possibly span multiple domain areas of knowledge. In other words, we aim to develop interconnected, denser neuronal networks in individuals as they evolve through learning. In other words, we achieve transfer of learning (see section 3.3) through education; once concepts/contents are learned in relation to one or a few situations, learners should be able apply the knowledge in relatively novel and different situations successfully. That is, learners have to identify connections between learned situations and new and different situations. In order to achieve this goal, learners should be able to recall appropriate information, retained possibly in various regions of the brain, readily, whenever necessary.

Further, by enhancing consciousness, we say we achieve human development (Dabrowski, 1970, 1972, 1977) into self-actualising (Maslow, 1968, 1993) human beings. This process of self-actualisation or human development can be a lifelong process; it indicates the additional goal of education in which individuals need to learn self-reliance in accommodating lifelong learning. As we can see, we have a broader goal of education that goes beyond merely training individuals to specific career paths. In the theory of multiple intelligences (Gardner, 2006), we have identified a number of intelligences a human being can possess. In our main goal of education, we want individuals to develop as many areas of intelligences across multiple brain areas. That is, individuals need to evolve continuously, getting introduced to new domains of knowledge and identifying the connections among them; getting into a career path should not confine an individual a single domain. In short, we want individuals to develop holistically, internalising knowledge in multiple domain areas, as opposed to in a restricted, one-sided manner.

In a teaching-learning environment, learners engage in explicit learning (see section 2.4); teacher gives instructions on what to learn and learners attempt to grasp what is instructed. When novel material is presented long enough, possibly from diverse perspectives, the contents become clearer to learners and we say that the brain has achieved magical learning. Now, if clarity is achieved to a high degree, what is learned explicitly becomes implicit, meaning that our brain can implicitly or unconsciously apply the concepts learned in a similar but different situation naturally and spontaneously; this is what we refer to as achieving transfer of learning. To achieve, transfer of learning, we need to associate sense (see section 3.2) deeply to new concepts learned through elaborate rehearsal (see section 3.4); in order to spend time in performing elaborate rehearsal learners need to have meaning (see section 3.2) in what they learn. In relation to a teaching-learning environment, the goal of education is to transform explicit learning to implicit learning. This process of transformation should continue endlessly; that is, once a number of concepts are transformed, from explicit to implicit memories, we do not stop there as the final goal; rather, we look for more concepts for similar transformation. The plasticity feature of our brain plays an important role here; neuronal networks in human brains can grow endlessly, explaining the concept of creativity associated with human beings, compared to non-creative machines or computers (Beale, R. and T. Jackson, 1990). In other words, human brains are selectionist, compared to computers, which are instructionist.

Most of our learning is identified to be implicit (Bowers et al, 1990; James, 1890; Metcalfe, 1986; Yzerbyt et al, 1998); that is we learn from day to day life situations we encounter by simply paying attention. In these situations, we do not learn explicitly in a selected domain per se, but retain traces of implicit memories in diverse domains. More specifically, we have evidence that gifted individuals learn implicitly or incidentally more naturally (Eide & Eide, 2004). That is, learners bring wealth of implicit memories or experiences to a classroom environment, albeit to different degrees depending on personal traits. Consequently, another goal of education is to transform these implicit memories to more explicit or declarative memories. We can achieve this goal by helping learners to associate sense to new concepts learned; this can be achieved elaborately by relating the new concepts introduced to diverse situations in multiple domains. Then, learners will be able to use and express this tacit knowledge more elaborately when the circumstances arise.

We live in a neurodiverse (Armstrong, 2011) society; every individual is neurologically and psychologically different from others. Some learners are identified to demonstrate visual-spatial abilities while others demonstrate auditory-sequential abilities more predominantly. The former category of learners is likely to be identified as gifted individuals (Silverman, 1998, 2002; Webb, 2005, 2008) who usually demonstrate overexcitable characteristics (Dabrowski, 1970, 1972, 1977) such as emotional, intellectual and imaginational. Taking into consideration this broad concept of neurodiversity, a goal of education is to provide a unique, systematic and fair form of education to every individual, despite their inherent differences. We need to send neurodiverse learners through a process of transfer of learning in an individualised manner and subsequently assess them reliably. Achieving this elusive goal of education can be a real challenge in a contemporary social environment.

In the following sections, we look at some important pedagogical practices through which we can reach out achieving the above mentioned goals of education. We essentially incorporate the perspective of educational neuroscience here.

