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Improving classroom practices using our knowledge of how the brain works

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Abstract

During the last decade of the 20th century (the decade of the brain) large sums of money were spent in researching how the brain works in relation to our day-to-day activities. As a result, we now know to a much greater extent the roles played by various regions of the brain when we are carrying out various activities including learning. We also know that different types of rewards and instruments can stimulate specific parts of the brain which enable individuals to carry out their daily chores efficiently. These findings when applied to a classroom learning situation, which is a step forward from theory to practice, might make it possible for us to improve learning for all learners. Thus, in this presentation we plan to combine our knowledge of how the brain functions with those of the other scientific disciplines to provide teachers with the tools they may need to be more effective and efficient teachers. More specifically, this paper aims to lay a foundation for an interfaculty collaboration in UBD towards helping teachers improve their thinking skills which in our opinion are of great importance to fostering their classroom practices.

Keywords: interest, popular science, images of science and scientists, attitudes, school science and teachers

Introduction

According to Spanish foremost neuroscientist Santiago Ramon y Cajal, every man can, if he so desires, become the sculptor of his own brain. This underscores the immense potential of the brain to adapt to new experiences by the individual, a mechanism that is generally referred to as neuroplasticity or brain plasticity. Thus the brain has a tremendous ability to organise and reorganise itself by forming new connections between brain cells mostly neurons throughout life including old age. Studies have shown that the brain is able to do this based on a number of factors which include the stage in the development cycle, genetic make up of the individual, the environment in which a person lives as well as the actions of that person. Notably brain plasticity occurs significantly, a) at the beginning of life when the immature brain organises itself; b) in case of an injury involving the brain to compensate for loss of function in the affected part(s) and/or maximise the remaining functions; and, c) through out adult life when something new is being learned. The brain is therefore able to adapt to meet the various challenges that a person may face at different stages and in varying experiences of life.

Experimental observations in both humans and animals have shown that the brain possesses a combination of fortuitous characteristics which has conferred on it this uniquely adaptability property. For example, in addition to neural plasticity, the brain has a large functionally uncommitted prefrontal, temporal and parietal cortices; the ability of their neural circuits (resulting from neuroplasicity), if trained to take on novel symbolic and non-symbolic skills; as well as a large prefrontal cortex which could use its working memory as a tuition management pad in which to train them (see Skoyles 1997). The mammalian brain is also known to exhibit a shift of function of anatomical structures if there is insufficiency in the ability of one part to perform its ‘traditional' role. For example, in those bom blind the visual cortex aids pointing of reference or bearing (Kujala et al 1995) and Braille reading (Sadato et al 1996, Uhl et al 1991); amputees experience remapping when somatosensory and motor maps invade areas that have lost their functions (Yang et al 1994); the functions of a motor cortex destroyed by brain tumours can be taken over by other motor and non-motor areas of the brain (Seitz et al 1995). This is not limited to humans as; in experimental animals similar phenomena do occur. For example in ferrets, visual input which is experimentally redirected to the somatosensory cortex causes it to develop into ‘visual cortex' (Roe et al 1991) and, in the blind mole rat, auditory input has been evolutionarily redirected to the visual cortex causing it to function as ‘auditory cortex' (Boron and Wollberg 1994). Another case which has demonstrated the effect of training or retraining on brain plasticity is that of a surgeon in his 50s who suffered a stroke and had his left arm paralysed. During his rehabilitation, his unaffected arm and hand were immobilized, while he was set to cleaning tables. This was at first almost an impossible task but slowly the stroke affected arm started to respond to the various activities as if to ‘remember' how too move. He also learnt to write again and is able to play tennis again (see http://www.sharpbrains.com/blog/2008/02/26/brain-plasticity-how-leaming-changes-your-brain/). The most parsimonious explanation for this is that the functions of the brain areas that were destroyed by the stroke have now been taken over by other regions of the brain. It is apparent that the process is helped by stimulating activities or training. Neurons in the frontoparietal mirror system constitute an interesting model in this respect. These neurons fire when one performs an action and when one observes someone else performing that same action. The system is thought to have a role in social cognition and, perhaps, in language acquisition. While is unclear how the mirror neurons map sensory input onto its motor representation Catmur et al (2007) have demonstrated that these representations are not innate and can be altered by training. In our opinion, this system can be targeted by teacher when they are teaching procedure related subjects, topics and/or skills: during such a session students could view demonstrators live or in a video while also carrying out the same procedures almost simultaneously.

