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The editors would like to dedicate this book to those deceased due to the ongoing pandemic.

Preface

Traditionally teaching learning process called pedagogy was being considered in isolation, but of late, advances in understanding human physiology and neural system have thrown open challenges to understand the working of the human brain to enhance learning. Further, the impact of digital technology revolution and advances in understanding human neural system are not allowing to consider pedagogy in isolation. Designing pedagogy to facilitate learning in encompassing all kinds of learners with normal health and learners with health concerns becomes important.

In the current age, where the interface between artificial intelligence and neuroscientific research have impacted all aspects of human learning, memory and behaviour at all age groups, the study of an interdisciplinary engagement of their impact on education and pedagogy needs more deliberation in the professional community. Teacher education and pedagogy are interdependent, now one more dimension gets added to this, such as neuroscientific research, digital technology and educational theories. A composite of all these are to be developed to enhance learning. If this is the case, meaning of curriculum and facilitation of learning may have to change, for example, online education and remote learning. Experiences of learning may have to change.

Effort is possibly still on in trying to understand learning from the point of view of some established theories in the past. With changing dynamics of technology, behaviour and social context, it has become essential to explore deeper aspects of learning and challenges in learning. It is time that we cannot work in silos. We need a collaborative approach to looking at various ways of learning and engaging our students. Several experienced experts in this book have been working to unravel this truth, and this book is another effort to add a new dimension. We hope it will open up a new window for innovation in this emerging area of research in teaching and learning and we need to nurture it being supported by modern technology and new knowledge in diagnosis of learning disabilities. Having said this, real-time tracking of learning behaviour may gain more emphasis.

According to Prof. Frank Pantridge, there are three type of people/lecturers/teachers: (i) those that make things happen, (ii) those that watch things happen and (iii) those that wonder what happened.

Learning about learning has been connected with higher levels of performance. Understanding of learning has advanced significantly in last decades (impacted by technology, new ways of behaviour and newer ways of understanding the human brain and how it functions). Though learning is believed to stem from 'student-centeredness', other factors such as 'learner autonomy and learner independence' matter a lot. Learning, specific to the social situation in which it was originally learned, the physiological basis of learning, challenges teachers today and we need to discuss the same.

Until now, the science of learning was rooted principally in behavioural sciences like education, psychology and technology. However, there are several reasons why learning and development should explore the study of neuroscience. First and foremost, it brings to bear new findings from hard sciences (such as physiology and chemistry) to learning theories.

Various fundamental tenets of integration of higher order thinking concepts occur in the human brain. Thus, the brain plays a vital role as the central governing system to map images of learning, and through a common language enables specific neural pathways to consolidate knowledge acquisition. The body clock or master pacemaker that is located in the forebrain plays a pivotal role in synchronizing learning cycles, metabolism and behaviour, thus creating an inextricable link between neuroscience and chronobiology, which is less understood. The most effective learning involves recruiting multiple regions of the brain for the learning task. These regions are associated with functions such as memory, senses, volitional control, emotional regulation, and cognitive functioning. By considering advances in medical technology, the understanding of various learning disorders and difficulties, such as autism, dyslexia, dyscalculia and Down's syndrome, is facilitated. Targeted experimental interventions also show that genetic modifications or mutations influence learning and behaviour tremendously. Due to neuroplasticity, new neurons are generated, to promote learning throughout life. Moreover, synaptic connections are dynamic and subject to influence by external sources such as technology, gadgets, text, print media and social cues. Neuroscience has also shown that lifelong learning is possible, irrespective of any age.

Neuroscience thus has a key role in investigating means of boosting brain power. Pharmacological companies are trying to come up with brain boosting supplements. However, natural hormones being a part of the natural diet need to be prioritized. Some insights from neuroscience are relevant for the development and use of adaptive digital or artificial intelligence technologies. It is fascinating to note that educational systems can be merged with human-ware. Research endeavours now focus on the field of neural networking in computer sciences and robotics in creating smart-chips not only for machines but for man-machine interactions. It is worthwhile to consider these research areas in investigating the interplay between human intelligence and artificial intelligence. These technologies have the potential to create more learning opportunities inside and outside the classroom, and throughout life. This is exciting given the positive effects this could have on well-being, health, employment and the economy. The learning style and adaptability to a learning space is special to each individual, and therefore learning depends on building the neuro-systemic awareness of the learners. *Education, Neuroscience, Technology and Pedagogy: Neuro-systemic Influence on Learning* intends to bring together insights of experts, researchers and professionals in neurosciences, artificial intelligence, brain sciences, technology, psychologists, medical education, engineering education and pedagogy to network and integrate neuro-science, artificial intelligence, educational psychology and pedagogy on a single platform to transform teaching, learning and education. The contents may open up areas of interdisciplinary research to augment educational and pedagogical practices in higher education.

Insights go beyond learning, though. It is also explained that the volume and depth of neuroscience research in recent years indicates a significant reciprocal relationship between brain functioning and the environments (including artificial intelligence and technology) in which humans behave.

Therefore, by gaining deep insight into how the brain functions – in support of learning, creating and problem solving – we can not only better prepare students, but build them as workers who can adapt to the evolving and expanding workplace. The subject that networks neuro-science, educational psychology and pedagogy may open-up areas of interdisciplinary research.

This volume comprises 25 well-versed chapters categorized into three parts: 1. Neuro-systemic, 2. Brain-Based Learning and Cognition, 3. Learning and Technology.

The first part deals with neuro-systemic dynamics encompassing neurocognition, neuroscience in educational practices, effective learning as a neurological / mental process, neuroscience in teacher training and others. The second part deals with brain-based learning and cognition, which cover learning and teaching that involve challenges, lastly the third part deals with learning and technology intervention covering knowledge management and technology transfer into education, impact of digital intervention in education, blended learning using technology, technology intervention in higher education and so on.

Contributors to this volume vary from teachers, educational psychologists, medical professionals, neuro-scientists and others, thus the volume becomes interdisciplinary. We hope that it may raise the curtain for further research in interdisciplinary nature covering formal science, educational technology, neuroscience, educational psychology and health science.

Bangalore, Karnataka, India
February 2021

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About the Editors

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Joseph Varghese Kureethara completed his doctorate in decomposition of graphs at Manonmaniam Sundarnar University, Tirunelveli. He has master's degree in economics and mathematics from Madras University. Dr. Kureethara received a gold medal with his bachelor's degree and has a postgraduate degree in mathematics; he is a recipient of the National Merit Scholarship for Postgraduate Studies. He is currently professor of mathematics at Christ University, Bengaluru. Dr. Kureethara is a catholic priest. He has over 16 years of experience in teaching and research at Christ University, Bengaluru, and has published over 100 articles in the fields of graph theory, number theory, history, religious studies and sports both in English and Malayalam. He co-edited three books and authored one book. His blogs, comments, facts and poems have earned about a total 1.5 lakhs views. He is the mathematics section editor of *Mapana Journal of Sciences* and member of the editorial board and reviewer of several journals.

Siddhartha Bhattacharyya [*FRSA (UK), FIET (UK)*, *FIEI (I)*, *FIETE*, *LFOSI*, *SMIEEE*, *SMACM*, *SMIETI*] completed his PhD (Eng.) from Jadavpur University, India, in 2008. He is currently serving as the Principal at Rajnagar Mahavidyalaya, Birbhum, India. Prior to this, he served as a Professor in Christ University, Bangalore, India. He served as a senior research scientist in the Faculty of Electrical Engineering and Computer Science at VSB Technical University of Ostrava, Czech Republic, from October 2018 to April 2019. He also served as the Principal of RCC Institute of Information Technology, Kolkata, India. He is a co-author of 6 books and a co-editor of 75 books and has more than 300 research publications in international journals and conference proceedings to his credit. His research interests include soft computing, pattern recognition, multimedia data processing, hybrid intelligence and quantum computing.

Part I
Neuro-Systemic Learning Methodologies

Chapter 1
Transformative Pedagogy Integrating Bloom's Taxonomy, David Kolb's Experiential Learning and Neuro-systemic Dynamics in Learning

G. N. Madhuranatha Dixit and Kennedy Andrew Thomas

1.1 Introduction

Following the work of David Kolb and others in "experiential-learning-engine", learner experiences a transformation while passing through a spiral of knowledge experience, reflection on experience, abstract conceptualisation and plan for further action. This is an interplay between objectivity and subjectivity, where experience to conceptualisation is referred to as the grasping or comprehending axis, whereas reflection to planning for further action is the transformation axis. These two axes together constitute experiential learning plane pivoted on Bloom's taxonomy of education and the neuropsychic system of the learner. Learner's personal preferences and the learning environment together may be called the learning space. Learning curve spirals upward, indicating development around the vertical axis to this plane, which depends on the style of learning, depending on the neuro-systemic dynamics of the learner that characterises student-centric learning.

Teachers create learning accommodation scientifically by knowledge and experimentation, called curriculum, they provide in the subject they want to facilitate learning; but this accommodation is also imagined in the student's own experience through the prism of his/her way of learning.

In the process of learning as experiencing knowledge, the human brain plays a vital role as the central governing system for mapping the images of learning – which can be called educational neuroscience – manifested as cognitive skills.

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Learner constructs knowledge images as perceived by him/her as an activity of the brain and then transforms these perceptions into concrete repeated actions called cognitive skills as a function of the brain, particularly in the case of learning. If this function of the brain with respect to learning activity is further investigated as a research problem, findings may develop a communication channel among educators, psychologists and neuroscientists. This research may be called educational neuroscience, which may open up educational opportunities and challenges.

Neuroscience has started making inroads into educational process to improve quality of learning and behavioural dimension of learner in terms of attitude. Individual differences in approaches for learning are to be scientifically investigated as an application of neuroscience. This may become a necessary input into framing educational policies. A teacher is a learner, and so teacher education is a process to train in the art of teaching that requires understanding the behavioural pattern of the learner and the facilitator (teacher) of learning. In both cases, neuroscientific influence needs to be investigated.

Neuroscience research may have to characterise the learning styles proposed by David Kolb. Therefore, teacher education becomes a neuroscience-based education. This need not be restricted to special education needs like dyslexia and others only. Research in educational neuroscience, for example, how the brain benefits from computational psychomotor skills including data analytics and how the brain understands computational numeracy involving many variables, can improve the design of educational technologies. This may pave the way for bridging digital technology area and neuroscience. In other words, neuroscience and technology intervention in facilitating learning may have to be researched, and access to technology aids like BYOD (bring your own devices) may have to be made affordable and more user-friendly. A dialogue between neuroscience researchers and cognitive psychologists may have to be strengthened to help the process of learning become diagnostic while suggesting remedial measures. Thus, understanding the implications of neuroscience for education opens up. In Finland, students use playing as a learning activity of the school curriculum. Physical activity relaxes the mind and removes stress in the brain. In this state of mind, learning becomes better (Report by Dorothy Bishop 2011; Bert 2010).

Subdivisions of the nervous system consist of the central nervous system (CNS) and the peripheral nervous system (PNS). CNS – consisting of the brain and spinal cord – is enclosed in bony coverings. PNS consists of all the nervous system except the brain and spinal cord. The most effective learning involves stimuli that sense organs and neurons collectively recognise in three steps, that is, sense organs respond to the external stimuli by sending impulses to the CNS which it identifies and issues commands to the glands and muscles. Neurons constitute the communication system of the central nervous system in three manners:

1. External impulses cause changes in the body. Neurons respond to these changes and stimuli due to external environment.
2. Neurons generate moving electrical signals.

3. Chemical neurotransmitter is secreted when electrical signal reaches the end of the nerve fibre. Chemical messengers (hormones) delivered to the blood stream recruit multiple regions of the brain for the learning task.

In light of the above, understanding learning difficulties like dyslexia and dyscalculia and certain type of learning becomes more effective. Furthermore, in the process of learning, new learning is commonly associated with old learning, so that the brain is subject to a continuous change, making the brain elastic in nature. This makes learning a spiral development throughout life. It is observed that the skill learnt will be lost if not reinforced by constant practice regularly. Thus, using the skill acquired is essential for lifelong learning and retention of the skill.

Research in the neural network in the field of computer science is using the analysis of the human brain function for the development of artificial intelligence science as an intelligent agent to perceive the environment like the human brain and to take digital science actions to achieve the goals successfully. This intelligence is not human but simulated by digital technology which may be used, e.g. in healthcare (the use of ECG, EEG, brain-computer intervention, robotics, etc.), financial management, traffic management, supply chain management by the corporate world and many more complex problems involving many variables that may not be easily handled by humans. Nevertheless, these gadgets cannot think and feel like the human brain however efficient they may be in making the job of humans easy as they do not constitute human biological neural network; the intelligence they have is therefore artificial, not natural.

A lot of research has gone in the field of neural network in computer science and robotics. It is worthwhile to consider these research areas in investigating the interplay between the human brain and human formal/natural learning. Neurons and neuroplasticity play an important role in learning which may be called neuro-systemic influence after the sense organs recognise the stimuli in any learning activity. The way of learning and adaptability to the learning area is special to each individual, and therefore the learning depends on the neuro-systemic influence on the personality of the learner. Learners suffering from dyslexia and dyscalculia may be good cases to consider.

Experts like Prof. Ranganatha Sitaram, a renowned brain machine researcher, opine as follows: each cell of the human body is indeed "intelligent", if intelligence can be defined broadly as the ability to sense and adapt to the surrounding environment for the sake of survival. However, except receiving and relaying signals from and to proximal cells, ordinary cells in the body do not communicate or form networks with distant cells. Neurons are special type of cells that differ in at least two distinct ways. Firstly, they form proximal as well distal connections with other neurons in the brain, the spinal cord and even the gut, leading to complex networks. Secondly, neurons in the brain themselves do not have any sensory apparatus except processing sensory signals from the visual, auditory, olfactory, gustatory and proprioceptive sense organs. That is why patient undergoing surgery cannot feel pain as there are no sensors in the brain. Despite the above differences which make the brains more "intelligent" than other organs of the body, the general spirit of the thought that cells are intelligent is well taken. Taking this idea even further is the branch of philosophy called panpsychism which holds that all matter is intelligent and sentient and forms the basis of consciousness. But that idea is currently hard to test empirically. This was the reply from Ranganatha Sitaram when he was asked by one of the authors (Dixit): “I guess each cell of human body is an intelligent system in its own right. The collective function of all these cells is human function and it is governed by the human brain. The interconnecting network is human neural network system. Do you agree with this?” (Ranganatha 2020).

Reflection upon the information or knowledge sense organs experience is an important function of learning. Reflection is a process carried out by the brain, but how the brain engages itself in this is an interesting question to be researched by neuroscience. As said earlier, the neurons process sensory signals received from the sense organs, and the sensory organs play a vital role in learning engagement. This may be called educational neuroscience. How teachers and other professionals engaged in managing education benefit from this kind of study appears to be interesting. How to engage them in this research is a question to be answered. (Bell 2014). This sounds a kind of interdisciplinary engagement by neuroscientists, educational psychologists and educators.

Neural networks in the human brain change through growth and reorganisation. This is called plasticity or plasticity of the human brain. This phenomenon includes individual neurons making fresh connections to systemic adjustments in situations, for example, promotion from lower level to higher level, failure in an examination, change of school, etc. like remapping on the outer layer of the brain. In this, neuroplasticity plays a vital role (https://en.wikipedia.org/wiki/Neuroplasticity). Studies in neuroscience show that learning induces change in the brain called brain plasticity, which does not stop changing through learning. Plasticity as a consequence of learning is mostly at the level of connections between neurons (Chia-Chen Chen et al. 2016).

If the ELT model of Kolb is considered, how reflective observation takes place and what changes it affects in the brain and how neurons and connections among neurons function in the process are interesting questions. Then, if these neurons and thereby the elastic nature of the brain (described above) take these reflective observations to abstract conceptualisation, the change has to become permanent, which may be realised by a planned action in which the brain as a whole participates, in which probably neurons play a vital role. Once this change becomes permanent, the brain (learner) looks for a new experience, and the same cycle continues. This is how a learner develops ever since the learner comes to this world as a child. This is how ELT model and neuroscience are interrelated, which is our conjecture. Neuroplasticity has an important role to play in this.

Using virtual reality tools, it is possible to bring the three-dimensional globe into the classroom demonstration to explain the different aspects of the Earth. The viewers can be immersed in the virtual experience in the “make-believe” world. Visual media these days show so many augmented reality and virtual reality pictures particularly in promotional ads. Architects use three-dimensional designs to make their customers feel the idea of the final outcome of their design. The customers can see the internal structure of the building and suggest alterations. Augmented reality tools extend physical reality to go a step beyond what the user wants, whereas virtual reality tools use technology to create simulated environments in which one can immerse oneself. On the other hand, artificial intelligence aims to equip technological devices with the insight and perception of a responsive being. Human intelligence is managed by a neural network (network of neurons), which is to be managed by external machines or by means of which the human neural network system may have to be simulated for the desired purpose. This is called artificial intelligence. In human intelligence, hormones play a role in keeping the system biologically balanced through chemical messaging, whereas in the artificial world, such a facility cannot be created. Hormones enable brain-like feelings or excitement through chemical messaging to correctly interpret the external data and manage learning. In this process, neurons also take part. Therefore, virtual reality tools and augmented reality tools become a kind of artificial intelligence systems that make humans feel the real situation but not actually experience it – a kind of simulation of a real situation.

Virtual Reality (VR) and Augmented Reality (AR) in Education

- Virtual reality and augmented reality have been at the forefront of innovation like machine design or architectural design using computer-aided design software. As said earlier, students can feel the positions of countries, cities, etc. on the virtual presence of the globe in the classroom. Users (students) require special goggles or other aids to meddle with the virtual images like altering the size, shape, etc., and augmented reality has been heavily involved in the learning initiative.
- Virtual reality (VR) is a digital technology that "make-believe" the stimuli of an imaginary world generated in real time. In this, the user is isolated from the sensorial signals of the real world. But the user feels that he/she is immersed in the situation. Examples for this may be group meetings with members from various places across the globe. In the meeting, deliberations take place virtually, but outcomes or action plans are real. The movie Spider-Man is an example that uses a VR tool in the film industry. Similarly, the Indian movie Baahubali is an example for using augmented reality in movies. Skype and WhatsApp are examples of VR applications.

Some International Scenario

Universities like Iowa State University, San Diego State University, University of Kentucky, University of Wisconsin at Madison, MIT and others are using VR aids in educational facilitation in engineering and science courses.

For example, fluid flow in a pipe can be shown in a virtual medium, and the abstract concepts of fluid mechanics can be made comprehendible to the learner in a virtual medium. More importantly students enjoy the freedom of altering the flow by altering the size of the pipe and experiment with the concept for better understanding the content. This is a kind of experiential learning in a virtual medium.

This Is How Augmented Reality Works

In a real-world scene, if virtual elements are added and then real-world objects are deleted, it becomes an augmented reality. This is not virtual reality because the environment is real. In the film industry, wide application of augmented reality is there.

In STEM (science, technology, engineering and mathematics) programmes, VR and AR tools are widely used to take laboratory feel to the doors of the learners.

Learning mathematics is understanding abstraction, which is purely a cognitive function. The author, Kelley, reviews recent findings in cognitive neuroscience, taking the example of learning mathematics. Perception of abstraction is special to each individual, and it is personal which may be partially understood or generalised empirically when that knowledge is applied in a situation. For example, four-dimensional space is hard to imagine and to make the students understand, because the concept of dimension itself is very abstract. In mathematics, concepts like n-dimensional space are dealt with. Therefore, it is understandable that not much is achieved in this area of neuroscience because of lack of empirical evidence (Kelly 2011).

1.2 Embedding Bloom's Taxonomy in David Kolb's Experiential Learning Model (Mcleod 2017)

1.2.1 Backdrop: Comprehensive, Culminating Outcomes and Experiential Learning

In Indian mythology, the popular epic is *Mahabharata*, and the other epic is *Ramayana*. The main characters of *Mahabharata* are from the royal clans Kauravas and Pandavas. The Kauravas, the children of the born – the blind old king Dhritarashtra, who was blind to the values as well – represent the innumerable ungodly tendencies within man, and the Pandavas, the children of Pandu, the first cousin of Dhritarashtra, represent divine impulses and righteousness in man. Dhritarashtra, the king of Hastinapur and the uncle of the Pandavas (sons of Pandu, the cousin of Dhritarashtra), had deprived the Pandavas the right to the kingdom of their share, and hence the war between the brothers Kauravas and Pandavas was symbolically a war between the good and the bad, referred to as the "Kurukshetra War". In the war, the Pandavas win, though their army was nearly half of the army of the Kauravas. This is the essence of *Mahabharata*. Dronacharya was the guru (teacher) of both the Kauravas and Pandavas. Thousands of people die in the war. It was the war between students of the same teacher Drona. This raises the question of the quality of learning Drona imparted to his students. He taught them the art of warfare but not the values of life consciousness and the social responsibility of the princes towards their subjects and welfare of the kingdom. That is what Drona gave them, learning, not education; education is the proper mix of learning and consciousness for values. Drona obviously taught them skills of war. The methodology must have been experiential and student-centric as each of his students perfected in one or the other trade of war. Comprehensive outcome of learning was mastery in the battleground using weapons, and the culminating outcome was "hatred". Comprehensive outcome is the outcome due to procedures and processes, whereas culminating outcome is due to attitude and environmental factors, associations, advisers, travel and other exposures like sense of judgement.

Renaissance means rebirth. Renaissance was a period during the 1300s–1600s in Europe when knowledge and intelligence played an important role in life. It was the education for non-clergy about man and nature relationship, whereas the only type of inquiry previously encouraged was about man's relationship with God. Painters, sculptors and writers began expanding their perspective, breaking away from the medieval period's almost total focus on religious figures and themes to begin celebrating man and man's accomplishments. This was a great step forward in terms of expressing abstraction like feelings in images that man can perceive or experience as a learning tool – abstraction to concreteness. Artistes (painters) and creative writers started expressing abstract images in their minds in a concrete form, either in figures or in words. The poet William Wordsworth, for example, brought natural beauty into words, such as in his poem *Daffodils*. This is a great step forward in the sense of learning theory as a beginning in the direction of experiential learning and creating knowledge images. Today we often use diagrams to express our perceptions and thought processes – a long journey in the process of experiential learning and understanding has traversed since the days of Leonardo da Vinci.

In India, way back before the Christian era, there was a school, Takshashila, where the teaching methodology followed was student-centric and a kind of synthesis of rote and experiential learning. The method of teaching was a gurukula system, a dedicated teacher to a student or a few students. Students would learn by experiencing knowledge in nature. Each student used to be special to guru. Same thing was true in ancient Nalanda University founded in the fifth century CE, which was active until it was destroyed by an invader during the late twelfth century. Here also the approach of pedagogy was student-centric experiential learning. In India, even now classical music is being taught following this method by individual gurus. This method of teaching classical music is institutionalised in institutions like the ITC Sangeet Research Academy (SRA), Kolkata, India, which is active now. If one browses the Internet looking for Taxila and Nalanda, he or she can know all the details about these ancient centres of learning (https://en.wikipedia.org/wiki/University_of_ancient_Taxila and https://en.wikipedia.org/wiki/Gupta_Empire, https://en.wikipedia.org/wiki/Nalanda).

A Chinese philosopher and a great teacher of the fifth century BC, Confucius, was a promoter of this kind of education. Korea and Japan were influenced by this Confucianism in education. This kind of education promoted by Confucius lasted for about 2000 years in that part of the world (http://www.ibe.unesco.org/publications/ThinkersPdf/confucie.PDF and Yang, H. 1999).

Reformation and Enlightenment followed the period of Renaissance. Man started exploring. Scientific thinking developed. Great scientists like Newton and others emerged; machines came into the hands of man. Industrialisation started. With this, the problem started in the form of emergence of materialism and power. Research in science became the order of the intellectual world. Unfortunately, science and research findings were used in developing nuclear weapons and tanks, etc., violating the principles of deontology. World wars happened as modern Kurukshetra. Now, there is COVID-19. All of this is due to a bad culminating outcome (explained below) of the educational process in the form of scientific research. If we consider Osama Bin Laden, Hitler and others, they were all intelligent and learned but with bad motivational culminating outcome in their respective personalities.

Nobel Laureate Amartya Sen put forward the concepts of culmination and comprehensive outcomes incorporating consequential outcomes in comprehensive outcomes (Sen 2009).

We see culmination and comprehensive outcomes on the education canvas below:

Outcome

- The outcome is the result obtained from the actions taken following certain rules and procedures.
- The outcome in the context of education can include the purpose of curriculum, teacher equipment and teacher training, physical resources, student-teacher ratio, learning resources, etc.
- The content of outcomes depends on the nature of the awarding body and qualification framework. It also depends on the nature of the governing body.
- Interpersonal relationship among the teachers and administrators may be seen as important and relevant to the decisional problem at hand.