5. Application of Findings from Educational Neuroscience in Our Pedagogical Practices/ Classroom Environments

5.1 Presenting New Content to Learners in a Teaching-Learning Environment

When presenting new contents to learners in a teaching-learning environment, we need to emphasise on the high-level concepts we present instead of on more specific details. By doing this, we will be able to utilise learners' limited working memory more effectively following the phenomenon of chunking. That is, when grouped or generalised knowledge is presented as a limited number of concepts, instead of a larger number of specific details, learners will be handling only a smaller number of knowledge rich items in their limited working memory. As a result, the initial rehearsing process of knowledge, making sense or connecting to existing neural networks of knowledge will be more efficient. Further, High-level concepts are retained in memory longer as semantic memory, which is independent of the time and space contexts (see section 2.3). On the other hand, specific details are stored as episodic memory which is more susceptible to forgetting; further, these specific details usually have references to time and space and their validity can be subjective. Since high-level concepts are usually more generalised knowledge, they tend to penetrate through multiple domain areas as well. In order to accomplish knowledge transfer process, we can links these concepts into as many domain areas or diverse situations/examples as possible. Consequently, by emphasising on high-level concepts, we not only create more lasting memories, through a process of transfer, but also enable the interconnection of knowledge in multiple domain areas. Further, when we relate the content presented to multiple domain areas, we essentially move learners from a restrictive, lower-order, and convergent thinking exercise to a more creative, higher-order and/or divergent thinking exercise (see section 3.8). To reiterate, to enhance wisdom in learners, we have to let them create knowledge across multiple domains. Here, we are penetrating across knowledge silos into more fluid, lasting knowledge that can be retained and recalled readily. Looking from a different perspective, we encourage learners to be creative, divergent or inductive in their thinking; we are targeting higher-order thinking/learning focusing on the higher-end of Bloom's taxonomy. It is worth noticing here that different parts of the brains work in inductive and deductive reasoning; right hemisphere is likely to be heavily involved in inductive reasoning while the left hemisphere on deductive reasoning. Consequently, following the revised Bloom's taxonomy, we can get learners to pay attention on generalised concepts without necessarily introducing extensive specific details (see section 3.8).

To reiterate, when we introduce new high-level concepts, we have to help learners to make sense or link them to their existing knowledge bases (Zull, 2002). Existing knowledge bases that can be recalled easily would most likely to be the concepts based on day to day life phenomena, spreading across multiple domains. In this way, we support learners to build more lasting and more integrated knowledge bases, instead of isolated pieces that are domain specific and susceptible for forgetting. In addition, when new concepts are presented, we can guide and get learners to link the new concepts themselves to their existing personalised body of knowledge. That is, learners attempt to identify relationships between existing and new knowledge while we encourage them to do so themselves. In fact, we can get them to do this as a secondary, elaborate rehearsal task, in order to enhance retention and recall. We encourage learners to be bold and fearless in the presence of new information and avoid any inhibitions and self-regulation, in order to be creative, divergent and/or inductive in reasoning/learning; this will activate learners' brain areas of individuality and self-expression (see section 3.7). The result is that learners engage in a process of creating personalised knowledge as highlighted at higher levels of Bloom's Taxonomy and in the theory of constructivism (Brooks & Brooks, 1999; Biggs, 2003) and do so in a relatively autonomous manner that would help them to proceed with a process of lifelong learning.

In order for learners to identify the mentioned relationships among pieces of knowledge, we can direct them by asking a series of open-ended questions in guiding them towards reaching the target; learners will get to the target by answering or attempting to answer these questions. This is essentially the technique followed by constructivist theory practitioners (see sections 3.3 & 3.8). Further, we can make use of related analogies or anecdotes to enhance clarity of the concepts presented. The key point here is that we make them identify relationships between existing and new knowledge themselves rather than we relate to them in order for them to commit to memory, as in a rote rehearsal exercise, which is unlikely to give a lasting impact. Even when we present a well-established theory to our learners, we should mimic the thinking process that would have gone through in the mind of the creator of this theory; the creator may have self-inquired himself/herself in numerous ways, against his/her exited knowledge bases, before confirming the knowledge. We should lead our learners in a similar path of self-inquiry mimicking a process of construction of knowledge, making sense or transfer during learning.