Brain Plasticity, Exercises, Learning and Memory

For a long time, it was believed that as we aged, the connections in the brain became fixed. Research has however shown that in fact the brain never stops changing through learning. Rather than being predetermined the neural networks in the brain underlying cognition are open to processing new skills (Skoyles 1997). Indeed studies have shown that the brain has a phenomenal capacity to change with learning. Thus a number of normal daily activities are known to elicit brain plasticity. For example, it has been demonstrated by van Praag et al (1999) that physical exercises improve learning and memory by a process of neurogenesis in the hippocampus of the mammalian adult brain. This is a process which literarily ‘gives birth' to new cells in the adult brain. Until recently the dogma is that the brain does not give birth to new cells: we now know that nothing can be farther from the truth. Thus, physical exercise, in addition to increasing the general blood flow to the various parts of the body including the brain has an effect in increasing the generation of new brain cells. This increases the capacity of the brain for learning and memory activities. It is intriguing that changes associated with learning occur mostly at the level of the connections between neurons and as new connections are formed the internal structures of the existing synapses change. A result of this phenomenon is that when a person becomes an ‘expert' in a specific domain, the areas of the brain that deal with the types of skill involved will grow remarkably. For instance according to Maguire et al (2000), London taxi drivers have a larger hippocampus (in the posterior region) than London bus drivers. Why is this? The explanation is that this region of the hippocampus is specialised in acquiring and using complex spatial information in order to navigate efficiently. Obviously taxi drivers have to navigate around London while bus drivers follow a limited set of routes.

Other human activities involving learning have also being linked to brain plasticity. For example, Mechelli et al (2004) observed plasticity in the brains of bilinguals and concluded that it appears that learning a second language is made possible through functional changes in the brain: the left inferior parietal cortex is larger in the brains of bilinguals than in those of monolingual. Plastic changes also occur in musicians' brains compared to non-musicians'. Gaser and Schlaug (2003) compared professional musicians who practiced at least Ihour per day to amateur musicians and non-musicians. They found that the gray matter (cortex) volume was highest in professional musicians, intermediate in amateur musicians, and lowest in non-musicians in several brain areas involved in playing music: motor regions, anterior superior parietal areas and inferior temporal areas.

Finally, it does appear that the nature of the material being learned and the intensity of learning activity parallel resulting brain plasticity. Thus extensive learning of abstract information can trigger plastic changes in the brain (Draganski et al 2006). They imaged the brains of German medical students three months prior to their medical exam and immediately after the exam comparing them to the brains of students who were not studying for exam at the time.

Medical students' brains showed learning-induced changes in regions of the parietal cortex as well as in the posterior hippocampus. These regions of the brain are known to be involved in memory retrieval and learning. We would like to see what difference using another cohort of medical students at the same level but not preparing for exams for comparison or as a third group. It is likely that the changes being observed may also have to do with type of subjects that they are learning and have to recall rather than being just because they learned relearned and recalled information.

Stages in the Development of Memory and Cognition

The ability to study the cellular and molecular basis of mental function has invigorated the impetus to examine and study cognitive processes such as perception, action, language, learning and memory. This has consequently led to major conceptual advances one of which reveals that learning is not a unitary faculty of the mind rather it consists of at least two distinct mental processes which include, learning about people, places and things (explicit or declarative forms of learning (Kandel 1995), and learning motor skills and perceptual strategies (implicit or procedural forms of learning (Polster et al 1991, Alberini et al 1995). The two forms of learning are localised to different systems within the brain (Zola-Morgan et al 1986). The regions involved in explicit learning are within the temporal lobe of the cerebral cortex which includes the hippocampus (Kandel 1995) while implicit learning involves only the specific sensory and motor systems recruited for the particular perceptual or motor skills utilised during the learning process (Squire 1992). Memory for both forms of learning has stages and is divided into two temporally distinct components of short term memory that lasts minutes to hours, and, long term memory that may last days, weeks or even years.