Comprehensive Outcomes

Joseph M. Juran, a quality expert, defines quality as the fitness for purpose. Comprehensive outcome in education setting is the quality in learning in the sense as articulated in the curriculum. The teaching-learning processes play a vital role in quality assurance along with other factors like resources, scholarship of teachers and so on. Curriculum articulates the purpose of learning. Quality assurance may have to be audited periodically to ensure the purpose is realised. Achievement of comprehensive outcomes is the outcome of the above process.

The appraisal of comprehensive outcomes can be an integral part of the assessment of state of affairs and thus a crucial building block in consequential evaluation.

Culmination Outcomes

- Culmination outcomes are those simple outcomes that are detached from processes, agencies and relations.
- Ethical binding and culmination outcomes go together in true education.
- An ideal system is one in which consequences of comprehensive outcomes and culmination outcomes coincide.

Culminating outcome is tacit and transcendental, whereas comprehensive outcome is measurable as producing a concrete effect on those interested in it.

In the epic *Mahabharata*, the character Krishna, the chief adviser of the Pandavas, is the symbol of consciousness and the embodiment of culmination outcomes, and the chief warrior Arjuna, one among the Pandavas, is the embodiment of comprehensive outcomes. Krishna drives the chariot of Arjuna – consciousness driving the comprehensive outcomes. If we interpret these concepts in the context of education and national development, comprehensive output may be social capital development, and culmination outcome may be gross national happiness (GNH). But unfortunately, there is no recipe yet available to incorporate developing consciousness in learning to transform the learner into a better citizen.

The elites in China and East Asian nations have the character of showing concern for national development without caring for self-interest more to use the privileges the state has provided to them. In spite of the bitter past some of these nations have faced, they look forward to the brighter days when they see the development of social capital associated with social cohesion and the development of human resources as the culminating outcome of education. Comprehensive outcome is realised out of processes including curriculum, pedagogy and teachers (Mahbubani 2004).

If the mission and vision of an organisaton or system are clear to all the functionaries of the organisation, culminating outcomes as a combination of human capabilities and social cohesiveness happen as the consequence. Productivity increases by the right kind of comprehensive outcome, while social ethic gets established by the right kind of culminating outcome as the cementing force to align people for a total purpose (Dixit 2018):

1. Vision should be clear to all involved in the growth process.
2. Deontology in the work is necessary when the professionals perform.
3. Quality norm as fitness for purpose is essential in performing the task along the path the professionals tread.
4. Information and resource sharing to realise the goal.
5. Sewing the educational functionaries together for realising the national goal.
6. Preparedness to manage change.

1.2.2 Bloom's Taxonomy, Experiential Learning and Neuro-systemic Influence on Learning

Bloom's taxonomy has six tiers, namely, knowledge, comprehension, application, analysis, synthesis and evaluation. Learner acquires knowledge from various sources including the environment around him/her which his/her brain processes depending on the purpose defined by the education system (curriculum). The teacher should act as a facilitator of learning in terms of gaining new skills or knowledge, behaviours, ways of thinking, sense of judgement and choices. After the learner is exposed to knowledge, he/she relates it to a context the learner is familiar with to experience the knowledge as the mental image of it (knowledge) in the context as a first step towards comprehension. This comprehension may be in the form of application of the knowledge in a context as a concrete experience upon which the learner reflects to conceptualise what the learner has done. Here one notices a transformation from knowledge to applied knowledge. Analysis of this transformation leads to ready knowledge for further planning of action of experience of this transformed knowledge. The learner synthesises different aspects of the knowledge comprehended for a desired purpose, through discursive reasoning borrowing knowledge from other areas if need be. Learner will evaluate this synthesis on the plane of aesthetics, ethics and theories of knowledge for further active experimentation or action while thinking out of the box. Next again, Kolb's cycle concrete experience, reflection, abstract conceptualisation applying theories and plan for further action or active experimentation follow. This is the synthesis of Bloom's taxonomy and David Kolb's experiential learning.

In the process of perception of knowledge, reflection, abstract conceptualisation and synthesis, the neuro-systemic influence – particularly neuroplasticity – of the learner's brain plays an important role as all these are individual-specific experiences. In the rubric given under the ELT model below, all six elements of Bloom's taxonomy are touched to show how Bloom's taxonomy is contained in the ELT model. Understanding or comprehension manifests in a successful application of knowledge corresponding to the purpose of learning. If the learner spreads the knowledge acquired in his/her mind and constructs an image in his/her subjective mind as the imprint of the knowledge acquired from various sources for the purpose defined in the curriculum, there gets created a knowledge treasure along with the knowledge images in the mind of the learner. If the learner is clear about the purpose where he/she has to apply this knowledge, the learner processes borrowing from this knowledge treasure to create a new knowledge piece, called the process of synthesis, and the validation of the new knowledge thus created is the evaluation. The teacher facilitates this whole journey of learning.

Experiential learning theory (ELT) defines learning as the process, whereby knowledge is created through the transformation of experience in which both hormones and neurons in the brain take part as the combination of feeling, thinking and acting. Knowledge results from the combination of grasping and transforming experience as the function of the central nervous system, in which plasticity of the brain may play a vital role. The ELT model portrays two related modes of grasping experience in which sense organs receive and the CNS processes it. The CNS issues commands to the glands and muscles which may be called collective cognitive function. Seemingly, concrete experience and abstraction are opposite in nature argumentatively. But in ELT, these two modes synthesise as cognitive function to change concrete experience via reflective observation. Next follows active experimentation as active function as a platform for new experience. This is a recursive process of constructing knowledge involving the four learning modes. Concrete experiences drive observations and reflections. These reflections are absorbed as abstract concepts from which new conclusions for action can be drawn. These conclusions if tested serve as guides in creating new experiences. While traversing through this cycle, the learner graduates to the next level of learning. One must notice that there is an interplay between the neurons and hormones, where neurons paste new learning on the old and hormones may energise by transferring chemical energy to the brain through blood flow to the brain. The learner graduates to the next level of experience by going through this cycle.

This is well demonstrated in the teaching learning process of fine arts. For example, if we consider Indian classical music, fundamental notes are taught to the fresh student following which rigorous drilling in these notes with different combinations is given to the student who will recite aloud. The teacher tests whether the student produces right frequencies of the notes or not; until the student gets them right, he/she will not be allowed to move forward or taught anything new. In other words, the neurons should register them properly; any wrongdoing also gets registered but would be rubbed off by repeated trials to put the right thing in place. Here we notice the effect of plasticity of the brain or neurons. As the training progresses, the notes which started as syllables transform to sounds which the student's brain registers and then phrases, musical sentences and a musical depiction in the form of a tune being supported by some literary piece. This tune has to be structured in a framework of some rhythm. Percussionist or rhythmist is a trained player of rhythm who accompanies the main artist in a concert. In Indian classical music, many times the main artiste and the accompanying rhythmist are drawn from different places who meet on the platform for the first time, but they together produce an excellent rendering. The brains of the performing artistes transact in an abstract aesthetic plane. This is out of hard learning and practice (Fig. 1.1).

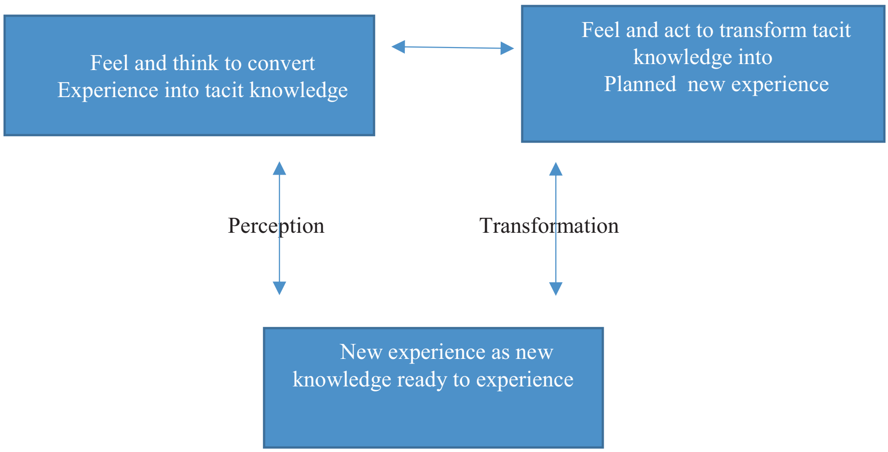

Fig. 1.1 Experiential learning engine to conceptual framework

Kolb's Experiential Learning Cycle Revisited

Kolb has given four basic styles of learning as below:

Learning style	Attributes	Preferred learning situations
Converging (abstract conceptualisation (AC) to active experimentation (AE) (doing and thinking, AC/AE))	Define the problem Logical approach to solve problem while making decisions Apply deductive reasoning	Identifying life application for ideas and theories for practical uses Handling technical tasks, rather than social and interpersonal issues Simulations, lab. Experiments, practical applications
Assimilating (reflective observation (RO) to abstract conceptualisation (AC))	Problem definition and analysis Create patterns Formulate theories Persevere to formulate theories	Comprehending a large data and analysing into concise and logical form Developing theory that has logical soundness, even more so than practical value Lectures, readings, time for reflection
Diverging (concrete experience and reflective observation)	Thinking out of the box Comprehending how others recognise problems Open house discussion Being democratic in accepting views of others	Observing rather than taking action Situations that invite a wide range of ideas and information Team-building Respecting views of members of the team with an open mind Getting each individual member's feedback
Accommodating (concrete experience and active experimentation)	Leading from the front by taking risks and initiating the work Being practical and adaptable to any challenging situation A leader and a team person	Learning from hands-on experience Being involved in new and challenging new and challenging experiences Situations that call for "gut" decisions versus logical analysis Working with others to define problems and solutions

Source: Adapted from Thomas (2008)

As consequence of true education through learning, change in behaviour takes place in the learner in three paradigms, namely, understanding the self, revision of belief systems and changes in lifestyle. In this process, neuro-systemic dynamics of the human mind is involved as a processor. Understanding and analysing this is the central part of neuro-educational research.

Features of the ELT Model or Rubric of the ELT Model
Journey from Concrete Experience to Reflective Observation (Feel and Watch)

Learners are inquisitive and see things from different angles. They prefer to observe it rather than do it. They like to collect information from various sources and look for different ways to solve problems through either brainstorming or other ways. In short, they are democratic in their approaches to solve problems or in viewing concrete situations. They like to work as a team, to listen with an open mind and to receive individual feedback from the team members.

Assimilating Journey from Reflective Observation to Abstract Conceptualisation (Think and Watch)

Assimilators look for a clear and logical approach. They expect a clear explanation more than the practical opportunity – expectation of the theory than the practical approach. These people are good in understanding broad spectrum of information or knowledge and rearranging the same in a systematic manner. These people exhibit interest in abstraction and show interest in ideas based on logical thinking and sound theories. These people prefer vast reading, listening to lectures, exploring analytical thinking and the like. These people show interest in science careers.

Converging Journey from Abstract Conceptualisation (AC) to Active Experimentation (AE) (Doing and Thinking, AC/AE)

Convergers combine abstract conceptualisation and active experimentation together – suitable for research and development. These people use their accomplishments through learning to solve practical problems and show more interest in technical tasks than in people and interpersonal skills. This type of learners is most suited to find practical uses for ideas and theories. They are good in taking decisions to answer questions and solve problems and like to experiment with new ideas, to simulate and to work with practical applications.

Accommodating (Doing and Feeling, CE/AE) Accommodators use the know-how and technique already available. These people take practical and experimental approach to solve the problems. These people get attracted to new challenges and experiences and derive pleasure in execution of plans. These people perhaps cannot explain how they carry out the challenge, but they just do it, and may not be able to document what and how they did it. They work on gut feeling and intuition instead of logical analysis. These people feel the challenge and do it.

Thus, to accomplish a task, it may be necessary to have a team consisting of assimilators, convergers and accommodators. This is what the leaders do in corporate world perhaps.

1.2.3 Student Portfolio

Student portfolio is a type of learner's diary created by the learner with the help of the teacher and the parents/guardians. This is a document tracking the learning behaviour of the student. Suppose this is available for a student from primary through higher secondary education, it becomes a documentary evidence for the parents/teachers to diagnose the strengths and weaknesses and the likes and dislikes of the student. If the rubrics suggested above are followed, it will serve as an excellent instrument to counsel the student to choose his/her career. This may appear to be too ideal a situation but a preferred system. In higher education, other measurement instruments may be available, like project works, as diagnostic tools to assess or guide the student further. In all these activities, neuro-systemic dynamics of the individual plays a vital role as this type of learning is individual-centric learning. Student portfolio is the record of student's cognitive and experiential response to knowledge and actions connected.

1.2.4 Some Examples

In the following examples, one notices that the learner moves from diverging (CE/RO) to accommodating (CE/AE) via assimilating (AC/RO) and converging (AC/AE) to end up in a final useful product. In this spiral motion of the learner, it seems neuroscience has a vital role to play, which requires a study to understand more and more about its influence on pedagogy and learning.

Freedom to think and reflect on what one observes produces some interesting cases of experiences and reflection thereof:

1. Anant Tadar was a student of higher secondary school from Arunachal Pradesh, India. One day, he saw a small blind girl struggling a few years ago. This ignited in him social concern to do something for the physically disabled due to blindness. He invented a special type of goggles to help the blind which would help them to avoid obstacles. He got international recognition for this invention exhibiting social concern (https://nif.org.in/innovation/intelligent-goggles-for-blind/1055).
2. Akash Manoj, a teenage boy, invented an instrument that predicts blockage of blood flow to the heart, causing heart attacks. He saw his grandfather dying of blockage of blood flow to the heart which became a stimulus for him to think of this innovation. AIIMS, Delhi, helped him to perfect this machine; Akash struggled for one and a half years upon this innovation to perfect it (Dutt 2017).
3. Harshwardhan Zala was a teenager from Gujarat. He created a laser drone which would identify and make landmines less dangerous. The Gujarat Government in India gave him a grant of an amount of 5 crores, and he signed an MOU with the Gujarat Government. The stimulus for him to pursue this project was when he came to know that the landmines kill equal number of soldiers as the war would

do, and these mines kill innocent people for years after the war would get over (Mishra 2017).

4. Shalini Kumari, a 19-year-old, invented a new design for an adjustable walker when she was just 12. She was then felicitated by the President of India.

   Motivation: Shalini Kumar's grandfather had an accident and hence could not climb up the stairs to go to the terrace garden that he always enjoyed (www.thebetterindia.com, 2014). The National Innovation Foundation recognised her work (www.thebetterindia.com, 2014).

5. Jayakumar, a 13-year-old "Sivakasi fire victim", invented a low-cost fire extinguisher which triggers water sprinklers when it detects heat from fire. Motivation: Jayakumar's mother suffered from severe burns in a factory fire in Sivakasi. She worked in one of the many firework factories there. In these factories, fire safety standards were non-existent (www.thebetterindia.com, 2016).

In all the above examples, the observer moves along the perception axis starting from stimulus to abstract conceptualisation and then moves along from the transformation axis starting from reflective observation of the concrete experience to active experimentation.

Note: Opinion of Harshwardhan Zala

One can imagine how difficult it would be for a boy, Harshwardhan Zala, of 16 years to become CEO of his own company, Aerobotics7, in terms of learning running rudiments of business and managing stress. He was on a fellowship in the Silicon Valley in 2016 where he learnt a great lesson of his life: one should be in stress at work. He applies this in running his company. According to him, everyone should take some time to enjoy life when he saw the playground in Google office for employees. This he shared in a private meeting of entrepreneurship programme in Mumbai (https://economictimes.indiatimes.com/magazines/panache/boardroom-lessonsfrom-a-16-year-old-ceo-dont-be-stressed-or-hyperfocused-on-work/articleshow/68697295.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst).

1.2.5 Freedoms for Learning and ELT: It Is Obvious That Providing Freedom for Learning Is Inherent in the ELT Model of Education

Learning is a search for contemporary meaning in the discipline of choice. Therefore, learning must start with the issues around which learners are actively trying to construct meaning about with an inquiring mind. Meaning requires understanding a context or a thing in its entirety and the parts as well in the context of the entirety. The purpose of learning for learner through experience is to construct learner's own meaning and reflect on this construction to proceed further with the journey of learning as a child does.

While coming to college, a student brings with him/her his internalised knowledge gained out of his past experiences with the environment or society, along with his/her previous learning, either formally or informally. Out of his/her previous learning, he/she may have to relearn some, may have to unlearn some other and may have to search for new meanings of his/her own for some more. In other words, a student at the institution/college should revalidate his/her earlier learning and proceed to gather new learning outcomes. A student or a learner should understand that learning is a continuous lifelong journey as he/she has to manage change to work on establishing a sort of dynamic equilibrium in the development of self and the institution he/she is associated with. Intellectual development occurs when expression or assimilation and practical activity and active experimentation converge. The learner plays an active role in the learning process to discover or rediscover self. To facilitate this process of rediscovering by a learner, the educational institution may have to adopt student-centric experiential learning environment, which means providing learner with enough freedom for learning (Dixit 2016).

Amartya Sen (Sen 1999) identifies five types of instrumental freedoms as means for development, namely, (1) political freedom, (2) economic facilities, (3) social opportunities, (4) transparency guarantees and (5) protective security. These instrumental freedoms contribute to the development of developing capabilities in the learner, and these freedoms are necessary for an effective implementation of ELT pedagogy in a learning environment. Here the political freedom means to choose an opportunity out of the many options provided for him in the institution, which includes the desired course, learning resources and project guides within or outside the institution. Economic freedom is important to support learning. The learner should be able to visit places which he/she likes that support his/her learning, maybe libraries, industries, other educational centres or laboratories, social institutions, museums and the like. Social opportunities refer to the arrangements that society makes for education, like scholarships, hostels, healthcare, equal opportunity guarantees to all, etc. Transparency guarantees deal with the trust in the system or institution. Learner must know about the regulations laid down in the system and the recognition of the qualification a student gets after he/she graduates. There should also be transparency in learner's assessment system and review system and opportunity to ask for the review if the learner is not satisfied with the assessment. Further, the system should be transparent enough to report to the learner about his/her strengths and areas of development (weaknesses) while suggesting ways to develop. Protective security is important in situations such as the widespread present pandemic COVID-19 – students require special healthcare protective systems, hygienic environment and the like. Those who need employment assistance may have to be arranged.

Here are some examples of giving functional freedom for learning in formal systems:

(a) A girl coming from an affluent family was undergoing a vocational training. She had to undergo training in leadership personality development as a learning outcome in one of the units she was studying. She was asked by the trainer to visit a slum area as a part of concrete experience in the issues. She resisted going as she was from an affluent family. Her father was very influential. The trainer insisted her to go, and she had to yield. In the field, she witnessed what poverty was. One poor lady had given shelter to a few destitute children, and she was struggling to take care of these children. This was an eye opener for the student regarding empathy. Her kindness towards that lady and the children under her care started acting. She decided to do something to take care of that group. She went to her father who was very influential to do something to save this group. He was also moved by the story, and he was astonished looking at the transformation that had taken place in his daughter. He rose to the occasion and did something contacting few friends of his. A continuous grant for the lady of the camp who was taking care of those children was arranged. He was doubly happy because he was helpful to somebody really deserving, and his daughter had become a changed person – a culminating outcome. A father's joy knows no bounds. This was the effect of the ELT as a transformative pedagogy.

(b) Fashion school: The courses were vocational and academic too, where students had to learn design principles; it was not just a skill training institute. Thus, courses were quasi-vocational/quasi-academic. Graduation degrees were awarded by a university. The institute had autonomy to introduce subjects to be studied in the curriculum. One of the subjects introduced was Research Methodology as an elective subject. Those students who did projects in this unit got good employments. The mode of teaching employed was ELT, sending students to conduct survey and collate data and then seeing it holistically to come up with a concrete abstraction of the concept to complete the project through active experimentation. The teacher was overjoyed when one of the students – who used to interact with the teacher well – was asked her opinion about the subject "Research Methodology" and said that she learnt how to interrelate different subjects in the qualification to help her do the project. That means that "she had learnt how to learn". The purpose of teaching as developing the culminating outcome was satisfied. This is the outcome of the ELT as an effective pedagogy.

(c) How an average student transforms into a useful graduate at the postgraduate level. A student had finished graduation from a college, scoring average percentage of marks. He was worried about his employment and career. His parents were also equally worried. He was coming from a lower middle-class family. He had developed a passion for a career in healthcare. His undergraduate qualification would not qualify him for admission to any such educational pursuit. He sought admission in a postgraduate institution offering distance education in Master of Business Administration in a traditional mode without using any technology support. This happened about 12 years ago. The institution, though it was a distance education centre, started offering on campus education, considering the average level of students. The class size was not huge, maybe around 15. The method of teaching applied was ELT mode. Learning outcomes in each subject were clearly identified by the institution, though the university did not articulate it. Teachers were expected to submit their programme delivery plan (calendar) according to the coverage of the unit(s) and learning outcomes they would teach. In the calendar, they were supposed to give the assessment calendar also, either assignment or test or both. An additional unit (subject) in the English-language skill was arranged by an effective teacher. There used to be periodic meetings of the teachers and faculty training also. There was assigned a mentor to the institution who was well exposed to ELT strategy. Students were placed for industrial training where they would do their project. Some chose banking sector, some chose industries, some chose hospitality, and this boy about whom we are discussing chose a hospital to get exposure in hospital management. He took a project in Hospital Management according to his passion. All of them did reasonably well in their qualifying examination. In the assignments and the project work the students did, their performable abilities were identified and articulated in their grade card special to each student given by the institution. This helped students write down their curriculum vitae intelligently as comprehendible to the employers in terms of what to look for in the applicant. Many got jobs of their choice, including this boy looking for a job in healthcare. He had done his project well. He got a reasonably good job in hospital management sector and is progressing well. His parents are happy. Most of them were problems to their parents before they had joined MBA in this institution.

This can be considered as a success story of the ELT strategy at the postgraduate level of education.

(d) What happens if there is no autonomy to student? Story of an engineering student. Raju (name changed) was a brilliant student who sought admission in a prestigious engineering college scoring a high percentage of ranking in the common entrance test. His choice of branch was Computer Science and Engineering. He was deeply interested in his subject of choice and started reading a lot in his subject on his own. The mundane examination system was not interesting to him, and the stereotyped classroom teaching without any scope for inquiry started becoming boring. He had enrolled himself as a member of the Computer Society of India. He started publishing papers. He started feeling bored to attend classes. He disliked the examination system of testing the memory of a student. And therefore, he started scoring less in the examinations, and in the fourth semester, he started realising the hard truth of the ground realities that if a candidate had not scored an average of 70% marks cumulatively, he/she would not be allowed to take the campus interview. He met a teacher according to the advice of one of his friends. The teacher was very patient listening to him. Raju was crying; tears rolled down his cheeks. So many thoughts at once came to his mind like parents' welfare and the like. The teacher gave him a cup of water and consoled him and listened to his complete story and assured him that there is no problem. The teacher gave him a solution as follows: "In the morning you get up one hour early than usual what you are doing and go to bed in the night one hour late than usual. Study the subjects according to the syllabus in the morning after you get up and do the same before you go to bed. You are good in studying from the point of view of examination which you have demonstrated by scoring very high percentage of marks in your qualifying examinations including common entrance test for admission to engineering. You can do it. Feel positive". What was the secret of this solution? In the morning, if Raju would study for 1 hour for the purpose of examination, he would start the day without a feeling of guilt, the same thing before going to bed. He would get a sound sleep. He felt confident and he asked for one more glass of water. He promised that he would do it and went out happily.

All ended well. He qualified himself for the campus interview, and he got an international assignment.

1.2.6 Learning Style as the Agent of Transformation

Robert J. Thomas applies Kolb's ELT model in his leadership training for the corporate leaders. He appears to be very much influenced by Kolb's learning style inventory. His opinions are (Thomas 2008):

- Learning styles vary enormously, and many a time there isn't a good match between teaching style and learning style.
- If they (leaders) do not have enough free time to reflect, how do they become more proficient? The answer is "experience".
- Two people can react differently to the same experience; one may grow, and it may not affect the other in any manner or even he may be demotivated. Experience by itself does not guarantee anything; it is the reaction by individual that matters.

According to him, crucible is a transformative experience as a boiling pot of challenges. In the context of education, it is a transformative learning experience. Thus, pedagogy should be transformative whatever the level of education is. Learning style is the agent of transformation. The extent of transformation as the outcome of learning is measured in terms of the abilities of the learner, like comprehending the knowledge or a context, performing the tasks, analysing, synthesising and evaluating the synthesis or all as a composite given a problem to solve. Thus, experiential learning is made measurable in terms of developing capacities to perform to the learner's passion. Here, the process of facilitating learning and passion for learning meets.