5.2 Controlling the Pace of Presentation Appropriately for Learners to Construct Knowledge

We need to present new contents to learners in a teaching-learning environment in a manner that they can link them to their existing knowledge bases (Zull, 2002). These existing knowledge bases or neural networks may be associated with multiple domain areas of knowledge and may have been spread across multiple physical regions of the brain, depending on individual neurological and psychological differences (Watagodakumbura, 2013). To reach out to these multiple regions, we need to essentially send messages to frontal lobes, which are highly connected to all the other regions (see section 2.1). However, when knowledge is processed in frontal lobes and connects with the knowledge in the other regions, this whole task takes relatively longer time, or the process is slower. This slowness could be due to the parallel processing that takes place within multiple brain regions. Further, this is a divergent or inductive thinking process as highlighted at the high-end of Bloom's taxonomy (see section 3.8). The time comparison done here is usually made with modern machines or typical computers composed of electronic circuits and runs sequentially in repetitive cycles at very high speeds. Also, we have to remember that frontal lobes are considered as the organ of civilisation; that is any processing involving frontal lobes or resulting higher-order processing has the impact of a deeper and better learning experience. Consequently, when presenting new contents to learners, we have to present them at an appropriate pace taking into account the relative slowness in processing that involves the frontal lobes.

Interestingly, the researchers who have worked independently on wait times (see section 3.5) have formulated interesting and related results. They observed that higher wait time after posing a question to learners, resulted in better, higher-order answers. Further, they identified that educators who tend to allow higher wait times, are likely to ask thought provoking, higher-order questions encouraging divergent thinking as well.

Looking from another point of view, frontal lobes are usually involved with the process of abstract conceptualisation (Watagodakumbura, 2013; Kolb, 1983); as a result, when new contents are presented by means of introducing new concepts, we need to allow learners adequate time to understand or conceptualise them. This contrasts from presenting contents to learners rapidly so that they have to commit them to short-term memory, involving in a convergent thinking exercise (see section 3.8), in order for them to reproduce the content in the exact form (i.e. rote rehearsal) later on, not necessarily getting the frontal lobes involved appropriately. That is, when new contents are presented, initial elaborate rehearsal (see section 3.4) in the working memory helps learners to send and retain them in long-term memory for recalling readily later. In other words, making sense (see section 3.2) and transfer (see section 3.3) of knowledge is done more efficiently within learners.

5.3 Motivating Learners to Engage in Deeper Learning by Giving Facts from Neuroscience

In a teaching-learning environment, for effective learning to take place, learners have to engage well in the learning process. More specifically, they have to be intrinsically motivated in learning; that is, they see some long lasting value in learning, not only for the purpose of getting through forthcoming examinations or their future careers, but in general in everyday lives, throughout the lifespan. That is, learners have to see some useful meaning (see section 3.2) in what they learn in order for them to develop motivation intrinsically. In fact, researchers have found that attention or focus is at the highest possible level when learners are intrinsically motivated (see section 3.6). In addition, if learners are able to identify a significant meaning in what they learn, they will be more inclined to perform more elaborate rehearsal (see section 3.4), resulting in better transfer (see section 3.3).

In order for us to motivate our learners to engage deeply in the learning process or have a meaning in what they learn, we can provide some useful facts about learning, in general, related to neuroscience. Our brains use more neural resources in learning new material (see section 2.7) and learning new material is relatively more engaging as well as challenging. However, even difficult contents can be mastered by simply paying attention for a longer period of time (i.e. elaborate rehearsal); then the brains do the wonder of learning – making lasting connections with the existing knowledge base as well as creating new connections. The elaborate rehearsal exercise can also be attempted at a secondary stage, leisurely, if learners see meaning in expending this time or motivated enough. That is, elaborate rehearsal in working memory will help improving clarity of even new and/or difficult content, enabling a more efficient transfer process. Put differently, learners are advised and encouraged to simply spend more time on any content that does not make a clear sense initially or unclear, rather than keeping away from them in a perceived fear of them, to enable a better transfer process; they can be instructed to avoid forced inhibitions and self-regulation and be bold in engaging in a creative, divergent thinking (see section 3.8) process. In addition, our brains have the natural property of neural plasticity that helps us to create new neural connections or networks altogether, provided that we rehearse the contents for an adequate amount of time. In fact, researchers found that we, as human beings, are novelty-seeking creatures and naturally motivated to create new neural connections (see section 3.6). That is, we can be creative and develop wisdom if we try to understand new concepts deeply by linking them to other existing concepts or frameworks, more specifically from multiple domain areas. This task of learning is a lifelong process that would not end at the completion of examinations or formal studies. The concept of distributed rehearsal (see section 3.4) is applicable here; learners go through or revise some contents they have learned before, after an extended period of time, say months or even years. They could see the knowledge they have gained before with a new set of eyes, through all the other learning they have done since, improving clarity and enabling them to make new useful connections. As we move on with our lives, we develop more integrated, useful neural networks that cross the boundaries of domain areas, thus enhancing consciousness and wisdom. In this way, we can become better problem solvers and decision makers by seeing the reality better by recalling well retained memories readily whenever needed, as an evolutionary process over the years of our lifespan. This idea of an ever extending neural network, provided that we engage in learning deeply, performing elaborate rehearsal, can be a contributing factor of creating intrinsic motivation within learners; every unit of effective time one spends on learning will give the person to see the reality or world more broadly or as it is.