The memory storage for both forms of learning seems to involve a switch or consolidation mechanism that appears to have common features and involve the induction of genes and protein synthesis (Alberini et al 1995, Alberini 2008). So this type of evidence has given rise first of all to the idea—and lots of other evidence—that memory has stages. There is the initial encoding stage, followed by a period of consolidation. In the case of animal lesion studies, this period consists of one or two weeks where the memories are vulnerable to accidents. It has been shown in a lot of other conditions such as head trauma and so forth. This is eventually followed by some long-term storage phase where the memories are less vulnerable to these sorts of accidents and no longer require the hippocampus (Alberini 1999). What this indicates is that the hippocampal formation plays an important role, maybe even an obligatory role, in these phases, the initial encoding and consolidation phases in memory formation but is not required for the storage because the old memories are still there without a hippocampus, which suggests that they are stored somewhere else. People have thought for a long time and there is increasing support for the idea, that they are stored in different areas of neocortex. For example, long-term visual memories would be in visual areas that are associated with and/or distributed throughout the neocortex (Rubin and Greeberg 1998).

Memory Consolidation and Reconsolidation

Memory consolidation has been defined based on the observations that a newly formed memory undergoes a transformation process becoming stronger and more resilient over time until it is no longer sensitive to disruption; the process of memory formation and elaboration are accompanied by transient yet crucial phases of protein synthesis (Alberini 2005). Studies have shown that memory consolidation is also dependent on protein synthesis and it transforms learned information into stable modifications (see Davis and Squire 1984 for review, McGaugh 2000). Another intriguing but related phrase that has cropped up in the literature in recent time is ‘memory reconsolidation'. This has come about because evidence has been presented to the effect that when a stabilised memory is recalled or reactivated, it becomes vulnerable to disruption and its maintenance is dependent on protein synthesis (Misanin et al 1968, Mactutus 1979). However, according to Alberini (2005), reconsolidation of activated memory and consolidation are characterised by distinctive features such as the involvement of different brain areas and circuits. In addition, consolidation seems to require several areas that are not essential for reconsolidation which might involve mostly modulatory systems. Furthermore, Alberini (2005) also asserts that consolidation and reconsolidation differ in their dynamics. Thus training always induces a labile phase during which memory is destructible as opposed to what happens in reactivation which does not always result in a labile memory. It is imperative for teachers to be aware of this so that the recalls of materials which are newly taught to students are not done during the destructible labile phase. This will no doubt require a specialised skill by the teacher to execute. Further work needs to be done by ourselves and others to facilitate this.

Classroom Applications

Neuroplasticity

With respect to the gains of our knowledge of the brain and how to improve teachers' classroom performance, one very important area which deserves significant attention especially in Brunei Darussalam at the moment is the early and nursery education. This is because at the present time research in this area especially in the Sultanate is scanty. Therefore in the next few years, we intend to focus our research efforts in this area. As mentioned earlier, brain plasticity occurs significantly at the beginning of life when the immature brain organises itself. This to a great
extent has an apparent bearing on the period when young children are often physically active. The combination of physical activity and an actively growing brain and body enhances the process of reorganisation and brainplasticity that favours improved cognition. However it is also a period when the young is vulnerable to cognitive insults: therefore if this period is not well managed it could result in cognitive disability. We know that children often attend childcare/ day-care centres for various reasons such as, both parents are working, parents are separated, grandparents' support not available or inadequate, etc. Preschool institutions are saddled with the education of children at this sensitive time and should make the best of it. Therefore, it is important for the childcare and preschool institutions to concentrate on a physical activity based curriculum. It is also important that at this stage of development, the association of physical activity and brain development should be cardinal to the school curriculum. However, like other Asian parents Bruneian parents put more emphasis on reading and writing for their young children. Hitherto it is this emphasis on reading and writing that has significant influence on the early childhood curriculum in the country. Consequently, in many childcare centres and preschools, children often spend most of their time sitting and learning languages often like adults than playing and engaging in physical activities. One other major influence on school curriculum in Brunei

is the learning of English language, which is second or third language for Bruneian children but it is often highly valued by parents. Thus majority of childcare centres and preschools concentrate on teaching the English alphabets. In this quest the teaching method often used is writing the symbols, telling the children their names and then using them in words. Ironically, the English alphabet symbols, their names and the sounds attached to them in most cases, represent a very abstract situation. The abstractness of the situation increases when the names of the letters and their sounds are different, for example L in Cat. The intriguing thing according to Piaget's developmental theory is that, at this age children cannot deal with abstract information, however, children learn the language using association technique despite the fact that they are not really capable of abstract thinking.