1.3 Experimentation: Case Study

One of the authors (Dixit) of this chapter applied this composite model as a composite of ELT and Bloom's taxonomy in various institutions where he worked as a teacher, educator and administrator. Results were encouraging. Implementation of this model would start with teacher training which would discuss Bloom's taxonomy combined with the ELT model. From the above discussion, we notice that experiential learning and neuro-systemic influence on learning are inseparable. In the curriculum, key elements used to be the achievement of learning outcomes and assessment strategies together with grading criteria. The content of the unit used to be suggestive, whereas learning outcomes used to be prescriptive. Tracking learner's behaviour was followed by continuous evaluation by periodic assignments. Each assignment would be addressed with respect to a learning outcome or more learning outcomes. Assignment would consist of assignment brief which the tutor would describe, followed by well-defined tasks which the learner had to complete. The learner was expected to submit the completed assignment on or before a specified date as prescribed by the teacher. In the classroom, the teacher would teach following Bloom's taxonomy, while the assessment used is governed by Kolb's ELT model. Achievement of a unit would mean completing all the assignments covering all learning outcomes successfully – success being defined as completing all tasks prescribed in the assignments. One out of the three grades, namely, pass for achieving the learning outcome(s), merit for exhibiting analytical ability and distinction for exhibiting synthesis and beyond, for each assignment used to be prescribed. The evidence for completing the tasks the learner provides had to be authentic in the sense that the work had to be his/her own work which the teacher would verify by asking the student to make a presentation or some other way. Feedback to the learners used to be given, covering the strengths and areas of development (not called weaknesses deliberately). Depending on the quality of evidence the learner would provide, he/she would be awarded pass, merit or distinction for each assignment and cumulatively for each unit. Periodic reviews, team meetings and teacher training used to be the hallmark of the entire exercise.

1.3.1 Results and Discussion

The model was applied on students of average level, those who had scored average marks enough to pass the graduation at high school level or higher secondary level to whom their parents had no hope that they would become habitable in terms of employment or higher education. This qualification was quasi-vocational. In each unit, well-defined learning outcomes were prescribed. The achievement of learning outcomes would tag learners with some performable values to the personality, and many got respectable employment; some others pursued higher education. These quasi-vocational qualifications were UK-recognised qualifications. The same model was applied at the postgraduate level on those graduates from various colleges in India with average grades. These qualifications were delivered when the technology support was minimal compared to the present day. This was the story that happened during the last few years of 1990s and the first decade of the twenty-first century.

The author used to feel happy seeing the parents with a smile of happiness on their faces, worth the hard-earned money spent on their wards.

The model works at all levels of education, the same model the author tried at school-level education with a reasonable success. The key requirement for this model to work well is an intense periodic teacher development programme in pedagogy relevant to this model. Teacher's scholarship in the subject is vital. Commitment of the school/college governing body to accept the change is more important.

1.3.2 Delimitations

Teacher-student ratio is to be low to see the success of the model, so that it becomes easy for the teacher to track the learning behaviour of the student. Institution should have full faith in the teacher, who is to be competent and be able to think out of the box with respect to teaching-learning process. The student should enjoy complete freedom to express himself/herself.

1.3.3 Postscript

- One of the authors (Dixit) of this chapter gratefully acknowledges the opportunity he got to work as a consultant to the Edexcel International, a division of Edexcel Foundation (UK) (now Edexcel Pearson), from May 1999 to May 2003, when he got exposure to David Kolb's ELT model as applied to BTEC qualifications of Edexcel.
- One of the authors (Dixit) thanks Sudhindra Sarnobat, Corporate Trainer from Pune, India, for his assistance in conducting some experiments in Pune.

1.4 Further Scope

If one tries the same/similar model with some appropriate modifications using today's new techno-world strategies, the story may be different. For example, the use of augmented reality/virtual reality tools for facilitating learning using this ELT will be multiple-fold. For example, the concept of laboratory work in science education will dramatically change. This increases student autonomy in learning; similarly teacher will enjoy more freedom in facilitating learning. With the COVID-19 pandemic, the educational sector has a lesson to use technology in diverse ways. This has opened up a new dimension of reducing gap between traditional classroom teaching mode and distance education. Under the circumstances, new strategies for assessment are to be evolved.

There is a scope for neuroscience research to enhance learning abilities and to track learning handicaps.

1.5 Conclusions

Experiential learning theory model is an effective model of pedagogy which can be used at all levels of education. In school education and tertiary education, this may be called a pedagogic tool, whereas in higher education, this takes the role of learning by research and cognitive experience. Bloom's taxonomy is integrated in the ELT model. The rubric of the ELT model diagnoses the learning behaviour of a learner. Student's portfolio is an important document to understand the learner's aptitude for vocational or academic education further. It seems artificial intelligence is yet to make an effective inroads into strengthening educational processes. It is recognised that neuroplasticity has an important role to play in this. A case for more research in neuroscience to analyse learning styles is raised. Technology may have to make "bring your own devices" affordable to facilitate students to use AR/VR gadgets.

References

Bell, D. (2014). Educational neuroscience: What can we learn? *Education in Science, 256*, 16.

Bert, M. (2010). *10 reform principles behind the success of Finland education*: https://bertmaes.wordpress.com/....why-is-education-in-finland-that-good-10-reform-

Business Standard. (2017, March 27). *Gadget Guru Anang Tadar creates history in the world of technology*. Retrieved from https://nif.org.in/innovation/intelligent-goggles-for-blind/1055.

Chia-Chen, C., Tien-Chi, H., & Yu-Wen, C. (2016). Animating eco-education: To see, feel, and discover in an augmented reality-based experiential learning environment. *Computers & Education, 96*, 72–82.

Dixit, G. N. M. (2016). *A call for educational renaissance in India* (pp. 237–238). Pune: The SMS Foundation, Swadesi Parigyan Prasaran Pratisthan.

Dixit, G. N. M. (2018). National university as a developer of social capital nation. *TATTVA-Journal of Philosophy*, *10*(2), 37–48. ISSN 0975-332X.

Dutt, A. (2017, March 7). Meet Akash Manoj, a student who built device to predict silent heart attacks. *Hindustan Times*. Retrieved from https://www.hindustantimes.com/health-and-fitness/preventingheart-attack

https://economictimes.indiatimes.com/magazines/panache/boardroom-lessons-from-a-16-year-old-ceo-dont-be-stressed-or-hyperfocused-on-work/articleshow/68697295.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

Kelly, A. E. (2011). Can cognitive neuroscience ground a science of learning? *Educational Philosophy and Theory, 43*(1), 17–23.

Mahbubani, K (2004). From confucius to Kennedy: Principles of East Asian Governance. In I. Gill, Y. Huang, & H. Kharas (Eds.), *East Asian visions – Perspectives on economic development* (pp. 135–165), Washington, DC: The International Bank for Reconstruction and Development, 2006, PP215.

McLeod, S. A. (2017, October 24). *Kolb – Learning styles*. Retrieved from https://www.simplypsychology.org/learning-kolb.html

Mishra, R. (2017). Harshawardhan Zala, 14 year old trends for 5 crore deal at Vibrant Gujarat Global Summit 2017, India. Retrieved from http://www.india.com/buzz/harshawardhan-zala-14-year-old-trends-for-rs-5-crore-deal-at-vibrant-gujarat-global-summit-20171758024/

Private communication with Ranganatha Sitharam, Aug. 2020. Quoted with permission.

Report by Dorothy Bishop (2011). FBA FMedSci, Colin Blakemore, FMedSci, Sarah-Jayne, et al 'The Royal Society Brain Waves' Module 2 I February 2011.

Sen, A. (1999). *Development as freedom* (pp. 38–39). New Delhi: Oxford University Press.

Sen, A. (2009). *The idea of justice* (p. 215). London: Allen Lane an imprint of Penguin Books.

Taxila from Wikipedia, the free encyclopedia, Nalanda the free encyclopedia. https://en.wikipedia.org/wiki/Gupta_Empire, https://en.wikipedia.org/wiki/Nalanda, http://www.ibe.unesco.org/publications/ThinkersPdf/confucie.PDF, https://en.wikipedia.org/wiki/University_of_ancient_Taxila

Thomas, R. J. (2008). *Crucibles of leadership (how to learn from experience to become a great leader)* (pp. 4–5). Boston: Harvard Business Press.

Wikipedia. https://en.wikipedia.org/wiki/Neuroplasticity

www.thebetterindia.com, 2014.

www.thebetterindia.com, 2016.

Yang, H. (1999). CONFUCIUS (K'UNG TZU) (551BC–479BC), *Prospects: The quarterly review of comparative education* (Vol. XXIII, no.1/2, 1993, pp. 211–219). Paris: UNESCO: International Bureau of Education. http://www.ibe.unesco.org/publications/ThinkersPdf/confucie.PDF

Chapter 2
Executive Functioning Skills, Neurocognition, and Academic Achievement of UG Students

A. Jahitha Begum, A. Sathishkumar, and T. Habeebur Rahman

2.1 Introduction

Executive functions (EFs) are an elaborate set of cognitive control skills used to self-regulate one's higher-order cognitive processes. They direct the individuals to attain and achieve the goals of any complex cognitive task through appropriate planning, working memory, and inhibition. The essential neuropsychological functions like language, visual and spatial, memory, and emotions are controlled and regulated by these EF skills (Germano et al. 2017). An individual's self-regulated and goal-directed behavior operates because of numerous cognitive control skills or activities (Decker et al. 2016). Executive functions involve two basic and complex constructs, namely, inhibition and working memory (WM); EFs consist of a set of top-down processes which control and monitor one's thought and behavior. Inhibitions, WM, cognitive flexibility, and attention are the essential constructs of EF responsible for behavior control in everyday life and play a key role in monitoring and self-regulation of executive functioning even from childhood.

An individual's executive functioning brings an improvement in his abstract thought, decision-making, organized behavior, and planning (Malagoli and Usai 2018; Dias and Seabra 2015; Diamond 2016).When we do automated tasks, we need these competencies to concentrate, think, and act, which require neuropsychological functioning (Diamond 2016). EF skills are responsible for focused, goal-directed, purposeful, appropriate cognitive and social functioning of young age as well as in adulthood (Jacobson et al. 2011). EF refers to higher-level cognitive

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process that controls low-level cognitive process involved in decision-making, finding out solutions in difficult situations, in achieving the goals (Remine et al. 2008; Prosen and Vitulic 2014).

Execution of complex activities require a set of cognitive skills in order to plan, initiate, organize, control impulses, flexibly achieve short- and long-term goals, sustain attention, adjust, and monitor the behavior, which are nothing but EF skills and are required in a complex problem-solving situation (Rau 2009; Bryce and Whitebread 2013; Pavetti et al. 2014; Kadian 2016).

Though the major constructs of EF inhibition, short-term memory, and changing tasks are interrelated, they remain distinct from each other (Prosen and Vitulic 2014; Bryce and Whitebread 2013). If we want to concentrate on various information at the same time and then revisit the information as per our needs, EF skills are necessary (Pavetti et al. 2014). Executive functions (EFs) are defined as a set of goal-oriented and self-initiated actions in order to reach the goals. The actions are performed, modified, and continued till the end (Bailey et al. 2018). According to Germano et al. (2017), EF is defined as the system of control mechanism within ourselves, which is helpful in organizing and guiding all cognitive activities as well as emotional responses and behaviors (Fig. 2.1).

Mann and Snover (2015) concluded that with the help of EF, one can control his cognitive process along with monitoring his ability, organizing thoughts and actions, prioritizing work, and managing time efficiently to arrive wise decisions. According to Barkley (2012), “EF is a complex brain process that eludes an easy operational definition.”

Cooper-Kahn and Dietzel (2009) defined EF as “a set of actions carried out by an individual by controlling and managing the resources with him to reach a goal.” EF is a complex term to define and has various connotations. Though it is an umbrella term, the main focus is on the neurobiological skills involving cognitive control and self-regulation. Anderson (2001) listed out that EF denotes the separate as well as integrated components such as attention, cognitive flexibility, inhibitive control, and goal setting. Welsh and Pennington (1988) defined in a different way that the skills possessed by an individual to solve a problematic situation to arrive a goal-oriented situation are called EFs. Based on the above definitions, now we can define executive functions as follows:

Executive functioning skills are the focused actions toward a particular accomplishment, and they are governed by neuropsychological functioning based on the cognitive control system that monitors and regulates one’s thinking and behavior toward achieving the goals through solving difficult situations and wise decisions. After reviewing the above features of executive functioning, reported earlier, we can arrive at the following conclusions:

1. Executive functioning is essential for appropriate focused, goal-directed behavior of individuals, which helps them to self-regulate their thinking and emotions.
2. The main components of executive functions are instant memory, inhibition, cognitive flexibility, as well as attention that help in planning, decision-making, adjusting, and solving the problem of the complicated situations in day-to-day life.

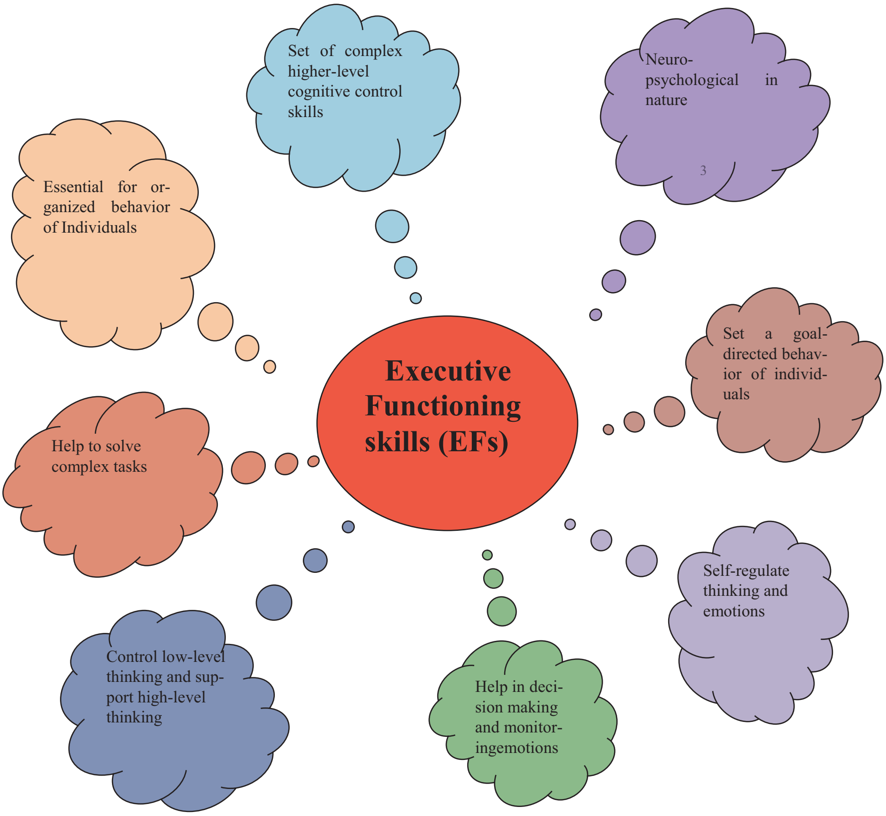


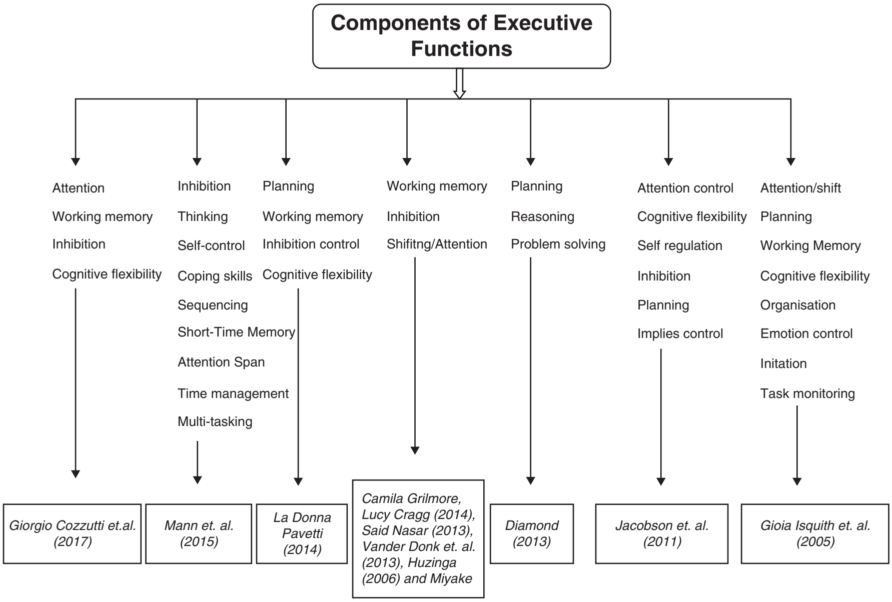
Fig. 2.1 Executive functioning skills in action

3. Executive functioning skills help to solve any complex task with an organized behavior, focused attention, flexible adjustment, and controlled low-level thinking among individuals.

2.2 Constructs of Executive Functioning Skills

Many exponents have come out with several constructs of executive functioning, like a set of multidimensional, interrelated, but distinct components, which are collectively named as executive functioning skills, most of the researchers, such as Gilmore and Cragg (2014), Huizinga et al. (2006), Gioia and Isquith (2004), Pavetti et al. (2014), Jacobson et al. (2014), Said (2013), Cozzutti et al. (2017), Van der Donk et al. (2013), Mann and Snover (2015), Miyake (2000), and Huizinga et al. (2006), mentioned inhibition, working memory, attention, cognitive flexibility, planning, and emotional control/self-regulation are the significant constructs of executive functioning (Table 2.1).

Table 2.1 Constructs of executive functioning skills



2.2.1 Inhibition

Inhibition is the capability possessed by us to resist or delay an inappropriate impulse and even stop it at the right time (Germano et al. 2017). This is called the inhibitory control skill which is helpful in suppressing a strong desire or a voluntary action or thinking which is initiated due to cognitive, emotional, and motor behaviors. These abilities inhibit inappropriate behaviors (response inhibition/self-control) from controlling attention and thoughts (interference control) (Mann and Snover 2015). According to Best et al. (2011), inhibition continues to develop with age and experience. It's important to subvert behaviors that may interfere with task performance and goal achievement. Executive Functioning skills is include an important component called inhibition (Pennington, 1998)

Inhibition is one of the core abilities of executive functioning. It is defined as a deliberate overriding behavioral and cognitive ability, such as managing impulses and interferences. Inhibition plays a crucial role in cognitive activities and social interactions to manage interfering stimuli, maintain attention, and suppress prepotent responses or override automatic actions when needed. Inhibition involves the ability to regulate one's behavior and to control one's emotions to support the regulation of expression (Malagoli and Usai 2018). Inhibition helps to avoid being distracted by irrelevant stimuli and incorporates selective attention. It closely resembles the concept of self-regulation. Inhibition includes emotional and motivational activities (Diamond 2013).

Controlling inappropriate thoughts and actions is not easy but has to be practiced continuously in order to stop a motive or action, so that the unwanted or inappropriate impulses can be stopped in the initial level itself. These abilities are called inhibition control skills, helpful in controlling and screening our thoughts and impulses so that we can delay or resist unwanted distractions without acting prematurely (Pavetti et al. 2014). Inhibitory control is defined as a mechanism to stop or suppress prepotent behavioral and cognitive responses (Prosen and Vitulic (2014). Inhibition helps us to move away from unwanted and inappropriate responses and to choose appropriate tasks and actions to solve the complex situations; by integrating all these abilities, we can solve more complex problems (Best et al. 2011).

2.2.2 Working Memory

Working memory is the short-term memory, a cognitive ability to hold the required information constantly to follow complicated instructions to complete a task (Germano et al. 2017). The ability of working memory (WM) is needed to maintain and manipulate holed information over a certain time (Mann and Snover 2015). With the help of WM, one can hold information in the mind and utilize it to organize and relate with other ideas (Diamond 2013). Baddeley (1997), who is the founder of the cognitive model of working memory (WM), stated that WM is responsible for active information processing and stores the information for a short time. According to the Baddeley and Hitch (1974), working memory constitutes short-term storages of verbal and visuospatial information in addition to the central executive component that coordinates these storage systems and allows the manipulation and storage of information at the same time. WM is a limited capacity of the central executive system which interacts with a set of two passive storage systems. They are phonological loop and visual sketchpad storage systems:

1. The short-term storage of verbal information is called the phonological loop.
2. Visual sketchpad is responsible for the storage of visual and spatial information.

These two storage systems, phonological loop and visual sketchpad, are directly connected with the central executive system and are related to mathematical skills.

WM is the central executive system that coordinates within the cognitive system (Baddeley and Logie 1999). Working memory gradually improves from 4 to 15 years of age (Mann and Snover 2015). The storage of information for a short term is primarily responsible for cognitive load based on which the acquired information is processed and elaborated with the help of higher-order cognitive abilities like thinking and reasoning. The thought is the product of WM which is needed in completing a cognitive task.

Many exponents defined working memory (WM), such as Pavetti et al. (2014) stated that it is the capacity to mentally store and process information over a short period of time. On the other hand, Prosen and Vitulic (2014) stated that working memory is capable of holding information in mind for a delayed period and helps in performing complex tasks. It increases and incorporates the ability to draw conclusions based on prior learning and apply to current situations (Dawson and Guare 2009). WM plays a key role in updating the new incoming information with the previous one. The irrelevant information is removed with more relevant new information for which monitoring, coding, and revising of information are done with the items held in working memory (Miyake et al. 2000).

2.2.3 Cognitive Flexibility

Cognitive flexibility (CF), yet another important component of EF, is the ability to adjust our behavior to the situation demands. One has to be creative in his approach and needs to change his perspectives, prioritize the actions needed to be performed, and consider the rules to be taken with different approaches to a situation. Finding and adopting novelty against the rigid and routine behavior will result in cognitive flexibility. Cognitive flexibility can be involved in a system of actions, including social interaction, spatial navigation, planning, and creative thinking (Dias and Seabra 2015).

Deak (2003) considers cognitive flexibility is required for the dynamic activation and modification of cognitive processes in order to respond to the changing task demands. Cognitive flexibility makes an individual to change his perspective and switch the attention to focus easily and quickly. The development of cognitive flexibility depends upon the other two constructs, such as working memory and inhibitory control and their joined endeavour (Cozzutti et al. 2017). In total, cognitive flexibility is the capacity which makes an individual to change his perspectives according to changing demands, prioritize his actions, and shift the focus for successful completion of the tasks (Pavetti et al. 2014). It is quite normal to face obstacles, setbacks, or mistakes in any endeavor, but with the help of CF, they can be reduced with the revised plans and required changes (Dawson and Guare 2009).

2.2.4 Attention Control

Attention is the important cognitive component of EF. The definition of attention control as EF is the ability to alter or switch a problem-solving strategy in the midst of solving a complex problem. Miyake (2000) states that attention control is the ability of shifting between mental states, operations, or tasks, which involves moving backward and forward between multiple tasks, activities, or mental sets.

Attention control is the ability to focus on tasks for which irrelevant information has to be resisted or avoided to complete the task (Prosen and Vitulic (2014). Sustained attention is the capacity to keep paying attention to tasks or situation in spite of distractibility, fatigue, or boredom (Dawson and Guare 2009). Executive functioning requires both specific attention on the task and continuing the attention till the task is completed with flexibility to change the focus as the situation demands (Jacobson et al. 2014).

2.3 Executive Functioning skills and Academic Achievement

Learning in the context of academic environment is mainly because of executive functioning; thereby, a strong correlation exists between learning and academic achievement. EF plays a dominant role in academic performance, because of the skills possessed by the students in attending and working memory to respond to rules of the classroom and in understanding the content (Germano et al. 2017). With the help of EF skills, students can identify their capacity as well as needs.

Kadian (2016) and Best et al. (2011) found out that there existed a strong positive correlation between academic achievement and executive functions. They also found that private school students possess high EFs than the students of public schools. Thorell et al. (2013) revealed that among the four countries, namely, China, Sweden, Spain, and Iran, the boys of three countries except China have better executive function than girls as reported by their parents.

Many studies revealed the significant role of executive functions in successful academic achievement and acquiring the skills of learning. Students are said to possess social, emotional, and behavioral competencies such as self-regulatory, emotional, motivational, and cognitive control skills before they enter the schools, and these skills are known to be the executive functioning skills as supported and highlighted by Dias and Seabra (2015).

Van der Donk et al. (2013) experimented that executive function intervention improved the academic performance of regular as well as individual school students, especially children with poor working memory. In their study, due to the poor working memory, 85% of the children were not successful in reading and mathematics achievement. Executive function intervention improved their working memory, attention, and cognitive flexibility and the academic performance in mathematics.

The classroom success of a student depends upon his attention to give an immediate response to the classroom stimuli and information processing as well as academic performance as found out by Balushi (2015). Oberle and Schonert-Reichl (2013) proved that inhibitory control, along with peer acceptance, is essential for academic success in the adolescent age. Inhibition and working memory were proved to be very much essential for academic success tested among the sample of four countries, viz., China, Sweden, Spain, and Iran (Thorell et al. 2013).