By giving positive facts about learning and contents presented, we can create positive emotions such as pleasure in the minds of learners. At the same time, we can get rid of any negative emotions such as fear (Zull, 2002) from the minds of learners with appropriate instructions and behaviour; for example if learners get a feeling that the contents are not difficult to master, if a systematic approach is persisted, they may not be fearful of them; if the teacher presents a non-authoritative figure, as that of a facilitator, in front of the class, learners will be more comfortable with no negative emotions. These positive emotions lacking negative ones help learners more specifically to be motivated in the learning process, extending a convergent thinking process to a divergent one. It is worth noting that positive emotions release the biochemical endorphins in the brain that stimulates the frontal lobes, broadening the scope of attention and enhancing critical thinking skills, while negative emotions release the hormone cortisol, activating defence behaviours such as fight or flight, thus turning the frontal lobe focus towards identifying the cause of stress (see section 3.6).

5.4 Getting Learner Attention Fully on the Teaching-Learning Process or Discussion

Neuroscientists have identified a concept referred to as binocular rivalry (see section 2.6) that explains that human brain can concentrate or pay attention only on one thing completely at a time. We can apply this principle to our teaching-learning environment by asking learners to only listen and see visuals by paying full attention and engage in the discussion. By doing this, we allow learners to engage in initial rehearsal (see section 3.4) fully, during the teaching-learning process by attaching sense (see section 3.2) to the content learned. Learners can be provided with summaries of the discussion and if possible a voice/video recording of the same for their reference later on; this will reduce harmful anxiety (see section 3.6) created due to the possibility of missing important points from learners. Still, if they want to write down some notes in their own words, we can provide note taking times separately for this purpose. This is different from jotting down presenter's exact words in order to be reproduced later on at the examinations/assessment (i.e. rote rehearsal – see section 3.4). We are trying to avoid learners undergoing a situation of divided attention that would have a negative impact on deeper learning or elaborate rehearsal. By doing this, we encourage learners to be fully vigilant by paying attention to the discussion during which time they construct meaning or perform abstract conceptualisations (Kolb, 1983) by linking new knowledge to existing knowledge bases; we encourage learners to extend a possible convergent, lower-order thinking exercise to a divergent (see section 3.8), higher-order one by utilising more effective time. Further, we can get the learner attention towards what we present by asking questions in order to build curiosity; these questions can relate the concepts we highlight to day-to-day phenomena. By building curiosity, we raise the level of concern to a helpful anxiety level, generating a positive atmosphere. In fact, constructivist theory practitioners, engage in teaching-learning process by posing open-ended questions to learners constantly (see section 3.8).

5.5 Useful Considerations when Setting Up Assessment

When setting up assessment questions, we need to consider getting involved learners frontal lobes that connects multiple brain regions, in providing answers. By doing this, we are able to test how well learners were able engage in deep learning (Biggs, 2003; Entwistle, 1998) or elaborate rehearsal (see section 3.4) by constructing individualised meaning (Yero, 2002). To achieve this objective, we can ask relatively novel and open-ended conceptual questions (Watagodakumbura, 2013). We deviate from asking questions that require regurgitation of factual and exact recalled information; such questions only require a rote rehearsal (see section 3.4) effort from learners. Open-ended conceptual questions allow us to test learners' higher-order learning abilities developed as a result of involving in high-end functions such as creation and evaluation of Bloom's Taxonomy. High level conceptual questions help us to encourage learners to provide generalised answers crossing multiple domains; in fact these are the traces in semantic memory that last longer (see section 2.3). In other words, we encourage learners to engage in adaptive decision making instead of veridical decision making even when answering examination questions. We ask questions from learners in order to discourage them from providing premeditated or habitual answers. That is, if they have answered a similar question before, they may provide a habitual answer; the brain plays an automaticity function (see section 2.7) here bypassing the engagement of cortical resources including the frontal lobe appropriately in providing answers. Consequently, even during the examination time period, learners engage in a process of elaborate rehearsal, integrating information from multiple brain regions, using frontal lobes; based on the clues given for open-ended questions, learners will have to recall retained information from appropriate regions of the brain in order to make valid inferences.