Research in neuroscience which has clearly linked physical activity to learning abstract information can be viewed to have a positive effect on the neural development and improved cognition in the child. There is now clear evidence that a lack of physical experiences will slow down the overall development of the brain in young children which unfortunately is to their disadvantage. On the other hand it is possible that due to the adaptable and compensatory activities of the brain, learning symbols representing language alphabets that are abstract in nature can functionally alter the children's parietal cortex as well as in the posterior hippocampus as has been observed in a group of German medical students: abstract information can improve plasticity of the brain (Draganski et al 2006). In addition, as enumerated above learning a second language seems to help improve cognition and brain plasticity. Therefore, an issue for educators to resolve is creating a balance of activities that would enhance the overall development of the child's brain as well as its reorganisation and subsequent reorganisation and memory consolidation. One approach to achieve this is to teach these young children through play techniques. Thus it is incumbent on teachers to be creative in developing new teaching techniques. Obviously this would also open up new research opportunities that include among others, the evaluation of curriculum in childcare centres and preschools, appraising the effectiveness of existing teaching techniques as well as the development of new teaching techniques which combine physical activities and various forms of learning. Another important element of these proposed interventions is that it would require the childcare and preschool institution licensing authority in Brunei to overhaul it mechanism of monitoring the curriculum of these establishments. They should be able to monitor the extent to which the curriculum is implemented by the childcare and preschool institutions.

At high school level, students in general can be classified into four categories: (i) very good in academic subjects, (ii) very good in non-academic subjects such as sports, (iii) very good in academic and non-academic subjects, and (iv) and others (not good in academic and nonacademic subjects). Expectedly, the fourth category is a serious concern to teachers, schools and society. It is therefore important to study the activity patterns of these students. This can be achieved by investigating their involvement in Physical Education and other courses. This kind of investigation and resultant intervention has to be carried out in their early stages. Research efforts that are aimed at identifying the activity patterns, improving on their physical involvement and investing the effect on the achievement of these students are crucial in tackling this problem.

Signal Diversion

Another neuroscience research finding that in our opinion is of great potential for use in the classroom is about signal diversion to put responsibility of a part of the brain that originally is not involved in doing the task which has been referred to earlier. The observation is that in case a designated area of the brain is not functioning efficiently, its functions can be automatically transferred to other locations. Since there are non invasive techniques to trace the location of signal, it is essential to research into finding out the location of signal if it requires diversion. Moreover, new teaching techniques that can divert signals need to be developed and their effectiveness for students in question is warranted.

Minimising Hippocampus Role

The information stored in the brain is as a result of establishing neural structures. Plasticity is a process of modifying these structures as the need arises. In a teaching process, the content for the students is often arranged from simple to complex as they progress to higher grades. This model of teaching requires students to learn, unlearn and relearn new information either by modifying or replacing the stored memory. Evidence from neuroscience suggests that the hippocampus plays a significant role during the processes of coding and consolidation. However, the hippocampus is by passed when information is permanently stored. It is therefore important that we teach content that lasts for longer durations to minimise the role of hippocampus so that students will not require a modification to their neural structures. Moreover, with a repeated use the long lasting neural structures become more rigid and the information becomes accessible more easily. For example, at lower secondary level, element is defined as "a substance that has same type of atoms’’. This definition requires a change as soon as students learn about isotopes, because all atoms representing different isotopes of an element are not of the same type. Hence the previously built neuron structure needs to be modified. Since the lower secondary students learn elements and atoms, if we can add little more information that an atom consists of protons, electrons and neutrons. If we teach that an element is a substance that has atoms containing same number of protons. It is most likely that ‘the change in brain structure' once formed will last till the students start learning a more advance level of the atomic theory.