Working memory contributed to mathematics achievement is reported by Cragg et al. (2017). The EFs are significantly correlated with overall mathematics achievement. The components of working memory, such as verbal and verbal-spatial memory, contributed to the mathematics achievement directly. Malagoli and Usai (2018) found out that inhibition and working memory tasks were intra- as well as intercorrelated. Clair-Thompson and Gathercole (2006) attempted a study through which it was confirmed that working memory and inhibitory process are essential to enhance mathematics, English, and science achievement of the participants.

Thorell et al. (2013) conducted a study among the teachers of four countries, viz., China, Sweden, Spain, and Iran, and found out that working memory is an important component for academic success in maths and language, whereas the parents' ratings revealed that there exists a correlation between executive function and mastery of language skills in all the three countries except China. Bull (2001) found out that EF measures were significantly correlated with achievement in mathematics, and there exists a significantly positive correlation between WM and mathematics ability. The higher the level of WM, the higher will be the mathematics ability. It is also proved that lack of inhibition and poor cognitive flexibility leads to poor mathematics achievement as proved by Bull and Scerif (2001).

Dias and Seabra (2015) identified that preschool students were improved in attention and inhibition abilities after the intervention of EFs, which leads to the mastery of curriculum and in acquiring metacognitive skills. Metacognitive skill is an important component of EFs and the most important predictor of academic achievement as reported by Bryce and Whitebread (2013). Metacognitive skills are the strong predictors of academic success in mathematics and highly correlated with executive functioning skills of younger children.

Cognitive flexibility, yet another component of EF skills, proved to be an effective academic achievement and academic self-efficacy as studied by Esen et al. (2017). Cognitive flexibility is an essential component for school readiness and children's approach to learning among preschool children, as emphasized by Vitiello et al. (2011). Stad et al. (2019) proved that children's learning and performance are positively correlated with cognitive flexibility. Performance in working memory is a prerequisite of mathematics academic achievement is reported by Laura Visu-Petra et al. (2011). Valiente-Barroso and Garcia-Garcia (2012) proved that achievement in mathematics is enhanced with improved working memory, attention, cognitive flexibility, and processing speed, which are the major components of EF skills.

Van der Donk et al. (2013) identified that working memory, the major component of EF, is found to be a strong predictor of mathematics achievement. Uopasai (2017) also emphasized that academic performance of higher education students depends upon their working memory, a more powerful predictor of academic success. Balushi (2015) proved that working memory is essential for comprehension, recall ability, and attention span, all of which constitute academic success in language skills. Fine (2014) identified that WM is an important construct of executive function and the best predictor of academic success than other constructs such as attention, emotional regulation, cognitive flexibility, planning, organization, self-monitoring, etc.

Van der Donk et al. (2013) found that students with mathematical difficulties are poor in verbal working memory. Hence, it is evident that among the two major components of working memory, verbal working memory plays a dominant role in mathematics achievement than the visuospatial working memory. Poor executive functioning is associated with low-grade point average (GPA) among the pre-adolescent and adolescent population (Mann and Snover 2015). Both verbal and visual working memory (WM) are essential for achieving success in the 3Rs (reading, writing, and arithmetics), whereas both WM and academic achievement have no impact on gender as verified by Napier (2014).

Elementary grade students with weak EF skills exhibited more academic and behavioral difficulties, and they have less self-regulatory skills and adjustment problems as revealed by Jacobson et al. (2014). Primary students with more difficulties in working memory, emotional control, sustained attention, etc. experienced more difficulties in task initiation as proved by Prosen and Vitulic (2014).

Executive function from childhood predicts that academic achievement is highly associated with goal-directed behavior (Prosen and Vitulic 2014). Visu-Petra et al. (2011) investigated the relation between executive function and academic achievement; the results confirmed the multifaceted nature of EF constituted to more academic outputs. A lot of empirical evidences are available in the literature regarding the key role played by EF in the development of academic skills as well as school performance and proved to be a predictor of school achievement as revealed by Laura Visu-Petra et al. (2011). Best et al. (2011) and Pavetti et al. (2014) stressed that the curriculum has to be transacted in such a way to promote executive functioning skills among the students. It can be concluded that EFs are critically important not only for academic success but also for the success of adults in getting the right placements.

Executive functions have been associated with learning difficulties. Germano et al. (2017) studied EFs in students with learning disorders. The students with poor executive functioning skills are lagging behind in emotional control, sustained attention, and poor academic self-concept. On the contrary, Said (2013) and Bailey (2018) reported through their studies that executive functions had not been significantly associated with academic achievement. The three important constructs, namely, attention control, emotional regulation, and cognitive flexibility, proved to not correlate with academic achievement as reported by Baginski (2015). Quite a few research studies proved that attention is highly correlated with working memory (WM) and academic achievement, whereas Napier (2014) found out that attention problems were not significantly correlated with WM and academic achievement.

It is evident from the majority of research studies that executive functioning is essential for academic achievement starting from preschool children. The various components of executive functioning such as working memory, cognitive flexibility, sustained attention, and inhibition had contributed to the successful academic achievement.

2.4 Neurocognitive Aspects of Executive Functioning Skills

The recent developments in brain science have revealed that the higher-order cognitive skills, like attention control, flexibility in thinking and behavior, inhibitive control, and shrewd memory, are cognitive processes essential to accomplish routine as well as complicated assignments, solve problems, strengthen attention span, follow the rules and regulation without omitting, sort out plans, self-regulate the actions, control unwanted unfruitful impulses, delay inappropriate behavior, and formulate and achieve short- and long-term goals. These are the skills essential for success in many aspects of everyday life, including academic success, to become successful parents and in workplace too. These skills are nothing but named as executive functioning skills which need a lot of social competence to make the individuals move toward better performers in their social as well in their family life. Executive functioning skills are very essential to the extent that those who possess these skills are capable of maintaining their employment, succeed in the family life and relations, and become successful parents.

The managing capacity of the individuals in all aspects needs a healthy high-level processing of the brain. Even after many research studies carried out in this area, we could not arrive an accepted operational definition as stated by Barkley (2012). Brain research revealed that many brain areas are involved in information processing from childhood to older age (Anderson et al. 2008). Due to the collaborative functioning of the many parts of the brain, for example, prefrontal cortex in the dorsolateral side, cortex parts in the orbitofrontal region, and anterior cingulate cortex along with parieto-temporal association areas, one can possess their executive functioning skills (Lundy-Ekman 2007). Executive functioning skills are more advanced higher-level brain functioning skills involving affective components and performing abilities with monitoring capability. These skills are the deciding factors of many cognitive skills as visible morphological characters in the later period of adulthood (Sowell et al. 2003) (Fig. 2.2).

Executive functioning skills are executed in the frontal lobes, and their role is important in carrying out actions related to working memory, inhibition, planning, mental flexibility, and impulse control. These skills related to executive functions are the mental activities which are activated due to the frontal lobe functions, especially in monitoring attention and memory skills needed in task completion as noted by Welsh and Pennington (1988). Varanda et al. (2017) identified the fact that these functions are impaired in people with neurodevelopmental disorders, i.e., involving deficits in frontal lobe functioning. People with frontal lobe injuries in the brain were found to have defects in their executive functioning skills (Halstead 1947; Luria 1973, 1980) (Fig. 2.3).

Majority of the studies in the brain have found out that dorsolateral prefrontal cortex is mainly responsible for successfully carrying out executive functions as reported by Seidman et al. Persons with ADHD also experience inadequate executive functioning skills. With the help of brain imaging, it was found out that children with ADHD have deficits in many brain parts, such as the dorsolateral prefrontal cortex. The studies conducted by Parker et.al (2006) revealed that ADHD participants experience poor executive functioning skills throughout their lifetime. Adolescents with ADHD demonstrated poor EFs as revealed by Toplak et al. (2008). Halperin and Schulz (2006) found out that neuroimaging research helped to find out that prefrontal and basal ganglia function are associated with ADHD behaviors (Fig. 2.4).

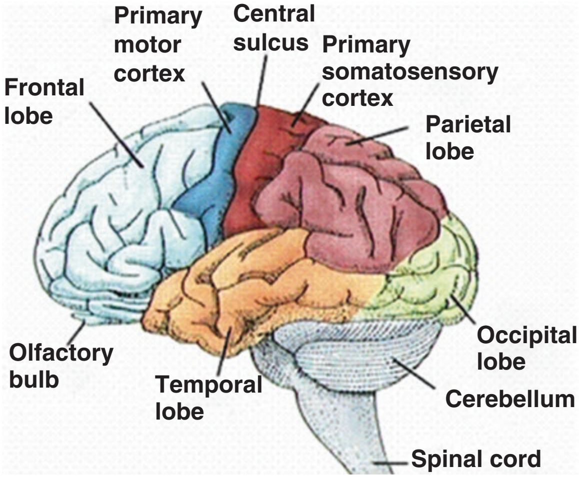


Fig. 2.2 Major parts of the Brain

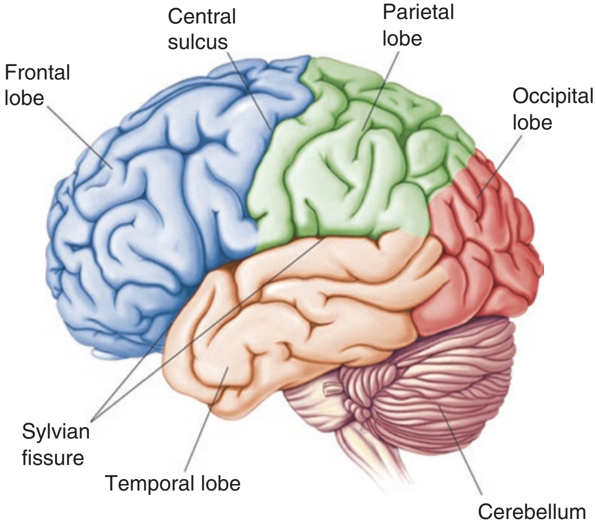


Fig. 2.3 Structure of the brain showing frontal lobes

Prefrontal cortex is an important area in the brain in controlling executive functioning skills. This part develops only after the age of 20. Negative environmental influences and poor socioeconomic status such as poverty or negative livelihood such as exposure to antisocial environment like violence have impact on the development of executive functions. EF is strongly dependent on the function of the prefrontal cortex (Vuontela et al. 2013). Longitudinal functional magnetic resonance imaging (fMRI) studies are helpful in finding out that children who experience inappropriate environment and grow up in poverty have impaired executive functioning skills. Hence, there exists a strong association between brain

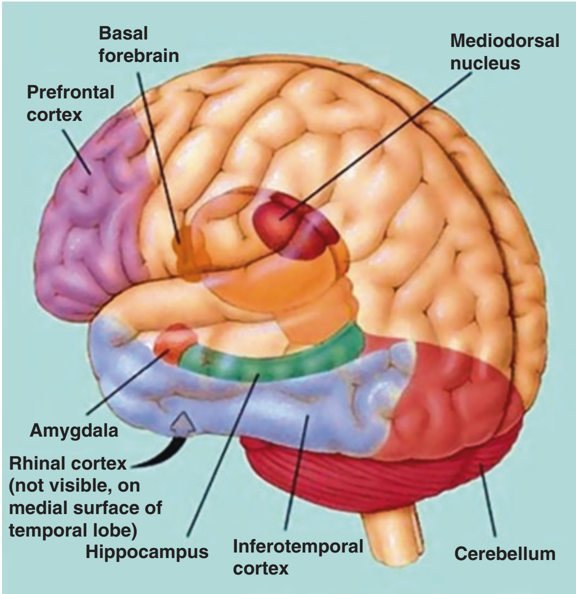


Fig. 2.4 Structure of the Brain showing prefrontal cortex

functioning and poverty, and researchers found out that experiencing poverty at the age of 9 has its negative impact on the brain at age 24 in the form of poor executive functioning skills. Likewise, people with aggression, depression, post-traumatic stress disorder, and anxiety disorders also are the victims of poor executive functions due to the deficits in the parts of the brain that control the EFs (Pavetti et al. 2014). The substantial structural and functional changes in the neurons such as synaptogenesis, myelination, and synaptic pruning also play a crucial cognitive development and behavioral control among children as well as young adolescents (Huttenlocher and Dabholkar 1997; Vuontela et al. 2013).

2.5 Research Design

This study is undertaken with the following objectives. The participants were administered in person the research tools in terms of various tasks to find out the level of executive functioning skills in four components of EFs, viz., cognitive flexibility, attention, working memory, and inhibition. Thirty students aged 18 and 19 years enrolled in the 2-year UG program (B.Sc. Chemistry) in Arts and Science at Salem District College, Tamil Nadu, India.

Objectives

- To find out the level of executive functioning skills in terms of cognitive flexibility, attention, working memory, and inhibition among undergraduate students
- To find out the level of achievement in chemistry among undergraduate students

- To find out the relationship between scores of executive functioning skills and chemistry achievement among undergraduate students
- To understand the neurocognitive aspects of executive functioning skills in terms of cognitive flexibility, attention, working memory, and inhibition among undergraduate students

Research Questions
1. Is it possible to find out the level of executive functioning skills in terms of inhibition, attention, cognitive flexibility, and working memory?
2. Is it possible to find out the achievement level of undergraduate students in chemistry?
3. Is there any correlation between chemistry achievement and executive functioning skills of the participants?

2.5.1 Tool to Assess Executive Functioning Skills

Executive functioning skills were assessed in terms of four constructs: inhibition, attention, working memory, and cognitive flexibility, as emphasized by many experts of executive function such as Malagoli and Usai (2018), Cozzutti et al. (2017), Cragg et al. (2016), Mann and Snover (2015), Andersonbaginski (2015), Pavetti et al. (2014), Gilmore and Cragg (2014), Napier (2014) Simona and Helena (2014), Said (2013), Van der Donk et al. (2013), Valiente-Barroso and Garcia-Garcia (2012), Jacobson et al. (2011), Huizinga et al. (2006), Gioia and Isquith (2004), and Miyake et al. (2000). The researchers evolved the instruments to find out the usage of the four components of EFs. The researchers working in the area of cognitive psychology were consulted in order to establish validity of the tool. The tool to assess cognitive flexibility is modified according to their suggestions. Their opinion is sought on the final tool. To assess the cognitive flexibility of the participants, we provided ten tasks, inhibition comprises five tasks, working memory has six tasks, and attention has nine tasks. The reliability of the tool is arrived using split-half method, in which it was found that the "r" value is 0.81 for cognitive flexibility, 0.75 for inhibition, 0.52 for working memory, and 0.64 for attention (Tables 2.2, 2.3, 2.4, and 2.5).

Executive functioning skills and chemistry achievement are positively and significantly correlated: $r = 0.652$, $p = 0.000$.

2.5.2 Findings

The above table presents the analysis of data, i.e., the scores in the executive functioning skills and achievement in chemistry are identified as low, average, and high level. Up to 39% is considered as low level, 40–59 as average level, and above 60 as high level. Out of 30 participants, 27 possess high level and 3 have average level in

Table 2.2 "Level of EFs in various dimensions of the participants"

	Dimensions of executive functioning (EFs) skills					
S. No	Inhibition (Score 20)	Working memory (Score 30)	Cognitive flexibility (Score 30)	Attention (Score 20)	EFs total (Score 100)	Level
1	16	24	20	15	75	High
2	7	22	13	15	57	Average
3	16	26	16	16	74	High
4	14	24	20	12	70	High
5	16	28	22	16	82	High
6	17	26	25	17	85	High
7	14	23	21	13	71	High
8	15	28	17	19	79	High
9	9	23	17	12	61	High
10	15	23	15	14	67	High
11	15	9	17	12	53	Average
12	17	15	20	12	64	High
13	15	27	22	16	80	High
14	14	24	16	13	67	High
15	15	27	26	19	87	High
16	13	24	20	13	70	High
17	15	21	14	12	62	High
18	14	26	21	13	74	High
19	13	21	16	16	66	High
20	17	28	20	18	83	High
21	13	27	18	15	73	High
22	16	26	22	12	76	High
23	14	20	19	13	66	High
24	11	22	15	13	61	High
25	16	27	23	18	84	High
26	16	25	20	13	74	High
27	13	25	17	14	69	High
28	16	26	16	16	74	High
29	18	28	22	15	83	High
30	14	11	15	9	49	Average

Note: *Score up to 39, Low; 40–59, Average; and 60 and above, High

their executive functioning skills, and 28 participants are high in academic achievement. The participants who scored high level in their executive functioning skills scored high in their academic achievement. The correlation coefficient "r" value is calculated using Karl Pearson method. There exists a high correlation (0.65) between executive functioning skills and achievement in chemistry. This confirms the research studies conducted by Germano et al. (2017), Kadian (2016), and Best et al. (2011), Van der Donk et al. (2013), and Valiente-Barroso and Garcia-Garcia (2012).

Table 2.3 "Achievement level of participants in Chemistry"

S. No	Achievement score (Max.100)	Level
1	80	High
2	60	High
3	60	High
4	66	High
5	88	High
6	88	High
7	72	High
8	88	High
9	60	High
10	40	Average
11	72	High
12	88	High
13	80	High
14	76	High
15	92	High
16	72	High
17	60	High
18	64	High
19	64	High
20	84	High
21	68	High
22	88	High
23	56	Average
24	72	High
25	84	High
26	64	High
27	72	High
28	68	High
29	92	High
30	60	High

Note: *Score up to 39, Low; 40–59, Average; and 60 and above, High

2.6 Conclusion

The teachers, teacher educators, and parents need to understand the importance of EFs. The successful completion of all cognitive tasks like planning, monitoring, judging, problem-solving, and decision-making requires the application of EFs. Managing one's own emotion through behavior is said to possess higher-order cognitive control skills; focused and goal-directed behavior is essential to achieve success in life. As far as the achievement in academic subjects are concerned, the students must have focused attention, should prioritize the tasks assigned to them

Table 2.4 "Level of executive functioning (EFs) skills and achievement scores of the participants"

S. No	Executive functioning skills (Max.100)	Level of EFs	Achievement score (Max.100)	Level of achievement
1	75	High	80	High
2	57	Average	60	High
3	74	High	60	High
4	70	High	66	High
5	82	High	88	High
6	85	High	88	High
7	71	High	72	High
8	79	High	88	High
9	61	High	60	High
10	67	High	40	Average
11	53	Average	72	High
12	64	High	88	High
13	80	High	80	High
14	67	High	76	High
15	87	High	92	High
16	70	High	72	High
17	62	High	60	High
18	74	High	64	High
19	66	High	64	High
20	83	High	84	High
21	73	High	68	High
22	76	High	88	High
23	66	High	56	Average
24	61	High	72	High
25	84	High	84	High
26	74	High	64	High
27	69	High	72	High
28	74	High	68	High
29	83	High	92	High
30	49	Average	60	High

Note: *Score up to 39, Low; 40–59, Average; and 60 and above, High

Table 2.5 "Correlation between executive functioning skills and achievement in chemistry"

Variables	Sample (N)	"*r*" value	"*p*" value
Executive functioning skills	30	0.652	0.000**
Achievement in chemistry			

Note: ** indicates significance at 1% level of significance from time to time, remember a lot of information, and must be emotionally cool and suppress the unwanted behavior. All these skills are termed as executive functioning skills. It is essential on the part of the teachers apart from providing the content to learn, they should know how to engage the young brains in these higher-order cognitive control skills as well. The participants in this study are high in all the four components of executive functioning skills and academic achievement. Therefore it is concluded that there is a high positive correlation between executive functioning skills and academic achievement.

References

Anderson, P. (2001). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology, 8*(2), 71–82. https://doi.org/10.1076/chin.8.2.71.8724.

Andersonbaginski. (2015). Attention Regulation, Emotion Regulation, and Cognitive Flexibility as Mediators of the Relationship Between Mindfulness and Academic Achievement in High School Students (2395) [Masters thesis, Eastern Illinois University] http://thekeep.eiu.edu/theses/2395

Anderson, V., Jacobs, R., & Anderson, P. J. (Eds.). (2008). *Executive functions and the frontal lobes: A lifespan perspective*. New York: Psychology Press.

Baddeley, A.D. (1997) Human Memory: Theory and Practice (Revised Edition). Psychology Press, East Sussex.

Baddeley, A. D., & Hitch, G. (1974). undefined. Psychology of Learning and Motivation, 47-89. https://doi.org/10.1016/s0079-7421(08)60452-1.

Baginski, A. (2015). *Attention regulation, emotion regulation, and cognitive flexibility as mediators of the relationship between mindfulness and academic achievement in high school students*. Masters theses, p. 2395. http://thekeep.eiu.edu/theses/2395

Bailey, B. A., Andrzejewski, S. K., Greif, S. M., Svingos, A. M., & Heaton, S. C. (2018). The role of executive functioning and academic achievement in the academic self-concept of children and adolescents referred for neuropsychological assessment. *Children, 5*(83), 1–13. https://doi.org/10.3390/children5070083.

Balushi, H. A. (2015). The influence of paying attention in classroom on students ’ academic achievement in terms of their comprehension and recall ability. In *Proceedings of INTCESS15-2nd international conference on education and social sciences*, Istanbul, Turkey, pp. 684–693.

Barkley, R. A. (2012). *Executive functions: What they are, how they work, and why they evolved*. New York: Guilford Press.

Best, J. R., Miller, P. H., & Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative National Sample. *Learning and Individual Differences, 21*(4), 327–336.

Bryce, D., & Whitebread, D. (2013). The relationships among executive functions, metacognitive skills, and educational achievement in 5 and seven-year-old children. *Metacognition Learning*, 1–19. https://doi.org/10.1007/s11409-014-9120-4.

Bull, R. (2001). Executive functioning as a predictor of children’s mathematics ability: Inhibition, switching, and working memory. *Developmental Neuropsychology, 19*(3), 273–293.

Bull, R., & Scerif, G. (2001). Executive Functioning as a Predictor of Children’s Mathematics Ability: Inhibition, Switching, and Working Memory. *Developmental Neuropsychology, 19(3), 273–293.*

Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *The Quarterly Journal of Experimental Psychology, 59*(4), 745–759. https://doi.org/10.1080/17470210500162854.

Cooper-Kahn, J., & Dietzel, L. (2009). *Late, lost, and unprepared: A parents' guide to helping children with executive functioning*. Bethesda: Woodbine House.

Cozzutti, G., Guaran, F., Blessano, E., & Romero, F. J. (2017). Effects on executive functions in the BAPNE Method; a study on 8–9 years old children in Friuli Venezia Giulia, Italy. *Procedia – Social and Behavioral Sciences, 237*, 900–907. https://doi.org/10.1016/j.sbspro.2017.02.126.

Cragg, L., Keeble, S., Roome, H. E., & Gilmore, C. (2016). Direct and indirect influences of executive functions on mathematics Achievement. *Cognition, 162, 12–26.* https://doi.org/10.1016/j.cognition.2017.01.014.

Cragg, L., Keeble, S., Roome, H. E., & Gilmore, C. (2017). Direct and indirect influences of executive functions on mathematics achievement. *Cognition, 162*, 12–26. https://doi.org/10.1016/j.cognition.2017.01.014.

Dawson, P., & Guare., R. (2009). Best practices in assessing and improving executive skills. *Best Practices in School Psychology - Student-Level Services, Ch. 24, 1–17.*

Decker, S. L., Ezrine, G. A., & Ferraracci, J. (2016). Latent dimensions of executive functions in early childhood. *Journal of Pediatric Neuropsychology, 2*, 89–98. https://doi.org/10.1007/s40817-016-0013-0.

Diamond, A. (2013). Executive Functions. *The Annual Review of Psychology, 64, 135–168.*

Diamond, A. D. E. L. E. (2016). Why improving and assessing executive functions early in life is critical. In *Executive function in preschool-age children: Integrating measurement, neurodevelopment, and translational research*. Washington, DC: American Psychological Association.

Dias, N. M., & Seabra, A. G. (2015). Is it possible to promote executive functions in preschoolers? A case study in Brazil. *International Journal of Child Care and Education Policy, 9*(6), 1–18. https://doi.org/10.1186/s40723-015-0010-2.

Esen, B. K., Ozcan, H. D., & Sezgin, M. (2017). High school students' cognitive flexibility is predicted by self-efficacy and achievement. *European Journal of Education Studies, 3*(2), 143–151. https://doi.org/10.5281/zenodo.244470.

Fine, K. (2014). *Executive functioning and grade point average in college students*. A Senior Honors Thesis submitted to the Faculty of the University of Utah, pp. 1–17.

Germano, G. D., Bastos, L. B., & Capellini, S. A. (2017). The opinion of parents and teachers of students with learning disorders regarding executive function skills. *Revista CEFAC, 19*(5), 674–681. https://doi.org/10.1590/1982-0216201719510817.

Gilmore, C., & Cragg, L. (2014). Teachers' understanding of the role of executive functions in mathematics learning. *Mind, Brain and Education, 8*(3), 132–136.