From the perspective of Bloom's Taxonomy, we ask learners to engage in the functions of creation and evaluation or in divergent thinking (see section 3.8) exercises. In the end, we evaluate transfer of learning (see section 3.3) with respect to the learner. As a result, time allocation per question becomes a key design factor of the examination; as we are not expecting premeditated, habitual answers requiring less brain resources (see section 2.7), we need to allocate adequate time, not only to write down but also to create the answer, utilising as much brain resources as possible, engaging in a divergent thinking exercise. In timed tests/assessments, since we have a limited time to evaluate learners, it is important that we create questions at higher complexity levels but not at higher difficulty levels; questions at higher difficulty levels may utilise more time and effort from learners' point of view, but not necessarily testing higher-order thinking abilities (see section 3.8) or transfer of learning. Further, since we have only a limited time to conduct timed tests/assessments, they become statistical analyses that allow only a sample set of questions rather than all possible questions. That is, we should take special care not to overload the examination paper with too many questions, not allowing learners adequate time to formulate and write down answers.

We would like to emphasise that the discussion in the above paragraph can be applied equally well even to science education, not only for social science education. Science usually works from the third person perspective, adopting an objective point of view (see section). However, recently there is a shift in seeing science from a first person perspective, especially by the scientists interested in studying consciousness. In this approach, phenomenological data is seen from introspection or self-report. Consequently, what we have discussed in the preceding paragraph can be applied to science education environments equally well encouraging learners to develop creativity and wisdom. In other words, assessments in science education do not have to focus on veridical decision making or asking questions with exact or precise answers; questions can be so constructed that learners can provide subjective answers, engaging in a divergent thinking process, without violating the rules or laws of a broad framework of knowledge.

6. Conclusion

At the broadest level, the goal of education is identified to be producing individuals who are sound problem solvers and decision makers, not only in their chosen careers, narrowly, but also in everyday life activities, in a more general sense; thus individuals get to see the reality better or as is. In other words, individuals develop a higher level of consciousness and/or wisdom, giving them the abilities of recalling retained memories readily, whenever the circumstances require. Consequently, we as educators, have to guide learners to achieve, primarily, transfer of learning by attaching sense and meaning, ideally across multiple domains, and performing elaborate rehearsal. In order to achieve this goal, we have to stimulate as many brain regions of a learner as possible, inducing creativity in problem-solving and decision-making; in this regard, we have to get the frontal lobes of the brain, the organ of civilisation, essentially involved during a process of teaching-learning and subsequent assessment. Since frontal lobes connect many other brain regions, we encourage learners, who are naturally novelty seeking, to integrate knowledge from multiple domain areas, thus enhancing their wisdom. To practically achieve these higher-order learning processes, such as creation and evaluation as highlighted in Bloom's taxonomy, in a teaching-learning environment, we have to highlight high-level/generalised concepts that are stored as semantic memory; semantic memory lasts longer in long-term memory, compared to episodic memory that relates to more specific details. Further, in assessment, we have to focus on open-ended, novel and high-level concepts-based questions in order to direct learners on a higher-order, divergent and/or inductive thinking learning path, as well as to maintain the validity of our assessment, in a lasting manner. Importantly, through emerging evidences from educational neuroscience, we, the educators, can now get guided in our pedagogical practices to provide a better learning experience to our learners; here, we are guided by scientific facts and what is better for our learners biologically to evolve in a process of lifelong human development into creative, fully functioning human beings with higher levels of consciousness and/or wisdom. Further, through these evidence-based approaches, we promote inclusive practices in a neurodiverse (Armstrong, 2011) society; widely-pronounced disadvantaged situations faced by gifted and creative individuals and/or visual-spatial learners (Silverman, 1998, 2002) in traditional educational environments will be reduced significantly; numerous adverse psychological issues faced by gifted individuals (Webb, 2005, 2008) demonstrating overexcitable characteristics (Dabrowski, 1970, 1972, 1977) will be minimised.

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