Another practical example is explaining the volume changes that take place when two liquids are mixed. For example if we mix 50 ml of water and 50 ml of ethyl alcohol, the total volume is less than 100 ml. The usual explanation assumes that smaller molecules take position in gaps created by larges molecules: the analogy used is mixing sand and marbles. Obviously this analogy is good to explain a decrease in volume however it does not explain an increase in volume. As the students advance into higher grades, they would need to learn how to explain an increase in volume when two liquids are mixed. This modification in learning will presumably drag the hippocampus into ‘an unnecessary action' again, which could have been avoided by
explaining the process in terms of force of attraction between molecules from their initial exposure to the subject. The above example can be explained thus ‘there is a force of attraction between molecules of water and similarly in the molecules of alcohol; when they are mixed another force acts between a molecule of water and that of alcohol, if this force is stronger then the two molecules will come closer and the total volume will be lower; however if this force is weaker then the molecules will be wider apart and the volume will greater than the sum total; if identical force exists between them no change in volume should be observed'. This explanation is logical and does not need modifications very often and is not likely to cause confusion for the students. Evidently, this sort of teaching demands that teachers be creative to think of alternate ways of presenting

content to the students: it will also help the teachers to improve their thinking skills.

Environment and Brain Development

According to Chan and Petrie (1998) the significance of the learning environment cannot be underestimated. Neuroscience research has highlighted the effect of the environment on the growing brain as well as the role of protein synthesis in memory formation during learning. Since, Jensen (1998, 2000) estimates that we use less than 1% of our brain's projected processing capacity as he differentiates between the brain being what we have and the mind being the process of what is done (p. 15), therefore the key to a brain-compatible classroom is to grow more synaptic connections between brain cells with minimal to no loss of existing connections to exploit the unused capacity of our brain. Literarily therefore an environment that is conducive to leaning will help neurons to syntheses more proteins which suggests that teachers have a great role to play in improving classroom learning environment. This is pertinent since protein synthetic process associated to memory can be completed in response to a 10-minute learning experience.

The brain learns faster in challenging, creative, accommodating, and healthy environments. To provide for the growing, learning brains of our children, we must not forget that the environments we design have a major influence in building smarter brains. Creating a classroom environment where student expression and choice are solicited provides a welcoming atmosphere for children to grow at independent rates. Bredekamp (1987) and Rushton and Larkin (2001) visualize this as a developmentally appropriate brain researched learning environment which allows an educational focus to preside while student autonomy prevails. For example, learning environments that provide student choice and empowerment of students, created through the utilization of hands-on, differentiated instruction allow children to be actively responsible for their learning, thus engaging several areas of the brain simultaneously. Such environments aid in the development of neurons, thickening the myelination sheaf and stimulating serotonin and other neurochemicals which enhance the child's wellbeing. Effective teachers support brain development by encouraging children to make discoveries in well-planned environments that support student autonomy. It is essential that teachers know how human brain works and how to use this knowledge to make their classroom compatible to brain development. More research how to integrate brain research and classroom teaching is desirable.

Consolidation and Reconsolidation

With respect to information consolidation it has been reported that it takes place about two weeks after coding but during this period the information is prone to suffer losses. The hippocampus plays significant role in consolidation till information is stored permanently. In our opinion, it is important for the teachers to ensure that during this period the taught information is supported to avoid loss. This can be achieved by linking new knowledge to the existing memory. Since learning stimulates the growth of new neurons teachers could help the brain to achieve this and increased neuronal connections by associating the new knowledge to 'common' and daily life experiences. Moreover, teachers should organise the topics they are teaching over this period to be interlined so that previously learned information is used for learning of new knowledge: inefficient organisation of taught content can promote loss of memory during the period of consolidation.

Understanding how and when to engineer enhancements in learning and memory development and consolidation will be important to helping teachers to improve their thinking skills and classroom practices. It would also foster in them and their pupils/ students improved problem solving ability and increase their potential to be maximally creative.

Neuron Connections

It is an established fact that different parts of the brain are interlinked and there are numerous connections with in a region. These connections make it possible to activated information stored in different parts of the brain as well as conceptual storage within a part of the brain. The efficiency of these connections is important for information construction and recall. Evidently some teaching techniques are more efficient in memory organisation than others. Thus of the traditional teaching, teaching using interactive white board and mind mapping techniques, the latter one has been reported to be more efficient (Dhindsa & Emran, 2006; Dhindsa, Makarimi-Kasim, & Anderson, 2011). Therefore to improve students learning outcomes by improving their memory storages, teachers should use these efficient techniques. It is our opinion that specials needs pupils and students will also benefit from this approach.

Finally, teachers need to be actively involved in action research to compare and/or develop new techniques that are more efficient; most especially work towards developing teaching techniques that will minimise the role of hippocampus during active learning, so that working memory can directly access the information.

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