Gioia, G. A., & Isquith, P. K. (2004). Ecological assessment of executive function in traumatic brain injury. *Developmental Neuropsychology, 1*(2), 135–158.

Halperin, J. M., & Schulz, K. P. (2006). Revisiting the role of the prefrontal cortex in the pathophysiology of attention-deficit/hyperactivity disorder, 132(4): PMID: 16822167. https://doi.org/10.1037/0033-2909.132.4.560.

Halstead, W. C. (1947). *Brain and intelligence: A quantitative study of the frontal lobes*. Chicago: University of Chicago Press/W.B. Saunders Company.

Huttenlocher, P. R., & Dabholkar, A. S. (1997). Regional differences in synaptogenesis in human cerebral cortex. *Journal of Comparative Neurology, 387*, 167–178.

Huizinga et. al. (2006). Age-Related Change in Executive Function: Developmental Trends and a Latent Variable Analysis. *Neuropsychologia 44(11), 2017–36.* https://doi.org/10.1016/j.neuropsychologia.2006.01.010.

Jacobson, L. A., Williford, AP & Pianta, R. C. (2011). The Role of Executive Function in Children's Competent Adjustment to Middle School. *Child Neuropsychol,17(3):255–280.* https://doi.org/10.1080/09297049.2010.535654.

Jacobson, L. A., Williford, A. P., & Pianta, R. C. (2014). The role of executive function in children's competent adjustment to Middle school. *Child Neuropsychology, 17*(3), 255–280. https://doi.org/10.1080/09297049.2010.535654.

Kadian, A. (2016). The relation between academic achievement, executive function, intelligence, and metacognition. *The International Journal of Indian Psychology, 3*(4), 166–174.

Lundy-Ekman, L. (2007). *Neuroscience: Fundamentals for rehabilitation* (3rd ed.). St. Louis: Elsevier.

Luria, A. R. (1973). *The working brain*. New York: Basic Books.

Luria, A. R. (1980). *Higher cortical functions in man (2nd ed.). New York: Basic Books.*

Malagoli, C., & Usai, M. C. (2018). The effects of gender and age on inhibition and working memory organization in 14- to 19-year-old adolescents and young adults. *Cognitive Development, 45*, 10–23. https://doi.org/10.1016/j.cogdev.2017.10.005.

Mann, D. P., & Snover, R. (2015). Executive functioning: Relationship with high school student role performance. *The Open Journal of Occupational Therapy (OJOT), 3*(4). https://doi.org/10.15453/2168-6408.1153.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex frontal lobe tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49–100.

Napier, D. E. (2014). *Predicting Adolescents' academic achievement: The contribution of attention and working memory*. Graduate theses and dissertations. http://scholarcommons.usf.edu/etd/5544

Oberle, E., & Schonert-Reichl, K. A. (2013). Relations among peer acceptance, inhibitory control, and math achievement in early adolescence. *Journal of Applied Developmental Psychology, 34*(1), 45–51. https://doi.org/10.1016/j.appdev.2012.09.003.

Parker, D. R., Hoffman, S. F., & Rolands, L. (2006). An examination of the effects of ADHD coaching. *Journal of Postsecondary Education and Disability, 24*(2), 115–132.

Pavetti, L., President, V., Support, F. I., & Priorities, P. (2014). Using executive function and related principles to improve the design and delivery of assistance programs for disadvantaged families. *Innovating to End Urban Poverty*, 1–15.

Pennington. (1998). Executive functions and working memory: Theoretical and measurement issues. In: Pennington BF, Bennetto L, McAleer O, Roberts Jr RJ (Ed). Attention, memory, and executive function. Baltimore: Paul H Brookes Publishing, 327–348.

Prosen, S., & Vitulic, H. S. (2014). Executive function in a different group of university students. *Review of Psychology, 21*(2), 137–143.

Rau. (2009). https://www.researchgate.net/publication/24312578_Williams_PG_Suchy_Y_Rau_HK_Individual_differences_in_executive_functioning_implications_for_stress_regulation_Ann_Behav_Med_37_126-140.

Remine, M. D., Esther, C., & Brown, M. P. (2008). Language ability and verbal and nonverbal executive functioning in deaf students communicating in spoken English. *Journal of Deaf Studies and Deaf Education, 13*(4), 531–545.

Said, N. (2013). Predicting Academic performance: Executive functions, metacognition, study strategies, and self-efficacy. *The 2013 WEI International Academic Conference Proceedings*, Orlando, USA, pp. 34–47.

Sowell, E. R., Peterson, B. S., Thompson, P. M., Welcome, S. E., Henkenius, A. L., & Toga, A. W. (2003). Mapping cortical change across the human lifespan. *Nature Neuroscience, 6*, 309–315.

Stad, F. E., Wiedl, K. H., Vogelaar, B., Bakker, M., & Resing, W. C. M. (2019). The role of cognitive flexibility in young children's potential for learning under dynamic testing conditions. *European Journal of Psychology of Education, 34*, 123–146.

Thorell, L. B., Veleiro, A., Siu, A. F. Y., & Mohammadi, H. (2013). Examining the relation between ratings of executive functioning and academic achievement: Findings from a cross-cultural study. *Child Neuropsychology, 19*(6), 630–638. https://doi.org/10.1080/09297049.2012.727792.

Toplak, M. E., Bucciarelli, S. M., Jain, U., & Tannock, R. (2008). Executive functions: Performance-based measures and the Behavior Rating Inventory of Executive Function (BRIEF) in Adolescents with Attention Deficit/Hyperactivity Disorder (ADHD). *Child Neuropsychology, 15*(1), 53–72. https://doi.org/10.1080/09297040802070929.

Uopasai, S. (2017). The effect of working memory training on the behavioral, electrophysiological and achievement change *TOJET: The Turkish Online Journal of Educational Technology*, *2017*(Special Issue for INTE), 331–339.

Valiente-Barroso, C., & Garcia-Garcia, E. (2012). Executive function, adolescent development and mathematical competence: importance of quantitative and qualitative analysis in educational psychology. *Procedia – Social and Behavioral Sciences, 69*, 2193–2200. https://doi.org/10.1016/j.sbspro.2012.12.185.

Van der Donk, M. L. A., Hiemstra-Beernink, A. C., Tjeenk-Kalff, A. C., van der Leij, A. V., & Lindauer, J. L. (2013). Interventions to improve executive functioning and working memory in school-aged children with AD(H)D: A randomized controlled trial and stepped-care approach. *BMC Psychiatry, 13*(23), 1–7.

Varanda, C. D. A., Dreux, F., & Fernandes, M. (2017). Cognitive flexibility training intervention among children with autism: A longitudinal study. *Psicologia: Reflexão e Crítica, 30*(15), 1–8. https://doi.org/10.1186/s41155-017-0069-5.

Visu-petra, L., Cheie, L., Benga, O., & Miclea, M. (2011). Cognitive control goes to school: The impact of executive functions on academic performance. *Procedia Social and Behavioral Sciences, 11*, 240–244. https://doi.org/10.1016/j.sbspro.2011.01.069.

Vitiello, V. E., Greenfield, D. B., Munis, P., George, J. L., Vitiello, V. E., Greenfield, D. B., … George, J. L. (2011). Cognitive flexibility, approaches to learning, and academic school readiness in head start preschool children. *Early Education & Development*, *9289*. https://doi.org/10.1080/10409289.2011.538366

Vuontela, V., Carlson, S., Troberg, A.-M., Fontel, T., Simola, P., Saarinen, S., & Aronen, E. T. (2013). Working memory, attention, inhibition, and their relation to adaptive functioning and behavioural/emotional symptoms in school-aged children. *Child Psychiatry Human Development, 44*, 105–122.

Welsh, M. C., & Pennington, B. F. (1988). Assessing frontal lobe functioning in children: Views from developmental psychology. *Developmental Neuropsychology, 4*(3), 199–230. https://doi.org/10.1080/87565648809540405.

Chapter 3
A Timeline from Neural Network to Python Through ANN and AI: An Introductory Tutorial

T. Habeebur Rahman and S. Iniyan

3.1 Introduction

An active process of acquiring and constructing meaningful experiences through interaction, exploration, and reflection is called learning, which solely depends on brain and cognitive development of an individual. One's cognitive functioning skills rely on his brain function. Information processing, storage, retrieval, and retention are controlled by the brain and its interneural connections. The findings of brain research and educational neuroscience have enriched the knowledge of researchers, educators, teachers, and learners in teaching and learning. It has revolutionised the thinking of educational practitioners by providing a lot of inputs based on the underlying principles on how the brain learns.

Cognitive science is an interdisciplinary scientific study of mind and its process. In the 1950s, cognitive science began as an intellectual movement, leading to cognitive revolution. Cognitive science attempts to study the neurobiological process of the brain, explain with more neuroscientific evidences how the brain processes, stores, and retrieves information regarding human behaviour, intelligence, etc. With the advent of new knowledge in cognitive science, we come to know elaborately about the brain and its organisation, structure, and function with a clear understanding of the complex phenomena such as memory, attention, thinking, reasoning, learning, and consciousness. The research findings of brain science and educational neuroscience are providing a lot of inputs to the fundamental curiosity about how people think and learn by observing human learning processes.

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The brain function of an individual depends upon the environment and neural connectivity, which leads to information processing and learning. Collaboration with other disciplines such as philosophy, psychology, linguistics, neuroscience, cognitive neuroscience, artificial intelligence, anthropology, sociology, etc. provides opportunity to study the structure and function of the brain and the plasticity of neuron and its role in the process of learning (Eisenberg et al. 1995).

3.1.1 The Brain and Neurons' Basis of Learning

Educational neuroscientists examine the structure and function of the nervous system in terms of anatomy, physiology, chemistry, and molecular biology with specific relation to the brain activity correlated with behaviour and learning. In order to understand how learning occurs in the brain, it is essential to know its structure and function. The brain is nothing but an amazing organ with a strong network of fibre pathways made up of approximately a hundred billion (10^{10}) neurons in three major parts: the cerebrum, brain stem, and cerebellum. The cerebrum is the primary part which plays a crucial role in learning, higher-ordered thinking, memory, and reasoning. Cerebrum is associated with many functions such as vision, hearing, speech, touch, working memory, long-term memory, language, and reasoning abilities; without these abilities, learning would not happen. The unit of the brain is called a nerve cell, or neuron, which is the learning part of the brain that receives information from the sensory organs and then sends that information to other neurons. The passage of information via axons across billions of neurons by transmitting signals to other neurons is through a process called synapse. The connections between neurons are called firing of the neurons via synapses, which typically link the axon of a neuron with the cell body or a dendrite of another neuron (Fig. 3.1).

There are approximately 100 billion of neurons in a human brain, which receive signals or impulse, process these signals, and transmit them to other neurons. This makes them form a neural network which leads to communication with other neurons through which the axon subdivides and branches out. The dendrites, which are

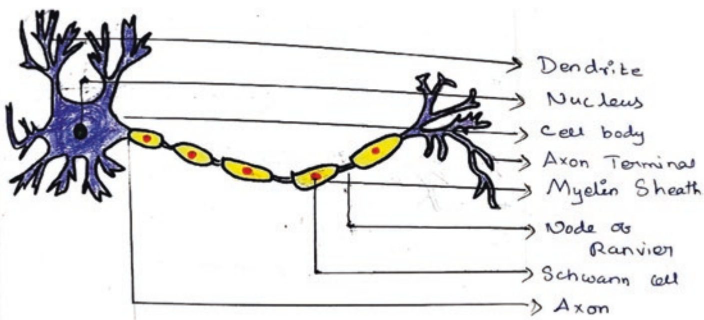


Fig. 3.1 Structure of a neuron

the growing part of the neuron, send information to the cell body and move out through the axon. When a neuron is stimulated, it sends an electrical impulse down the axon to the terminals at the end of the axon branch. This releases chemicals (neurotransmitters) which cross the synapse between the axon terminal and the dendrite of the receiving neuron (Fig. 3.2).

Growing dendrites during firing of the neurons in large sizes and numbers physically increases the weight of our brain, which is a dense neural network. When the neurons are frequently used, new connections and networks are framed, leading to more dendrite pathways and synaptic connections. The more the neural networks are used, the connections will be stronger. Whenever a complex skill is learnt, it is because of the increased number of growth of dendrites on neurons. The brain is capable of new learning and continues to change throughout the life, called plasticity. As a result, we can say that the brain undergoes considerable changes when we are learning. Drubach (2000) claims that when learning takes place, two types of changes occur in our brain.

Modifications occur in the internal structure of the neurons because of neural firing or synapses. When number of synapses are more, a dense network is formed due to growing number of dendrites among neurons (Fig. 3.3).

The neuroscience researchers are now capable of understanding the mechanism going inside the brain and try to probe how learning takes place at the molecular level. New technologies, such as diffusion imaging, functional magnetic resonance imaging (fMRI), positron emission tomography (PET), etc., helped the educational cognitive scientists make a breakthrough to thoroughly understand the learning mechanism going on inside the brain (Ford 2011).

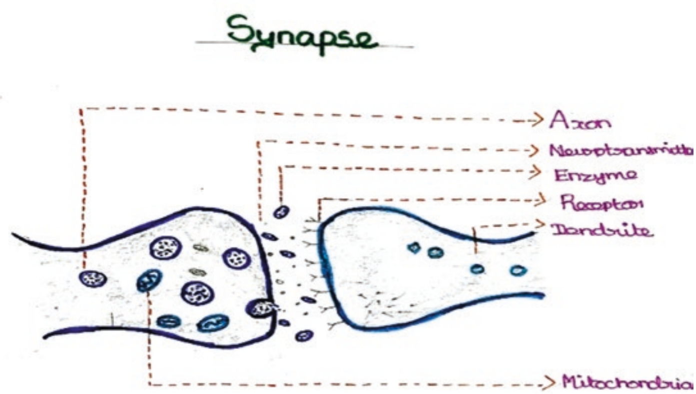
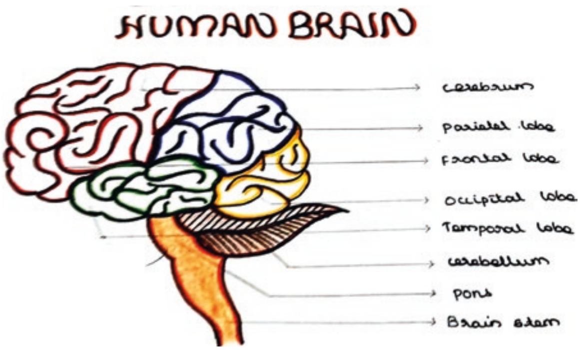


Fig. 3.2 Synapse

Fig. 3.3 Major parts of the Brain



3.1.2 Learning and Memory

According to the neuroscientists, the mechanism of learning and remembering information is due to the strengthening and weakening of neural connections across thousands of neurons or brain cells. Experimentation with mice proved that it is possible to identify and observe the changes in the brain while learning a new activity or information as cited by Ford (2011). Learning new task leads to forming new connections of dendrites within the brain, which is nothing but firing and wiring of the neurons. Continuous practice and rehearsal will make our neural network stronger to pass these information accurately by storing them for immediate access later in the form of memory.

3.2 Artificial Neural Network

The neuroscience research findings helped computer scientists to find the intelligence in machines by imitating the neurons and its function in machines. Hence, artificial neural networks (ANN) are created akin to the natural neuron systems. Like biological neurons, ANN consists of entity, named neurons, and interconnections between them.

ANN is attempted to simulate the human neurons and their functions. The human brain is solving real-life problems, like which ANN is designed to solve the problems by learning. In ANN there are different layers of mathematical processing, and when the data is given, it will process the information. Millions of artificial neurons are arranged in a series of layers. The data is received by the input layers and passed through the hidden layers and then processed and then transformed to the output layer in the form of results. The majority of the neural networks are fully connected from one layer to another. These connections are weighted; the higher the number, the greater the influence one unit has on another, similar to a human brain. As the data goes through each unit, the network is learning more about the data. On the other side of the network are the output units, and this is where the network responds to the data that was given and processed.

Subsequent to particular trainings on the given set of data, ANN is very helpful in making predictions for cases that are not in the training set, because of its pattern categorisation ability. After training, ANN is capable of making extremely fast results. By simplifying training data, it can house new patterns or even novel operating conditions. Neural networks are pertinent in almost every situation in which a connection between the input (predictor, independent) variables and output (predicted, dependent) variables exists; the liaison is very composite and not simple to articulate in the normal terms of "correlations" or "differences between groups". Examples of some neural network problems are given below, which have been applied successfully:

- Prediction of stock market
- Assignment of credit
- Machine's conditional monitoring
- Management of engine
- Medical diagnosis
- Neuromorphic computing
- Neural networks in nanotechnology
- Signal processing
- Weather forecasting
- Robotics
- Pattern finding
- Pharmaceutical industry/medicine
- Speech production and recognition
- Commercial/business applications
- Financial applications
- Data compression
- Game playing

Traditionally, regression analysis has been the most popular modelling technique in predicting energy consumption. After knowing the importance of the ANN approach, it is possible to make energy applications more viable and more attractive to potential users, such as energy engineers. This approach has the advantages of computational speed, low cost for feasibility, and ease of design by operators with little technical experience. Therefore, the use of ANN for modelling and prediction purposes is becoming increasingly popular in the recent decades. This is mainly because ANN has very good approximation capabilities and offers additional advantages, such as short development and fast processing times. ANNs are especially useful in predicting problems where mathematical formulae and prior knowledge on the relationship between inputs and outputs are unknown.

ANN is applied to improve reactive power management, power forecasting etc. Quality prediction of load evolution at different levels of distribution networks is a basic requirement for an adequate operation planning of modern power system.

An algorithm using the artificial neural network (ANN) method can define good-quality estimations of future values. ANN offers several advantages:

- No system model required
- Bizarre pattern toleration
- High adaptive capacity

Literature review shows that the artificial neural network (ANN) models have been used in different fields such as psychology, medicine, mathematics, engineering, finance, and economics. As the literature shows, the applications of the ANN models in economics include sectors such as water resources, tourism, and energy sector.

3.3 Artificial Intelligence

Artificial intelligence is the growing field with the advent of computers to accomplish the tasks that previously require human intelligence, like visual perception, speech recognition, and language translation. AI made the computers to master the datasets to understand the underlying data structures and the procedures to make the effective use of data.

AGI (artificial general intelligence) denotes to the computers which are able to perform the tasks usually carried out by humans. Machine learning refers to all techniques that make the computers to learn without teaching them or programming. Deep learning is an emerging technology which makes a computer to understand patterns from both named and unnamed dataset, whereas AI is a broader concept than machine learning or its subset, deep learning.

Artificial intelligence basically changes the human perception about the world. With the help of algorithms, routine procedures of work are done by saving the time and the hard tasks involving decision-making, thinking, and creativity.

The difficult actions are automated based on behavioural patterns and work routines, making time and space for higher-level thinking. Higher-order skills are augmented by artificial intelligence to remove the natural obstacles to understand better the conceptualisation and implementation of creative efforts. At present, with the help of AI, more creative arts and music tools are used, which make the composition process more suitable according to the creators' objectives and goals. AI becomes a companion to human beings, which makes them to move away from their past limitations and bring new ideas and concepts towards innovative adventures. Artificial intelligent tools now become a converging point for both old and new career education. As a result, most meaningful, useful, and interesting products and solutions are possible to succeed in the consumer market.

The world is going faster with the help of technology, and a lot of tremendous changes are taking place. AI has revolutionised in three major aspects regarding connectivity networks as given below:

1. It helps in correct traffic and pattern analysis to find out solutions to problems when they occur.
2. It makes uninterrupted state of connectivity that will be helpful in optimisation for any experience across any set of devices.
3. It draws dissimilar information from multiple sources, which makes user requirements simple and faster.

AI has a greater impact on our lives, making many aspects more comfortable and easy. It enables more personalisation by saving our valuable time to do routine work. AI influences the way we think and interact with technology in our daily lives.

3.3.1 Mirror Neurons and Artificial Intelligence

There are mirror neurons in our brain parts that have an impact to modify, control, and mirror the activities related to sensory and motor in nature. The brain areas where mirror neurons are present are primary motor cortex, dorsal premotor division of the ventral premotor cortex, inferior lateral and ventral intra parietal areas of the parietal lobe. Mirror neurons are activated by seeing somebody perform specific activities and also when anyone witnesses someone does the same actions. Artificial intelligence is a field which emerged as a result of in-depth analysis and simulation of neural function specifically and is formulated with the advent of neuroscience. Vice versa, the progress in the field of brain research is also positively motivated by developments in AI. The concept of mirror neurons and the approaches are very much pioneers in the progress of AI and development. The same mirror neuron concept is implemented in AI. But the human brain is very much superior and complex than computer, i.e. that the brain is more than a set of reductionist computer algorithms.

3.4 Machine Learning

Artificial intelligence (AI) has its subset which makes the existing computers more efficient to train without making them undergo vigorous programming, called machine learning (ML). ML is particularly concerned with learning interest in going beyond computer programs to make them capable of changing the unprotected data to novel data. ML algorithms can be divided into three categories, namely, reinforcement learning, supervised learning, and unsupervised learning (Praveena and Jaiganesh 2017).

3.5 Supervised Learning

The objective of supervised learning is to analyse the given input-output paired data. With the help of supervised learning, we can perform typical tasks such as regression, i.e. predicting the real value, classification as predicting the category, and ranking, i.e. forecasting the order. Most common data analysis is done with supervised learning and now more extensively studied in the statistics community over a long period of time. A recent trend of supervised learning research among the machine learning experts is to use all the information in addition to the input-output paired data to improve the forecasting accuracy. At present, semi-supervised learning uses additional input-only data, transfers learning on borrowed data from the same learning tasks, and solves multiple related learning tasks simultaneously.

3.6 Reinforcement Learning

Supervised learning is a powerful approach, but getting input-output paired data is very expensive. Unsupervised learning is not so expensive to perform, but its results are more temporary in nature. Reinforcement learning is not so expensive like supervised learning and gives better results when compared to unsupervised learning. There is no need for providing explicit supervision, i.e. output data, but it is essential to learn the input-output relation behind the data. Instead of output data, reinforcement learning uses rewards, which are capable to evaluate the validity of predicted outputs. When rewards are given as implicit supervision, it is usually much easier and less costly than giving explicit supervision. Hence, reinforcement learning becomes a valid approach in modern data analysis. There are many supervised and unsupervised learning techniques that are used under the framework of reinforcement learning.

3.7 Python: A Programming Language in Machine Learning

Machine learning is subset of ANN and AI. Python is evolved as a programming language in machine learning. Applications of Python in ANN, such as word cloud processing, medical image processing, prediction, etc., are discussed below. In these days' fast-paced IT globe, there is at all times the benefit of being ahead of others despite having a deep understanding about a particular technology. Python as of now is an extensively used language and offers umpteen numbers of possibilities for passionate students. Erudition of the usage of functions correctly with Python is an important skill for any Python programmer/developer.

Sebatian Raschka et al. (2020) claims that smart applications are making good use of insights gained out of data, influencing almost all domain and research areas.

At the heart of this evolution are the gears that drive it, from practicing the vast amounts of data engendered daily to scholarship and accomplishment. With the advancement of classic machine learning and scalable graphics processing units (GPUs) generally used in computing, deep fibre networks have become an integral part of artificial intelligence, preventing many of these amazing successes from being enabled and adopted. Python remains the language of choice for technical calculations, machine learning, and data science, promoting both presentation and efficiency by facilitating the utilisation of lesser-level libraries and cleaning the upper-level APIs. This review provides a thoughtful insight of machine learning domain with Python, travels via some relevant topics, and highlights a few of the software and hardware standard that enable it. This cover extensively used concepts and libraries, compiled for general contrast, with the aim of enlightening the learner and advancing the area of Python in addition to machine learning.

Boule (2019) says that Python is a sophisticated high-level programming language that is very much used among the scientific community. The main reasons that make Python an attractive platform for scientific computing can be cited as follows:

(a) It is interpreted (rather than compiled) and typed dynamically (i.e. mutations can vary by type) as a programming language that enables rapid prototyping of scientific applications.
(b) The syntax is clear and easy and therefore easily accessible to non-professional programmers.
(c) Python runs on various operating systems (OS), including three major desktop operating systems, viz. Windows, Mac OS, and Linux.
(d) It is independently disseminated with a compliant license that supports easy circulation of library modules and programs.
(e) Python has numerous libraries (located in the standard library and available through a third party) that allow us to solve completely anything that we think of. These applications in science and engineering include vector programming with NumPy (https://www.numpy.org/), common purpose scientific computing with SciPy (https://www.scipy.org/), symbolic computing with SymPy (https://www.sympy.org), image processing with scikit-image (https://scikit-image.org/), statistical analysis Pandas (http://pandas.pydata.org/), machine learning (scikit-learn, http://scikit-learn.org), path (Matplotlib, https://matplotlib.org/), and many others.

3.7.1 Platforms for Python

1. Atom
2. IDLE
3. IPython
4. Jupyter Notebook

5. PyCharm
6. PyDev
7. Rodeo
8. Spyder
9. Sublime Text
10. Thonny
11. Vim
12. Visual Studio Code
13. Wing

3.7.2 Various Applications of Python for Sustenance

1. Pywr is a tool for solving network resource allocation problems in a timely manner using a linear programming approach. Its main use is in the allocation of resources in the water supply network, although other uses are expected. A network is represented as a direction graph using Network X. Network nodes can be assigned interrupts (such as minimum/maximum flow) and costs and can be connected as needed. Parameters in the model may vary based on limiting conditions (e.g. an entry time series) or states in the model (such as the current segment of a repository). Models can be developed using the Python API, either scripted or interactively using IPython or Jupyter Notebook. Alternatively, models can be defined in a rich JSON-based document format Tomlinson et al. 2020.
2. Word cloud is a type of weighted list for displaying cloud text or language data, which gives a lot of avenues for more attention and a lot of employment opportunities as big data time approaches. At present, there are many text or word cloud generators available for users with simple requests, such as repeating exact sentences or collecting text data from a web page. Additionally, most existing word cloud generators cannot support non-English characters, which are limited to English-speaking users. There are also programming language packages for creating word art clouds, which require coding and are not easy to use. The Python programming language focuses on the development of graphical user interface (GUI) software to create word cloud maps with easy operation (Jin 2017).
3. This chapter introduces Magpylib, a free and lightweight Python package that currently calculates the magnetic fields of static magnets and moments based on analysis models. The package has an easy-to-use interface to evolve, modify, classify, and represent those magnetic sources and calculate the area they create. A brief description of Magpylib's architecture and work is provided, followed by a discussion of possible applications and the design of various models for magnetic systems. In this context, special attention is paid to the possibilities of computational performance (Ortner and Bandeira 2020).
4. The use of embedded systems is ubiquitous in our daily lives, for example, on smart phones, automotive devices, or tablets. Such devices are capable of

handling complex image processing tasks, such as real-time facial recognition or high dynamic range images. However, the size and computing power of an integrated system is a limited requirement. In order to ensure students understand the complicated problems, a new laboratory course "Video Signal Processing and EMED in Integrated Systems" has been developed. Raspberry Pi 3 Model B and the open-source Python programming language have been chosen due to the low cost of hardware and the free availability of the programming language. In this lab course, students learn to develop, implement, apply, and debug a permanent alternative to Python, MATLAB, image signal processing path, and embedded image processing system. Python and Raspberry Pi are introduced at the beginning of the lab course. After that, various experiments are developed in the laboratory course, such as installing a sensor to find out the corner and creating a panoramic image (Jaskolka et al. 2019).

5. In this modern globalised era, death from cancer is a major problem for humanity. Although many types of treatment are available for a few types of cancer, till today there is no remedy. One of the most common types of cancer is breast cancer, which has to be diagnosed, and early diagnosis is the most important thing in its treatment. Proper diagnosis is one of the most important steps in the treatment of breast cancer. A lot of research studies are carried out to predict the specific nature of breast cancer.

   In doing so, information in the form of data was collected to predict the types of breast tumours. The techniques used with the help of machine learning and data visualisation, including logistic regression, neighbourhoods close to K, random forests, support vector machines, decision trees, naive Bayes, and roaming forests, were applied to this dataset. Python and Minitab were selected to apply many machine learning techniques and visualisations. Applications are compared to diagnose and detect breast cancer. Data visualisation and machine learning techniques are successful in the process of cancer detection and decision-making process in providing significant benefits. The logistic regression model gives accurate results with all the characteristics and the highest classification precision (98.1%), and the proposed approach showed an increase in precision performance. Hence, the machine learning applications indicate the capabilities to open new possibilities in the diagnosis of breast tumour (Muhammet Fatih 2020).

6. Kernel Cobra is a new interdisciplinary learning approach used to classify and solve problems with several predictors. Kernel Cobra is a nonlinear learning strategy as well to integrate any generated number of predictors. Kernel Cobra is based on COBRA algorithm proposed by Biau et al., with combined estimates based on a close prediction assumption in data training. The COBRA algorithm utilised a binary threshold to indicate in which aspects the training data was similar and useful, with generalisation by using cores to very well enclose the needed data. This type of smoothing core results in a more representative weight during each training point that is helpful in making general and final predictions, and systematically, the Kernel Cobra completed the COBRA algorithm.

Although COBRA is representative, Kernel Cobra is concerned with classification and representation. Kernel Cobra is embedded as part of the pycobra, an open-source Python package (0.2.4 and higher), presented by Srinivas Desikan. Numerical experiments were conducted to find out Kernel Cobra's usefulness in real life and synthetic datasets in terms of forecasting and computational power (Guedj and Desikan 2020).

7. Cybersecurity Toolkit, Cybersec TK, is one of the straightforward libraries in Python for preprocessing data and bringing out features of cybersecurity. Due to advanced digitalisation, huge and big data needs to be analysed through automatic access. At present, people working in the field of cybersecurity are using machine learning techniques that help in the processing and analysis of data. But the cybersecurity experts are lagging behind in training to implement machine learning to find out solutions for their problems. Now this problem is solved by formulating a Python toolkit, which is helpful in processing familiar types of cybersecurity data. This will be useful to cyber experts to implement the machine learning process from beginning to end (Calix et al. 2020).
8. Landscape genetics is a part of study that can assist and comprehend a lot of endemic environmental procedures, which requires significant interdisciplinary collaboration. Geographic information system (GIS) software can be used by non-experts with little modification. In order to reach this objective, a number of Python script-based GIS tools are formulated that are helpful in landscape genetics studies. The scripts change the files, represent genetic correlations, and weigh landscape connectivity using low-cost path analysis. The scripts are found in the ArcToolbox and are available for free with Python code. Python scripts allow researchers to make use of common software, which yield more development options throughout the user-free community, and minimise time spent in arriving solutions (Etherington 2011).
9. The dedicative emotion plays a major role in the examination of knowledge as well as one's emotional status. The same principles are utilised in Python technology analysis and optimised artificial intelligence technology. As a type of destination, image research is important for visitors to make decisions and create destination images. Snow and ice tourism is very much wanted nowadays, and research has focused on the concept of snow image tourism. Python programming is helpful to travel online on the Internet on snow and perform ice tours in Jilin State to find out the frequency of commonly used vocabulary; its grouping, especially the lexicon cloud and coexistence networks; and similar aspects of the image. It is used to track the magazines to read the reviews and proceed to emotional perception, emotional reflection, emotional imagery and general image processing. Research in this area found that the concepts related to snow travel images can be divided into five sections: tourist attractions, tourist activities, tourist facilities, tourist features, and tourist service environment. The frequency of tourist attractions is the highest, followed by tourist facilities and tourist service environment. Positive emotions represent 67.23% of the tourist reflections of snow and ice. Passengers gave positive reviews of Changbai Mountains, Taichi Snow View, and facilities of a ski game. In the meantime, critical emotional

outputs constituted 21.07%, and visitors provided continuous assessment of transportation, travel, food, and accommodation. Visitors talked a lot about the overall picture of the snowy trip in Jilin province, but some people were ready to see it again. As a result, strategies are presented to improve the perception of the images related to ice tourism and snow and contributed to their sustainable development (Sun 2020).

3.7.3 Functions in Python

Python functions are a typical instance of such reuse. Therefore, to give out a broad choice of application, from math computing and GUI to web expansion and testing, the interpreter in Python is previously outfitted with many functions that are constantly accessible for usage. And it also adds to other modules/libraries to the program, which enclose predefined functions easily on hand for employment. All its useful functionalities will only be imported into the code. Thus, on one occasion definite, a function could be used umpteen numbers of times at any point in whichever of its codes. Python is used hand-in-hand with the software engineering principle, DRY [DRY expands not to repeat itself], which endeavours to replace any pattern repetition of software code with the thought to avoid idleness and ensure they can be freely used without releasing any inner facts in their accomplishment. This concept of having reusable code blocks is so critical to achieve generalisation in Python. Therefore, to employ a function, name is needed and also its intention and its arguments if necessary in addition to the type of result if it returns any. It is the same as using a car or a phone, where it is necessary to need to understand how the mechanism works. To a certain extent, it is already created to hand out the general principle that can be used directly to achieve the respective objectives and to use the quality time employing every inventive feature of the application agenda. It is quite uncertain regarding how the function performs within their program as long as it gets the job done, which is actually a demerit in terms of technicality in gaining knowledge.

A Python function shall be termed as an integral of the program coded for a single time, and later the same could be run as needed by the program, causing reuse of the code. The function is an applet which works with data and fabricates a few results. To define a Python function, the keyword “def” should be looked for before the name of the function, and braces should be added at the end, followed by the symbol colon. Indentation is used by Python so as to specify blocks in place of braces so that it makes the codes more readable. A Python function shall comprise zero to “n” number of parameters. When we need the function to labour with the variables from other blocks of the code or from the parent program, it could produce results by considering any number of parameters and then come up with the desired outcome. Optionally returned value could also be returned by a Python function. The corresponding value could be an outcome produced by the execution of the function or could of an expression or a specific value that was specified following the “return” keyword. Later, after executing a return statement, the flow of the program returns to the state next to the function call and starts running from that position.

3.7.3.1 Python Operators

There are several operations/operators in Python as shown in Fig. 3.4, such as in other languages, viz. arithmetic, logical, special operators, etc., which are discussed in detail in the following sections.

3.7.3.2 Arithmetic Operators

Basic arithmetic operators such as addition, subtraction, multiplication, and division could be performed easily as in every mathematical package as shown in Fig. 3.5. Simple addition and subtraction are performed as unary operations, whereas in multiplication and division problems, the result could also be obtained as float as done in the case of division in the worked example.

3.7.3.3 Assignment Operators

In the third command (Fig. 3.6), we derive to a point that X = 2 and the same is printed, considering the same value of X and taking the exponential of the same, by the command “**=”, i.e.:

Fig. 3.4 Python operators

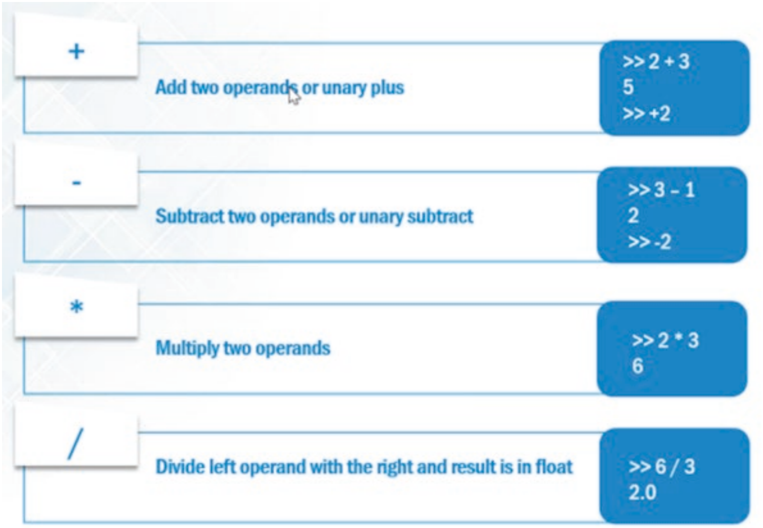


Fig. 3.5 Arithmetic operators

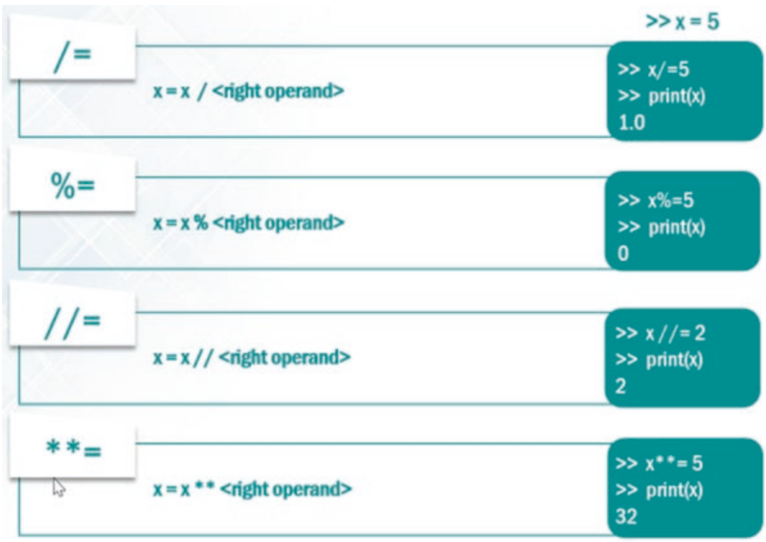


Fig. 3.6 Assignment operators

$$X \wedge 5, \text{which is equal to} 2 \wedge 5 = 32.$$

This is a simple example for assignment operator in Python.

3.7.3.4 Comparison Operators

Considering the left operand (operator) and right operand (operators) as 2 and 3 respectively, in the first case, 2 is not greater than 3. “True” may be printed only if the left operand is bigger than the right, which actually is not the case. Hence “False” is printed.

In the second case, “True” is printed as in Fig. 3.7, because the left operand is actually less than the right.

3.7.3.5 Logical Operators

Three simple gates depicted in Fig. 3.8, such as AND, OR, and NOT functions, could be performed with the help of these Python operators. And it is not restricted only to these gates, but it could also be extended to other gates such as XOR, NOR, etc. But it is sketched in such a way that the symbolisations and other coding differ with respect to basic mathematics and also to other programming packages.

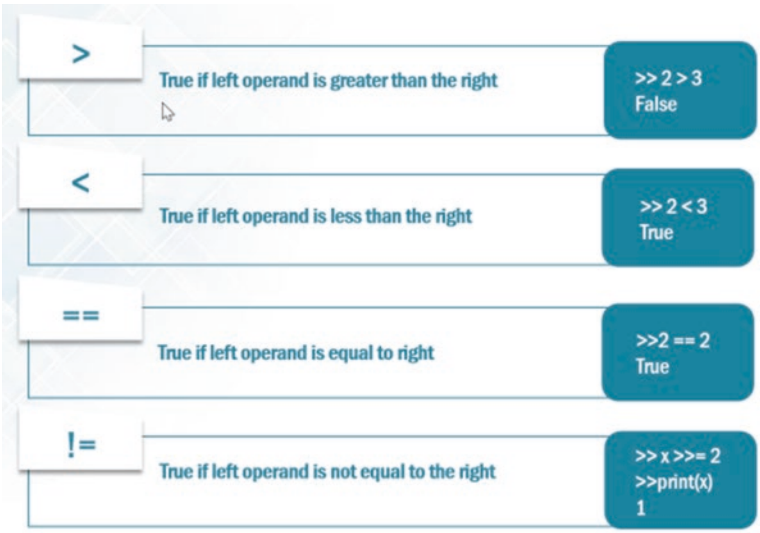


Fig. 3.7 Comparison operators

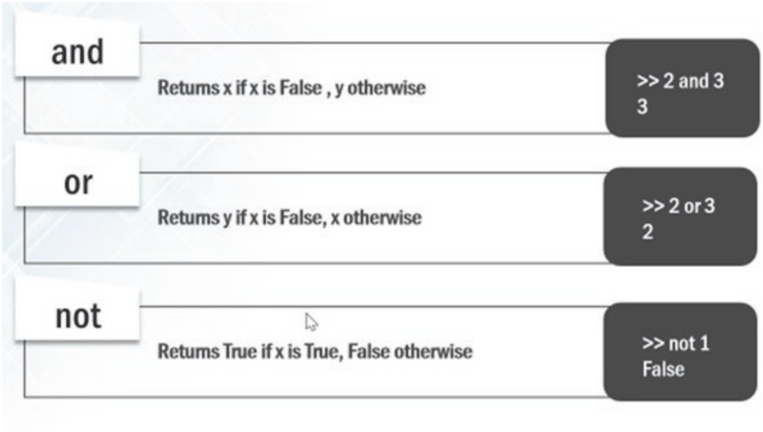


Fig. 3.8 Logical operators

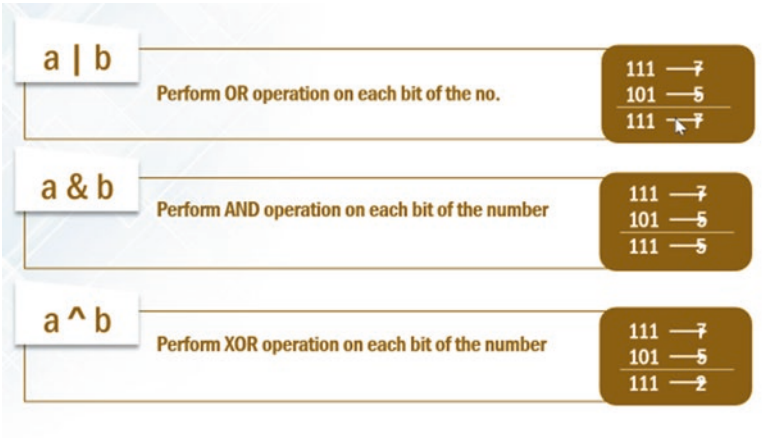


Fig. 3.9 Bitwise operators

3.7.3.6 Bitwise Operators

As the current height in this technological data era has touched yottabytes (YB) equal to 1024 zettabytes (ZB), calculations as simple as bitwise operations could also be performed in Python. An example of the same is illustrated below in Fig. 3.9.

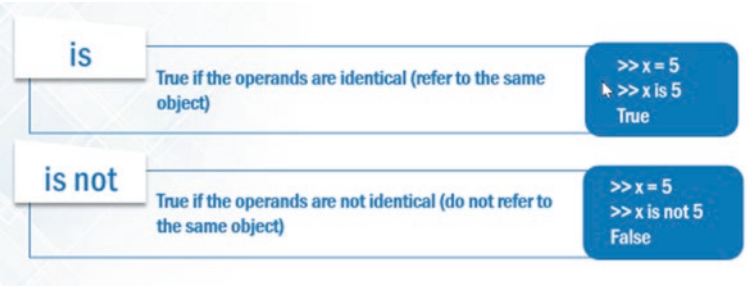


Fig. 3.10 Identity operators

3.7.3.7 Identity Operators

“Is” and “is not” are two basic identity operators which compare the two operands on either side. If both operands “are” identical, it prints True. If both operands “are not” identical, then it is printed as “False” as seen in Fig. 3.10.

3.7.3.8 Membership Operators

In the case of membership operators, we have a set X = {1, 2, 3, 4, 5}.

From Fig. 3.11, we could see “True” is printed in “Is” case because the command “3 in X” is actually true, whereas the result for the Python command “3 not in X” is “False” because 3 is actually an element of X.

3.7.3.9 Data Type

Python is a freely typed language. Hence, there is no urge to actually define the data type of various variables. And it is also not necessary to declare the variables before using the same.

The data types can be broadly classified into two categories (Fig. 3.12):

(i) Immutable
(ii) Mutable

Immutable data types can be further classified into numbers, strings, and tuples. Mutable data types can again be classified into lists, dictionaries, and sets. Then, subcategories are almost self-explanatory.

3.7.3.10 Hands-on Exemplar

The hands-on tutorial is practically explained in this section of the chapter [12] as follows:

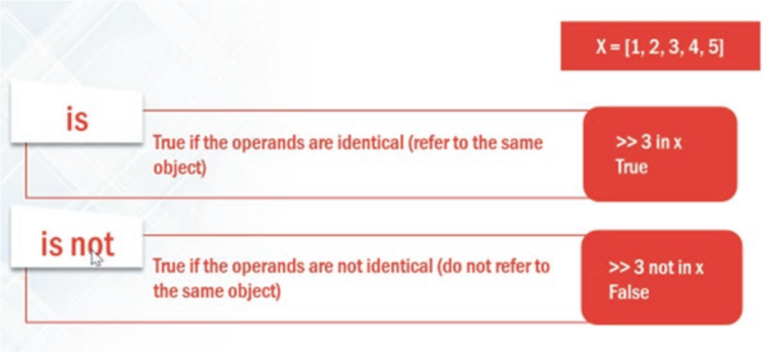


Fig. 3.11 Membership operators

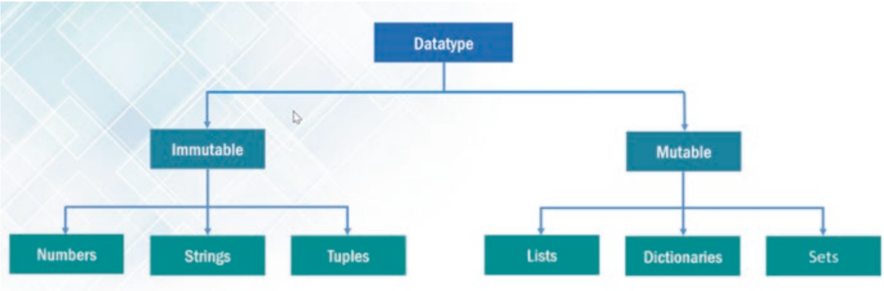


Fig. 3.12 Data type

The required libraries can be called initially (Fig. 3.13) so as to perform the necessary calculations and activities. In this case, Pandas is being called. Later the .csv file, i.e. the comma-separated file named "tips", is also read from the destination.

Two different sets such as student details and mark details are defined in this case initially. It could be of numbers, strings, floats, etc. In "stu_details", three subsets are embedded. And in the case of "marks_details", two subsets are defined. Later, the data frame could be saved, and from then on, it could directly be called as "df".

The student data frame has several columns in Fig. 3.14 such as "stud_id", "stu_name", "region", etc. as shown in Fig. 3.13 corresponding to the three subsets as mentioned earlier.

The marks data frame (Fig. 3.15) has two columns such as "stud_id" and "marks" apart from the serial number as shown in Fig. 3.14 corresponding to the two subsets.

Sales and profit datasets are defined randomly for the analysis of the defined data in Fig. 3.16.

```
In [3]:  import pandas as pd
```

```
In [4]:  pd.read_csv('tips.csv')
Out[4]:
```

	total_bill	tip	sex	smoker	day	time	size
0	16.99	1.01	Female	No	Sun	Dinner	2
1	10.34	1.66	Male	No	Sun	Dinner	3
2	21.01	3.50	Male	No	Sun	Dinner	3
3	23.68	3.31	Male	No	Sun	Dinner	2
4	24.59	3.61	Female	No	Sun	Dinner	4
...	...	...	...	...	...	...	...
239	29.03	5.92	Male	No	Sat	Dinner	3
240	27.18	2.00	Female	Yes	Sat	Dinner	2
241	22.67	2.00	Male	Yes	Sat	Dinner	2
242	17.82	1.75	Male	No	Sat	Dinner	2
243	18.78	3.00	Female	No	Thur	Dinner	2

Fig. 3.13 Importing libraries and reading the file

```
In [14]:  stu_detail = {'stud_id':[1,2,3,4,5],
                        'stu_name':['A','B','C','D','E'],
                        'Region':['N','S','S','W','E']}

In [15]:  marks_detail = {'stud_id':[1,2,3,4,6],
                          'Marks':[30,35,32,36,32]}

In [18]:  pd.DataFrame(stu_detail)
Out[18]:
```

	stud_id	stu_name	Region
0	1	A	N
1	2	B	S
2	3	C	S
3	4	D	W
4	5	E	E

Fig. 3.14 Student data frame

3.7.4 Conventional Programming Vs Python

Considering the previously mentioned sales and profit dataset, the profit ratio could be calculated using both the for-loop usage and Python coding.

In Fig. 3.17, a typical for loop is being used, and thus the profit ratio is calculated after appending. The results are printed.

```
In [14]:  stu_detail = {'stud_id':[1,2,3,4,5],
                       'stu_name':['A','B','C','D','E'],
                       'Region':['N','S','S','W','E']}

In [15]:  marks_detail = {'stud_id':[1,2,3,4,6],
                         'Marks':[30,35,32,36,32]}

In [19]:  stu_detail = pd.DataFrame(stu_detail)

In [20]:  pd.DataFrame(marks_detail)
Out[20]:
```

	stud_id	Marks
0	1	30
1	2	35
2	3	32
3	4	36

Fig. 3.15 Marks data frame

```
In [44]:  sales_us =[3434,3455,3332,2213]
          profit_us =[320,434,223,543]
```

Fig. 3.16 Sales and profit data

```
In [47]:  profitratio = []
          for i in range(0,len(sales_us)):
              profitratio.append(profit_us[i]/sales_us[i])
          profitratio
Out[47]:  [0.093185789167152,
           0.125615050651230l,
           0.06692677070828332,
           0.24536827835517397]
```

Fig. 3.17 Profit ratio using "for loop"

The same analysis is carried out using Python, except for importing the required libraries such as Pandas (called already) and NumPy (Numerical Python) and defining the datasets; the lines of coding required for calculating the profit ratio are hardly one line. In this case, no for loop is necessary. Such is the significance of the usage of Python.

The results after the analysis in both cases are found to be almost exactly same in Fig. 3.18, except the precision in the decimal points.

To find out the square root of a given number (Fig. 3.19), we just have to type np.sqrt(x) which means numpy.square root, which gives the desired output.

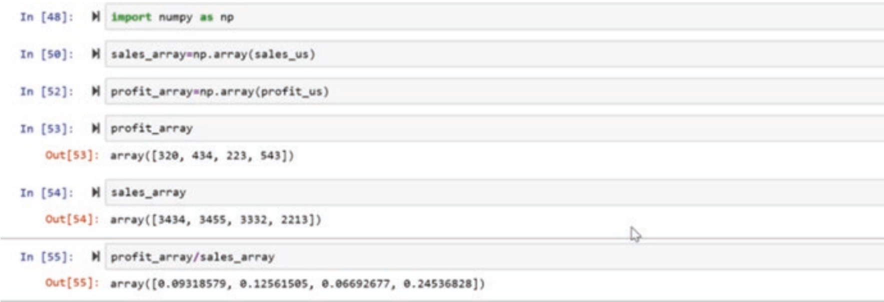


Fig. 3.18 Profit ratio using Python

Fig. 3.19 Built-in commands

3.7.5 Data Visualisation in Python

For data visualisation in Python (Fig. 3.20), a powerful library that could be called is Matplotlib. The command "plt.plot (year,slaes, 'red')" represents "plt.plot (x axis, y axis, color of the graph)".

The command procedure is almost the same for all the three attributes. "plt.title", "plt.xlabel", and "plt.ylabel" could be used for assigning the title of the graph, X axis label, and Y axis label, respectively. In this demo in Fig. 3.21, the X axis is 'Years', Y axis 'Sales and Profit', and the heading of the graph 'Sales and profit over the period of time'. "plt.show()" command displays the graph.

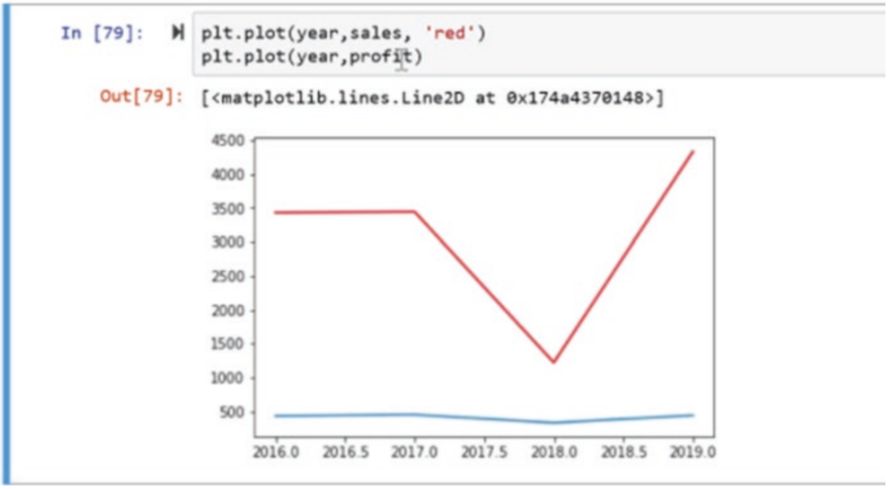


Fig. 3.20 Data visualisation with profit and sales

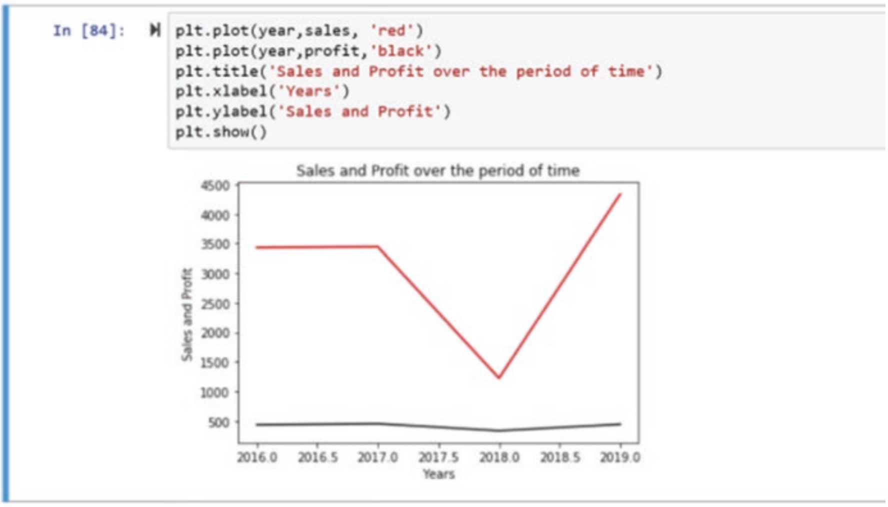


Fig. 3.21 Addition of labels for X and Y axes and title

3.8 Conclusion

The features of Python sustain diverse programming pattern. Also Python ropes process-oriented programming and also object-oriented programming. Codes in Python shall call upon libraries from the C language. It also knows how to invoke from C++ programs. Not only that, but it also can be integrated with Java and .Net components. Programming language like Python has grown leaps and bounds and is almost at its pinnacle. It is vastly used in machine learning, deep learning, and AI environments. Not only that, but it could very well be used in terms of managing sustenance in almost every domain like medicine, automotives, manufacturing, GIS, and also environmental sustenance.

References

Calix, R. A., Singh, S. B., Chen, T., Zhang, D., & Michael, T. (2020). Cyber security tool kit (CyberSecTK): A Python library for machine learning and cyber security. *Information, 11*(100), 1–14.

Drubach, D. (2000). *The brain explained*. Upper Saddle River: Prentice-Hall, Inc.

Eisenberg, N., Fabes, R. A., Murphy, B., Maszk, P., Smith, M., & Karbon, M. (1995 October). The role of emotionality and regulation in children's social functioning: A longitudinal study. *Child Development*, *66*(5), 1360–1384. PMID: 7555221.

Etherington, T. R. (2011). Python based GIS tools for landscape genetics: Visualising genetic relatedness and measuring landscape connectivity. *Methods in Ecology and Evolution, 2*, 52–55.

Ford, D. J. (2011). https://www.trainingindustry.com/content-development/.../how-the-brain-learns.aspx

Guedj, B., & Desikan, B. S. (2020). Kernel-based ensemble learning in Python. *Information, 11*(63), 1–12.

Jaskolka, K., Seiler, J., Beyer, F., & Kaup, A. (2019). A Python-based laboratory course for image and video signal processing on embedded systems. *Heliyon, 5*(e02560), 1–9.

Jin, Y. (2017). Development of word cloud generator software based on Python. *Procedia Engineering, 174*, 788–792.

Muhammet Fatih, A. K. (2020). A comparative analysis of breast cancer detection and diagnosis using data visualization and machine learning applications. *Healthcare, 8*(111), 1–23.

Ortner, M., & Bandeira, L. G. C. (2020). Magpylib: A free Python package for magnetic field computation. *SoftwareX, 11*(100466), 1–7.

Praveena, M., & Jaiganesh, V. (2017). A literature review on supervised machine learning algorithms and boosting process. *International Journal of Computer Applications, 169*(8), 0975–8887.

Raschka, S., Patterson, J., & Nolet, C. (2020). Machine learning in Python: Main developments and technology trends in data science, machine learning, and artificial intelligence. *Information, 11*(193), 1–44.

Sun, G. (2020). Symmetry analysis in analyzing cognitive and emotional attitudes for tourism consumers by applying artificial intelligence Python technology. *Information, 12*(606), 1–23. https://www.edureka.co/blog/python-functions.

Tomlinson, J. E., Arnott, J. H., & Harou, J. J. (2020). A water resource simulator in Python. *Environmental Modelling and Software, 126*(104635), 1–18.

Chapter 4
Inclusiveness: Neuroscience Behavior in Teaching and Learning

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4.1 Introduction

4.1.1 Knowledge or Education? MCQ or PBQ?

What is education? It is often believed that education is going to school, having regular attendance, concentrating on lectures, reading in the library, going through latest articles and journals, collecting data from various resources, learning, remembering, reproducing at appropriate occasions, framing answers in legible handwriting, and scoring good marks. Of late, I see educationists emphasizing too much on moral values in education!! Is education a mere source of gaining knowledge, a moving computer which will help one to earn money? Or is it a process of imbibing moral values in life?

Education should help develop wisdom, not only build up knowledge or moral values. Education is not only a conduit for earning one's livelihood but a process which makes one happy. If mechanically fed data and an overwhelming amount of information are considered education, then our smartphones and laptops should be considered as the greatest universities!! In other words, Internet search engines can provide comprehensive data within a fraction of a second, and we do not need human beings for that. Education should definitely improve knowledge, because knowledge is power and knowledge develops wisdom. Wisdom will inculcate the ability to solve problems in life and help us live with happiness.

That is why instead of long question, short notes, and multiple-choice questions (MCQ), it is better to give problem-based questions (PBQ) to students. This will help students apply what they have been taught in a subject to realistic scenarios, in

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order to reach a solution. After all, knowledge is not the recollection of facts but application of such facts to real-life scenarios.

4.1.2 Care or Scare?

Students should have the ability for critical thinking and decision-making. They must be wise and not become mere data storing servers! When this approach is embraced in a society, a doctor would be able to successfully treat and cure most of his patients, a lawyer would be capable of getting justice for his clients, and an engineer's project would be almost flawless.

Unfortunately, we are living in a world that is in contradiction to the above ideal. It is often seen these days that when a patient visits a doctor for the most minor afflictions, the doctor would suggest multiple treatments that the patient must undergo and a list of medications, regardless of whether it is required or not. But the wisdom of the doctor should adopt a medical policy, that is, "Cure rarely, care mostly and comfort always."

If you go to a lawyer with a family dispute, he will exaggerate the situation, promise you the moon, and go ahead with engaging the endless legal procedure. However, the wisdom of the lawyer should be in adjustments and arbitrations.

In the classrooms, teachers read a hundred slide PowerPoint presentation, which the student will not understand. Furthermore, teachers insist that students join tuition classes in addition to their regular classes, without which it is unlikely that they pass their exams.

Doctor wants to have more diseases and patients, lawyer wants to have more disputes in the society, and teachers want to encourage tuition centers. Basically, we live in a society where everyone has knowledge *but uses it to scare rather than care!*

4.1.3 Indian Students Are Deprived of Technology

In the twenty-first century, technology and education go hand in hand. It is believed that students of a developing country like India are comparatively less exposed to technology. However, there are multiple media reports showing the technological exposure of our students and investment on technology by private and public sectors.

There are numerous technologies being sold to educational institutions. These include GPS tracker to track the school bus route, biometrics for efficient and convenient identification, cameras focusing on students' faces to monitor whether they are paying attention, maintaining students' academic records digitally and sending them to their parents every day, etc. These have become an integral part of educational institutions. However, despite these technological advancements, it has been psychologically proven that the best way to help a student focus on his academics and ward off distractions is through a simple phone call that he/she makes to his mother every day. The best example is the EDUSAT program, wherein all learning resources for rural schools provided through satellite education failed miserably in Karnataka, basically due to lack of inclusiveness.

Inclusiveness is the most important technology for involving the students in teaching and learning. Faculty should focus on interactive teaching methodology rather than showing the same old PowerPoint presentations to students. We insist on attendance. Who is responsible if students do not attend the classes? Students have come to learn. They will definitely attend useful and interactive classes than one-way lectures. It is unnecessary to be very strict with the attendance. Teacher-student interactions establish positive vibrations. The coronavirus global crisis has taught us an important lesson. All students are at home and attend online classes. An interactive methodology of teaching named "answer first discuss next" or GRASP (see Best Practices) is very popular with students.

Inclusiveness and interaction are much more important than technological instruments.

4.1.4 Teach to Learn, Not Only to Earn: Teach for Yourselves!

Insecurity and competition are the two issues I observed in higher education, especially in professional schools. I would like to give two examples which I have witnessed personally:

There is a high rate of failure of local students in postgraduate medicine exams!! Many examiners, who are practicing in the same region, have an insecure feeling about the rising competitors in the same field of specialization, especially when they feel local students will pass the exams and practice in the same locality as consultants. Usually, the bright students from the same place are made to fail at least once, mainly to avoid the competition.

The other example is teaching by senior consultants; when junior consultants are around, they are biased in teaching and training the students. I have seen reputed radiologists who will read and interpret medical reports behind closed doors! The senior surgeons will not allow competitive junior surgeons to help them, fearing competition. Meanwhile, I have worked with great teachers like Dr. Leonard Swischuk, who was my teacher in the University of Texas, Medical Branch, at Galveston (UTMB). He not only used to read the images in the corridor in front of students and junior faculty members but also showed each and every academically interesting case. This should be the attitude of great teachers.

It is quite common to find people with insecurity in every profession, especially when a fresh batch of juniors is joining the team. Insecurity neither reflects our strengths nor is related to our happiness. A junior will not remain incompetent because you have not taught him; instead, I have seen insecurity and competition working against a senior, as the junior will take it as a challenge and learn much more through other resources. It is better to teach him and be eternally grateful for creating a well-rounded individual who can serve society. Learn to deal positively and gain from it.

Good things will always come back to you! And as you teach, you learn more.

4.1.5 Come Out of Inferiority Complex

Another issue that we see often as educators is the feeling of inferiority. As of now, students are more technologically equipped compared to teachers. They are more techno-savvy to prepare their assignments, study, and research. Some teachers, however, are not receptive to such use of technology and staunchly believe in the idea of "old is gold." It is absolutely imperative that such an approach is rejected; a senior teacher has the wealth of knowledge, experience, and values, while a student is equipped with the knowledge of technology. Rather than the teacher feeling like he/she is on the back foot, he/she should embrace the knowledge he/she lacks with respect to technology from a student, so that together a comprehensive teaching can be delivered.

COVID-19 is the perfect example of how teachers, both old and young, enthusiastically embraced technology in order to teach students online.

4.1.6 The Subject I Teach Is Not Important; Students Do Not Respect Me!

In every field, there are certain subjects that are given more importance over others. This occurs due to various considerations, the economic viability of pursuing a particular subject, the scope for further studies, etc. There always exists a certain preference that is given to certain subjects or courses over others; this preference is highlighted not only by students but the educational institution as well when it comes to grading subjects or the weightage of marks given to certain courses or electives.

The problem arises when faculty teaching courses, which are not considered "essential" or "lucrative," feel that they are given less importance by their students. It is only natural to feel this way. However, a teacher must understand that every course or subject is important; this is the reason why the subject is part of the curriculum in the first place. These subjects are required to provide a comprehensive course. Hence, the responsibility lies on the teacher to make students understand the subjects' importance and not disregard. Make them understand that the subject is the stepping stone for the student to gain complete knowledge of the course. Make classes interesting and interactive as discussed earlier. There is no need for teachers teaching accessory subjects to feel inferior but rather to make themselves understand the importance of their subject so they can impart the same to their students.

Remember, the subject may be inferior or superior, but the way we teach should never be inferior.

4.1.7 Every Child Is Born Genius, Goes to School to Become

Indigenous work of the students must always be encouraged. Do not interfere, guide them, and see that they are in the right tract. The child is always inquisitive and has an innate capacity to innovate. We as faculty restrict them to classrooms or some fixed textbooks. Respect the ideas of the students and motivate them.

We often come across situations especially in the case where students have to choose a topic to pursue their thesis, where teachers reject topics because of lack of literature on the topic. Teachers also reject topics when there is too much literature available, thus not requiring the student to carry out a thesis on a topic that is already well researched. Here the student is faced with a dilemma, a topic that has few references, a new and innovative topic, and hence a lack of literature available. Students themselves are apprehensive of pursuing such a thesis, as it requires extra effort and dedication from the student's end. Thus, when a student has made up his/her mind to pursue such an issue, it reflects his/her passion for the subject and dedication to learn more about it. Teachers must encourage such initiatives as it helps not only the student but the teacher as well to learn something new, and in the end, this helps academia as a whole.

As APJ Abdul Kalam said "Children should be taught how to think, not what to think".

4.1.8 No Examination, Focus on Regular Assessments!

The frequent complaint is students focus only on scoring marks and are not interested in research and innovation. The apex bodies, like UGC, MCI, and AICTE, have designed the curriculum such that the students do not have time to do research or innovate. There are whole-day classes, 6 days a week, assignments, homework, and preparation for regular exams. The syllabus is complicated and vast. Students need to reserve long hours to study because of the rat race to score good marks. With this kind of a busy schedule, assigning time for research is almost impossible.

A curriculum to motivate our students for research and to stimulate the innovative thoughts is the need of the hour. All sorts of examinations should be restricted. There should be regular assessments during each class. Marks or credits should be given for hands-on work done (skill-based projects) and innovative concepts (research). Induct the students as working robots and research scholars, not as theoretical computers. The data is readily available online; students need not remember everything. The faculty should create an atmosphere of research and research mindset among the students. Encourage them to take up good research work, respect their investigative mind, and allocate enough funds directly to their account to innovate and discover.

Instead, faculty members utilize students' time and energy for their own research. They are keen to see their names in the student research and publications. A great teacher is one who puts the student's interest and work above everything else. Instead of counting on faculty research for promotion, etc., apex and management bodies should insist that all research publications from academic organizations should compulsorily have the student name as the first author! Educational institutions should be student-centric.

4.1.9 Do Not Preach; Be a Role Model

There was a school trip in a bus. The students were busy with their smartphones, all faces looking down. But one student was just enjoying the trip and scenery outside. The father of this student was asked how come his son was not addicted to the mobile phone. The father said "we parents do not watch mobile phone too much and use it only if necessary!"

The children look up to their parents at home and teachers at school. The faculty should be role models to their students. Hence, their character and behavior influence the pupil to a great extent. Students learn faster and more effectively, observing the actions and behavior of their elders and teachers. When we expect students to be truthful, obedient, honest, etc., we ourselves must be truthful, obedient, and disciplined and must respect all.

It is often said "Our teachers have diarrhea of suggestions but serious constipation for implementation."

There is an interesting incident between a father and his 9-year-old son. The father used to preach all the good things to his son "Satyam Vada, Dharmam Chara" (meaning "Speak the truth and do the right thing"). One day, when both were at home, the phone rang. The son answered the call. It was from the bank manager enquiring about the payment of a pending monthly installment of the loan. The father asked his son to tell the manager that he is not at home. The boy literally followed his father's words and told the manager "Father told me to tell you that he is not at home." This incident was really an embarrassment and an eye-opener to the father, who always insisted to speak the truth and do the right things. After some time, the father took his son to a zoo and asked for two tickets. The ticket vendor told him that one ticket is enough as entry was free for children below the age of 9. The father said his son is more than 9 years. The vendor said that he could not have made out that the little boy is more than 9 years. The father answered proudly, "yes you cannot make out, but my son knows he is more than nine years." This is the truthfulness one should follow always. These small instances will have a deep impact on children's minds throughout their life.

4.1.10 Credits for Wrong Answers!

"Our students do not have confidence" is the most common complaint. Why? At the end of the class, when the teacher asks "Are there any questions?", no one will get up to ask questions. "Please raise your hands if you have not understood"; no hands will come up. "Raise your hands if you have understood", no response again. How to solve this problem? I was trying my best to find out the cause for this attitude of the student's and solution for the same. I got a fairly good answer during this coronavirus crisis when conducting online teaching programs when I saw almost every second a student raising questions in the chat box.

Traditionally, when a student gives a right answer, we praise him/her a lot, and when he/she gives a wrong answer, most of the times, he/she will be insulted or humiliated in front of the whole class. I have encountered several incidents where the teacher is upset for not getting right answers for simple questions and starts yelling at the student and even uses nasty comments. This will not achieve anything; instead, the student will lose his/her confidence and self-esteem and develop hatred toward the subject and the teacher. It will create fear and make him/her nervous. Subsequently, he/she will hesitate to stand up and answer, even though he/she knows the right answer. An environment where the students can answer, ask questions, and express their views fearlessly should be created.

The teacher should respond positively for wrong answers with empathy. Who is responsible if the student gives the wrong answer? I feel the faculty is equally responsible. Instead of dismissing the wrong answer given by the student directly, accept that as your own mistake; try to understand how he/she arrived at the answer. Give credit for his/her effort and explain patiently where he/she went wrong. Praising, not scolding, is a better classroom behavior.

If a student answers wrong, it does not mean that he/she is stupid or useless. Remember, the faculty does not have the license to insult a student. If a picture of a tiger is shown and the student says it is a cow, the teacher should not be upset because it is nothing but a reflection of the standard of his/her own teaching!

All answers from the students should be accepted and respected. Never insult the student for wrong answers. Instead, reward the student for the effort he/she has put in to arrive at the answer. The teacher's role is to teach, inspire, and boost the confidence of students to answer fearlessly. I have gone to the extent of rewarding them for wrong answers also. But remember the two most important things: *they are not intentional and not repeated.*

4.1.11 Psychology More Important Than Pedagogy: Teach with Love and Affection, Not with Grit and Punishment

It has been acknowledged by researchers that there is a triangular relationship between the teacher, student, and content. These are crucial for learning and there is no pedagogy better than psychology.

The best pedagogy in education is to understand the student's psychology; the best psychological technique is to love your students, and the best way to love your students is to know your responsibilities as a teacher. This attitude of the faculty will make our students wise and responsible citizens. We must realize that scoring high in examinations is not the only path to success. There are many instances where last benchers and school dropouts have succeeded beyond expectation. In fact, there are a number of successful scientists, innovators, discoverers, and business tycoons who are school dropouts and still have succeeded well in life, the greatest example being Thomas Alva Edison. (The reverse, however, is not true, and all school dropouts need not be successful!)

Teachers have the most important role to nurture students' innate capacity to understand and learn. Learning is a slow process and is neither immediate nor linear. Though learning is fun for some, there are inevitable moments of frustration and hurdles to overcome that can lead students to crippling self-doubt. At times, a social, political, and cultural context constantly sends false messages.

4.1.12 How to Have a Loving Relationship with Students

First of all, teachers should love themselves and should not have any inferiority complex. Second, they should love their profession. Once in the teaching profession, teachers should feel that they have selected that profession by choice and not by default and not because they could not get into Medicine, Engineering, Law, Economics, Management, etc. When they start working, they should have a feeling that they are manufacturing the building blocks of the nation in the form of good students, just like the stonecutter who said, "I am building the temple" (Chapter II, 4, three stonecutters). Another thing is teachers should not expect any credit from students. These two things will enable the teacher to have an affectionate relationship with the students. Great teachers continuously keep learning, constantly update their knowledge, and keep improving their communication and teaching style. At the same time, they should inspire and motivate students unconditionally.

What is the connection between the work efficiency and functioning of the human body? What is the relationship between work and the biological behavior of the human cells? What is neuroscience behind love, affection, and confidence? Let's discuss in the next section.

4.2 The Aspects of Bioscience, Neuroscience, Research, and Spirituality

Teachers may have one question: why should I teach and pass on the entire knowledge to my students? Doing our work or fulfilling our responsibility has got direct relationship with the health and happiness. This can very well be explained by analyzing the human development from single cell stage and the most complicated structure of each and every organ in the human body and studying the function of each and every cell in the human body. Every microscopic component of the human body exists basically to do the best. The bioscientific nature of the human body and the neuroscientific concepts, along with science and spirituality, will be described in this section.

4.2.1 Give-and-Take Aspects of Bioscience

Usually, we strive hard and do many things to enhance our health: healthy eating habits, eating lots of fruits (monkeys should not have any disease!), drinking lots of water (fish should never die!), taking long morning walks, and doing lots of yoga and meditation. Of course, teaching is a profession that calls for an immense amount of patience and requires a balanced mind.

However, the satisfaction of conducting a good class for the students results in a chain of positive reactions in the human brain, for example, the secretion of "feel-good" hormones especially serotonin. It also results in overall social development. "Give and take" is the ultimate secret of genuine success, good health, and happiness. The best example for this is the episode of "Samudra Manthan, the churning of the ocean of milk," in *Bhagavata Purana*. The Samudra Manthan explains the origin of Amritha, the nectar of immortality.

4.2.1.1 Churning of the Ocean of Milk

The Gods, who had become weak because of a curse by the short-tempered sage Durvasa, invited the asuras to help them to recover the potion of immortality, the Amritha, from the depths of the cosmic ocean. Mount Mandara was used as a churning stick; Vasuki, the giant serpent, was used as a churning rope. The mountain was steadied at the bottom by Vishnu in his avatar (incarnation) as the tortoise Kurma. In the churning of the ocean, many wonderful treasures that became the prototypes for their earthly and heavenly counterparts were brought up from the depths. The Gods and the asuras started fighting to eat the celestial food. The Lord Vishnu advised them to sit and consume it. He offered the asuras to have it first but with a condition that they cannot bend their arm while eating it. The asuras agreed and sat in front of the food. But they realized that they cannot eat without bending their arms. Next, it was the devas' turn. The devas sat with their food, opposite to each other. They started feeding the devas sitting opposite to them so that they did not have to bend their arms. This is a great example of give and take. This instance explains the best how one can get benefitted by serving others.

4.2.2 Students Are Very Intelligent and Learn on Their Own: What If I Do Not Teach? Be Ready for the Punishment!

In 1946, the special group of the WHO Executive Board (1998) proposed that the Preamble of the Constitution should be amended to define "health" in the following manner: "Health is a dynamic state of complete physical, mental, spiritual and social wellbeing and not merely the absence of disease or infirmity." However, in the author's opinion, health is nothing but working and carrying out one's duty. One who gets up in the morning and goes for work is healthy, even if he/she is harboring many diseases. One who does not have interest to do his work is unhealthy, even if he/she is not suffering from any disease.

To understand this, one should have basic knowledge of the human body. The human body is made up of minute fundamental units called cells, which in turn contain organic compounds, nothing but mainly carbon and hydrogen. There are roughly about 100 trillion cells in our body which are categorized into around 200 types. The red blood cells (RBC) are the most predominant. Interestingly, human cells are not the only cells in our body. There are more than 50 trillion microbes, such as bacteria, present in the body. Hence, there are more foreign cells than native cells. Human health depends on the balance between the strengths of human and foreign cells. When the human cells become weaker, the foreign cells will take the upper hand and cause diseases.

The lifespan of each of the 200 types of cells is different. Various types of cells are produced at different rates. For instance, RBCs are produced every day and live for around 120 days. After that, macrophages in the spleen and liver remove RBCs from circulation. Simultaneously, specific stem cells replace the dead RBCs at approximately the same rate. Most of the cells in our body will sooner or later die and be replaced. A healthy human body is capable of maintaining a precise balance between the number of cells produced and the number of cells that die. For instance, our body produces 173 and 259 billion RBCs each day, and roughly the same number of RBCs will die.

It is quite difficult to find out exactly how many cells in the human body die every day. Red blood cells live for 120 days, white blood cells for a few hours to 13 days, and liver cells up to 18 months, and brain cells will stay alive throughout a person's life. The balance between the production and destruction of human cells decides the health of a human being. If there is more destruction than production of new cells, it results in disease condition.

Hence, the human health depends upon two things:

1. Fight between the strengths of human and foreign cells
2. Difference in the production and destruction of healthy cells

Researchers also have found out that when the human body is active, lots of good hormones are produced; the native cells are stronger and are continuously replenished. Hence, there is a strong recommendation that one should keep working and should not take retirement so that his/her cells are active without any diseases. If the human body is lazy and lethargic, the foreign cells will take the upper hand over the native cells, and this may cause diseases easily. Hence, the working body is healthy, and the lazy body is prone for all diseases. Most of the statistics in the present COVID-19 infection crisis also proved that the fatality ratio is more in lazy and lethargic people rather than active people. The dreaded diseases like cancer spread to almost all organs except the heart and skeletal muscle, basically because they keep working continuously.

4.2.3 Punishment for Not Doing One's Job: Is There Any Proof? Facts on Acidity and Gastritis

Gastric (peptic) ulcers affect 25–30% of the world's population. The patients will suffer from heartburn, abdominal pain, and left chest pain and gastroesophageal reflux. Often, it is confused for heart attack, and patients undergo various tests including angiography and stenting. The cause is excessive secretion of hydrochloric acid in the stomach. (A type of bacteria called *Helicobacter pylori* (*H. pylori*) is the most common bacterial cause of gastritis. Robin Warren and Barry Marshall, pathologists from Australia, discovered that gastritis and peptic ulcer are caused by infection of the stomach by the bacterium *Helicobacter pylori*. They were awarded the Nobel Prize for Physiology or Medicine in 2005. The author has mentioned the bacterial cause below.) The nerve which stimulates the secretion of acid in the stomach is called the vagus nerve. It arises in the brain and branches along the surface of the gastrointestinal tract. Vagotomy or cutting the nerve by a major abdominal surgery was the most important type of treatment for gastritis in the 1980s. The same nerve is also responsible for peristalsis or the emptying of the contents of the stomach into the small intestine. Hence, along with vagotomy, one more procedure was also done to prevent hold up of food in the stomach. This surgery is called gastrojejunostomy or connecting the stomach directly to the intestine. Hence, vagotomy with gastrojejunostomy was the main treatment procedure for heartburn for many years. The benefits of this surgical procedure were very limited, and patients used to suffer with various side effects because of the non-functioning of the important vagus nerve and also by direct connection of the stomach with the intestine.

Later, it was discovered that it is not the vagus nerve but the microbes in the stomach which are responsible for the heartburn. The stress, tension, and other behavior of the human beings suppress the normal cells, especially the cells which provide the protective mucosal coating called mucin. The research also showed that the microbe, *H. pylori*, in the stomach becomes stronger and causes damage to the surface of the stomach. The research has clearly proved the fact that the discrepancy in the strength of human cells and microbes is responsible for many diseases, including peptic ulcers. For the last 30 years, the need for major surgical management of this condition has greatly decreased. Antibiotics to treat *H. pylori* and antacid tablets cure most of the hyperacidity diseases. But in people who do not do their work, this disease persists.

Who is my enemy? I searched everywhere. Finally, I found out! My enemy is within me and he is called laziness. Absence from work activates the bacteria and viruses within the body. Activation of bacteria and viruses within the body causes more diseases than microbes from outside. That is why most of the diseases are endogenous than exogenous.

Doing one's duties and responsibilities is of utmost importance for health. Health is not a status of feeling; it is a status of working. It is not the status of matter; it is a status of energy. Living organism is a combination of matter and energy. Our eyes can see only the matter or the physical body, and we keep worrying about it. We unnecessarily keep worrying about the food we eat, the water we drink, and the exercise we do. The energy is the most important part, but it is not seen by the human eye. Energy expresses itself as a function. Hence, everyone should see that they function well. Anyone who functions well is healthy, even if he has any mental problems, diabetes, hypertension, cholesterol, depression, stress, anxiety, or anything from common cold to cancer. One who is ready to work after getting up from bed in the morning is healthy, and one who does not is unhealthy.

Research work on absenteeism due to sickness is carried out for several years. Studies are often based on explanatory models addressing the causes of absence at the workplace. I have observed a beautiful correlation between work efficiency and absenteeism. Very efficient workers in the factory are hardly absent because of ill health. Those who are 60–80% efficient take leave sometimes with minor complaints like common cold, whereas employees with 50–60% efficiency often suffer more diseases like headache, backache, etc. Well, those with less than 50% efficiency frequently suffer from major illnesses like ulcer, disc prolapse, heart, and other body ailments. Hence, there is a strong relationship between work efficiency and health.

4.2.4 What Is Happiness? Money, Power, Charity, or Sacrifice? The Three Stonecutters

Several years ago, a traveler going around India came across a beautiful place, where a temple was being constructed. He saw a few stonecutters working there. So far, he had seen only machines cutting the stones and not humans performing such a strenuous job.

Curious to know what the workers were feeling about their job, he approached the first worker. The cutter was just looking around; his whole body was sweating; there were wrinkles on his forehead. He had just finished about 40% of the job and 60% was still pending. The traveler asked, "What are you doing?" The worker responded quickly, "Can't you see? I am cutting stones. I must have done some sins in my last life. This life I am born as a stone cutter. This is my Karma. Do not disturb me."

The traveler asked the same question to the second worker. The second worker paused for a moment and replied, “I am a stone cutter, trying to make enough money to support my family by cutting the stones.” The cutter was focused but looked tired; he had finished about 60% of the job and 40% was still pending.

Having two different answers to the same question, the traveler approached the third worker. He was cutting the stones with ease and comfort, he had finished almost 80% of the job, and only 20% of the uncut stones were there. His body was at ease and comfort, his lips were humming a soft song, and his head was shaking rhythmically. He looked content. The traveler asked him, “What are you doing with these stones?” Without stopping the work, with the same rhythmic movement of cutting stones with chisel, the worker smilingly looked at the traveler and replied, “I am a stone cutter; you see there, the temple is getting constructed. So lucky I am! Cutting stones with my own hands and building the temple!”

All three stonecutters were doing the same job. But the one who works cursing every one including his/her past life will never be healthy or happy. I am sure as stonecutters all three will get the same salary, unless the owner gives incentives for better work efficiency. Certainly, the worker with greater output in an organization will have better reputation and respect. The workers who keep escaping their responsibilities with hundreds of stories need to salute every one for their survival, as the great Dr. Abdul Kalam has quoted:

> If you salute your duty, you need not salute anybody, if you pollute your duty, you have to salute everybody.

4.2.5 Is My Heart Beating Properly? My Experience!

As a radiologist, I conduct many scans and routine healthcare services regularly. I do see a lot of people approaching me for health issues. Most of them are related to diabetes, blood pressure, obesity, or general well-being. Several months back, a lady came to my office and kept her health report card in front of me. There were numerous test reports on blood, urine, and liver function tests, showing the level of various liver enzymes and functioning of other organs. After some time, anxiously she asked me, “Doctor, is my liver working fine?” I simply asked her “Are you working well?” She was surprised. I told her that if she works well, her brain, heart, liver, kidney, and all other organs will also work properly, and there was no need to conduct so many medical checkups!

Remember, teaching is our primary duty; we should teach and do justice for our profession. In-depth study and preparation, before each and every class, are much more important than morning jog, exercise, etc. We eat, take rest, sleep, walk in the morning, do yoga and meditation, and others to do the best in our jobs. We should be fit to do our work, not work for fitness! Consider your teaching job not just for earning but doing it as your responsibility, which will give you good health and ultimate happiness.

4.2.6 Who Am I? The Body? Mind? Or Consciousness?

We all know that the heart plays the role of a pump in the body. It is an amazing organ which pumps oxygen and nutrient-rich blood to all parts of our body to sustain life. This fist-sized powerhouse beats (expands and contracts) around 72 times a minute, 100,000 times a day, 3,600,000 times a year, and about 2.5 billion times during a lifetime. A normal heart pumps about 7500 liters of blood per day. From the heart, blood flows through 60,000 miles of blood vessels, the smallest vessels called capillaries, every day. Blood contains cells called red blood cells (RBC), white blood cells, and platelets. There are five million RBCs in 100 ml of blood; each RBC's diameter is 7.2 microns. These RBCs pass through the smallest capillaries which are sometimes less than the diameter of these RBCs. Just imagine the power or capacity of the heart to pump blood through all these small capillaries.

The energy of the heart is sufficient to drive a truck 20 miles every day. In a lifetime, it is almost equal to driving to the moon and back. This wonderful little pumping engine that we carry in our body runs without cessation till death. Even though its function involves all the principles of hydrodynamics, it is beyond anybody's wildest imagination to think such an engine is within our chest.

Finally, it is understood that the heart is not pumping the blood but sucking power of each and every cell in the human body. The analogy is the same as a big banyan tree. The water deep beneath the soil reaches each and every tip of the leaf several meters above the water source. The cells which work more suck more blood, and the cells which work less suck less blood. That is why, when there is an injury to the finger, it becomes red as it draws more blood for the healing process. The heart never pumps, but the working cells extract blood from the heart. The heart just operates as a junction, segregating the pure and impure blood.

It is not the heart which is pumping blood; it is the working cells which extract blood and oxygen. Moreover, we do not have any control on the functioning of the heart. We have control over the skeletal muscles of the arms and legs. The mechanical action of the skeletal muscles while working is very essential for proper functioning of the heart. Ultimately, there are microscopic pumps in each and every cell, called the sodium potassium pump, which controls the health of each and every cell in the microscopic unit of all organisms.

4.2.7 How the Human Brain Works Is Still a Question

Our body houses nearly 200 billion nerve cells called neurons, millions of miles of linear thread-like structures called axons, and 500 trillion connections between these axons. Till today, nobody is able to explain exactly the concept of consciousness and how we receive various sensations and build perceptions out of these sensations. No one could describe precisely the origin and extent of emotions and our ability to make judgments. No one knows which part of the brain drives confidence, motivation, and feelings to succeed. Similarly, the points that are responsible for negative feelings like anger, revenge, ego, and selfishness or positive moods like joy and happiness are not known exactly.

Apart from these, there is also a higher mind: soul or soul consciousness, which functions beyond the limits of matter, energy, and mind. These have totally unexplainable effects on human behavior. We call it various names like sixth sense, telepathy, super conscious powers, precognition, retrocognition, past-life memories, or subtle-plane personalities such as ancestors, ghosts, devas, spirits, power of white magic or black magic, etc. These also have a significant effect on our performance.

According to modern physics, it is not just neuronal connections but the chemical transmitters or secretions in the brain that bring about changes. The three main happy hormones are dopamine, oxytocin, and serotonin. When you teach or do some work to achieve or succeed, the hormone dopamine is secreted in the brain. Dopamine gives the feeling of happiness. Oxytocin is secreted when you show love and affection to others. Serotonin is noted in abundance when you serve others. This is backed by scientific research proving the reason for health and happiness of an individual. So "happy hormones" are generated in our body when we do our duty sincerely, show affection to our students, and serve others unconditionally. Remember, these hormones are also responsible for good health and happiness.

Hans-Peter Emeritus is the president of the Max Planck Institute of Munich and succeeded Albert Einstein recently. He realized that there is no matter different from energy. The immense supreme energy is the universal consciousness (or God), and we humans are just a tiny particle of that consciousness, the cellular consciousness. This cellular consciousness is present in each and every cell of human body and comes from hard work, affection, and service.

4.3 Best Practices

Generally, it is easy to give guidelines and suggestions but difficult to implement. It is often said we have diarrhea of suggestions and serious constipation of implementations. We operate on a policy of flurry of suggestions for others. Actions are much more important than advices. Most of the policies in an organization fail miserably by the famous 4D strategy, known as do, defer, delegate, and delete! I would now highlight some of the best practices and action points for an effective education system.

4.3.1 The Most Effective Technology: Call Your Mother!

Medical Education is special and certainly different from other courses. It is one of the toughest; the highest number of breakdown in the USA is in the field of Medical Education. If one can clear medical exams, he/she can clear any exam today. In the

USA, medical education starts after completing college, i.e., after 10 + 2 + 3 years. In India, students enter medical school after 10 + 2, i.e., at the tender age of 17 years, and most of them are quite innocent. For the first time, they have to move out of their homes, depart from their parents, live on their own in the hostels with some unknown roommate, and eat totally different food. Suddenly, everything will be different, on top of that the toughest subject to study, especially dissecting a dead body and studying the complex human anatomy. This also entails a new level of exposure and freedom, which students either use to their benefit or misuse. When speaking of misused freedom, the author refers to bad habits such as smoking, drinking, and taking drugs, which students most often tend to indulge in during this period in their lives. However, there is a simple yet effective solution to ensure students remain on the right track and focus on their academics and building healthy relationships with their teachers and peers.

Before the commencement of the course, the university conducts an induction program, which is attended by both parents and their wards. For the last 9 years, I have given only one important advice to parents. They should call their children every day before going to bed. During the conversation, there should be friendly discussion about general things like the accommodation, food, sports, extracurricular activities, and friends, and they should avoid discussion about curriculum, vision, mission, hard work, success, and career! Believe me this has done miracles. During initial days when mobile phones were uncommon and hence phone tariffs were high, I encouraged parents to speak to their children late into the night as during this time the mobile charge for calls is relatively cheaper. I even contacted mobile companies and requested them to give a special rate plan for "mother and child."

This practice has worked very well with students. It has been noted that there is a significant fall in the number of students getting into bad habits. To my surprise, it has also improved the academic performance of the students. Unfortunately, I do not have any scientific backing for this. But it has psychologically proven that a conversation between parent and child can lead to various positive effects on mental health and overall well-being of the student.

The dynamic flow of energy, the frequency, and the vibration involved in the discussion between mother and child have got a very powerful effect on child's psychology and can do miracles. Every teacher must encourage such a discussion between parent and child to ensure complete development of the students' performance and personality.

4.3.2 Flip the Classroom and Assessment During Each Class: GRASP

Assessment is more important than evaluation. Assessment is to increase the quality and should be done on a regular basis. Evaluation is to judge the quality, done at regular intervals in the form of examination. GRASP (Guidance in Radiology for

Aspiring Senior Postgraduates) is an innovative methodology I use to teach my Radiology students. Later, this has been incorporated to teach all the subjects in the university and is also known as Z to A or answer first, discuss next methodology.

As a teacher, I always used to wonder when and where the higher education students learn the most. Is it during regular classes or during study holidays and exams? Typically, in a year, a student spends around 2000 h in the class (250 days × 8 h) and 600 h studying at home (300 days × 2 h). During study holidays and just before exams, students would spend 300 h on revision (10 h X 30 days). But it has been proven that students have the highest grasping power when they study before the exam as they are able to recollect and remember what they have read in a short span of time.

This made me think what makes students learn and collect data so efficiently during a short span of 25–30 days during study holidays. During exams, students learn faster. So, why not we conduct assessments more often, almost in every class? The assessment need not be always be a paper-and-pen test but can also be a simple question-answer session to stimulate critical thinking of students. It is also helpful for the teachers to know how much the students have understood the topic covered in the previous class before they move forward with a new topic.

All forms of questioning in the classroom are effective. The questioning can be general or open, which are asked to create the inquisitiveness of students. Some questions are being asked without expecting answers as it goes in flow with the teaching and makes teaching interesting. The teacher can question the whole class and not to a particular student by asking "Can anybody answer this?" This will avoid putting one student in the spot and still kindle competitiveness among the students. Open-ended questions inspire students to contemplate beyond textbook-based answers, thus prompting a range of responses. They also help the faculty to assess the students' understanding of concepts.

The best methodology that I found useful and follow in classroom teaching is the "answer first and discuss next" method. It has three components: read, write, and discuss. The students are first asked to study a topic and come prepared to the class. During the class, at least ten questions or images are shown to the students, and they are asked to write the answers. This generally will not take more than 3 min. At the end of the class, I discuss the answers. This methodology is very effective as it makes the students learn beforehand and be attentive during the class, and also the faculty will know about the standard of the students, around which he/she can discuss the topic.

Advantages of Answer First Discuss Next (Z to A) Methodology

A. **For Students:**

1. Enhances self-interest through preparation at home: Students will start studying at home for the next class. Flipping from classroom studies to studying at home, so that students will learn in the classroom rather than merely listen to lectures.

2. Enhances the thinking capacity of the students: As students would have studied the concepts earlier, they invest their potential in thinking out of the box in class.
3. Enhances the writing skills: With the advancement of technology, writing is taking a backseat. So, scripting answers enhances the writing skills of students.
4. Since it involves writing the answer and submitting, the students are relieved from the stress and nervousness of answering in front of the whole class.
5. Easy assessment: Since the complete class takes the written assessment, 100–150 students can be assessed within 8–10 minutes.
6. Finally, allowing students to answer first and discuss later fulfills many of the well-established training skills like critical thinking, before learning, thought stimulation, problem-based learning, case-based debates, involvement, and giving feedback and assessment. Active participation of all students leads to an easy solution of difficult issues.

B. **For Teachers:**

1. Saves time for teacher: Since the students come prepared to the class, it takes lesser time for the teachers to explain the concepts, which in turn reduces their pressure to complete the syllabus.
2. Accountability: The faculty is made accountable. They cannot run the same old routine of displaying PPTs in the classes.
3. Regular preparation by the faculty: The teachers need to come thoroughly prepared to the class as they have to evaluate the students' answers and should even be prepared to answer questions of the students who have come prepared as well to the class.
4. Teacher training programs may not be necessary: Since teachers prepare and come, they will be updated with the current knowledge and scientific advancements. In fact, most of the teacher training programs are not productive. Teachers are known to just mark attendance and disappear.
5. Teaching is more interactive, and the teachers also get to learn from students.
6. They will do continuous assessment of students rather than just evaluating them in the final exams. This will establish a better teacher-student relationship. This will help the teacher understand each student's potential better and provide more concentration on students who need more attention to perform better.

4.3.3 Action Research

Action research is a family of research methodologies that pursues action (or change) and research (or understanding) at the same time. It is generally applied in the social sciences and results in an effective change through the simultaneous process of taking action and doing research that are linked together by critical reflection. The benefits of action research methodology are:

- Enhances the role of research in educational standards.
- By taking up environment-friendly projects, students can contribute to the society and the environment.
- Empowers both teachers and students by more focused and effective research programs.
- Economic and social development.

The actions for better learning and research are:

(a) PLEASE: Higher education students teach in rural schools.
(b) TBRP: Summer camp for rural students in technology centers.
(c) Rural Digital Libraries as Learning Centers
(d) Social Work: Green Graduation – Students graduate with planted saplings, Happy Schools, Adoption of Lakes for rainwater rejuvenation, Adoption of Heritage Centers as tourist hubs.
(e) Healthcare: Telehealth for rural areas, SEVA/service in charity hospitals.

4.3.4 How to Make Students Learn?

Participative Leadership in Education and Social Empowerment (PLEASE), is a project which makes the students to work and learn simultaneously. When one works, he/she learns.

I read and I forget; I write and I remember; I do and I know.

The postgraduate students (Participating Student Teachers: PSTs) in universities will teach their core subject at least for 2 weeks in rural schools. They teach Mathematics, Science, and Computers. The primary aim of PLEASE project is to:

1. Provide quality education to the students of rural schools with cost-effective implementation.
2. Develop leadership qualities in our young postgraduate students by involving them in rural education and rural development.

Long-term achievements of "PLEASE" project are:

1. Solves the problem of shortage of teachers in rural schools.
2. Improves the quality of education in schools by incorporating the core competent students and postgraduate student teachers (PST) into educational projects.
3. Improves teaching skills of PSTs during their learning phase.
4. Inculcates leadership qualities in PSTs at a young age.
5. The participation of young PSTs in rural schools can throw major light on rural education programs.

6. PLEASE will be the first innovative project, in which young competent students will participate in rural education and empowerment.
7. PLEASE can eventually emerge as the most important project for social empowerment. It helps in enhancing the knowledge and teaching skills of rural school teachers and increases the student enrolment in government schools by providing quality education.

4.3.5 Technology Barrier Reduction Program (TBRP)

As the name suggests, Technology Barrier Reduction Program aims to contribute to removing barriers that prevent rural students from exploring their full potential. In this project, rural students will come to the higher education centers to learn during their summer vacation. The students of higher primary school will spend time in the higher learning centers instead of spending money on commercial summer camps. These higher education centers have better infrastructure with vast libraries, well-equipped labs, huge auditoriums, and project centers, where students will get exposure to effective teaching and learning and also higher education students can assist them in this process. The duration could be for 2–4 weeks. Universities can conduct this program for 2 weeks and provide accommodation and food to the students. Many NGOs sponsor this program for students. Students who want to pursue engineering will spend time in technical institutions. Children who are interested in medicine will learn in medical colleges, and those who are inclined toward research will learn in science centers.

4.3.6 Rural Digital Libraries

4.3.6.1 Digital Learning Facilities in Rural Public Libraries

Introduction There are many public libraries in Karnataka. The town and village Panchayat libraries are in planned locations, which are accessible to most of the rural students. Nevertheless, these libraries mainly stock hard copies of books and other learning materials which are outdated and are not of much use to present computer age students.

Digital library is a modern platform to access library resources in a very fast and efficient way. Availability of these resources will encourage students to undertake self-study at any time. Any student who wants to learn more about a topic taught in the class can access unlimited resources available in the library. Students can study till the thirst for knowledge is quenched. During exam times, the same material can be accessed by multiple students without any hassle. Libraries should to be equipped with computers, connected to a server that is loaded with teaching materials preferably for students from 8th to 12th grade. The higher education students could spend their weekends teaching these rural students.

Advantages
1. Libraries are central places for learning.
2. Accessibility to all students.
3. Self-study undertaken by students.
4. No compulsion as in classrooms.
5. Round-the-clock availability.
6. Information retrieval is easier.
7. Students need not depend on teachers for information every time. Hence, less burden on teachers too.
8. Unlike traditional classrooms, students can pursue their interests here.

Here are the few ideas for social work that can be introduced for students in institutions:

- Green Graduation: Students graduate with planted saplings.
- Adoption of lakes for rainwater rejuvenation.
- Adoption of heritage centers as tourist hubs.
- Healthcare: Telehealth for rural areas and SEVA/free service in charity hospitals.

4.3.7 Green Graduation

"Green Graduation" is a novel initiative by Sri Siddhartha Academy of Higher Education (SSAHE), Tumkur, since 2014. For the very first time in the history of Medical Education, first year Medical/Dental students will be planting tree saplings within a month of their joining the college. They will look after the sapling till they complete their course. The photograph of the 3–4-year-old tree will be given to the students or if possible printed on their graduation certificate, as a Green Graduation Certificate upon completion of the course.

In the first phase, it will be taken up by the Sri Siddhartha Academy of Higher Education. The second phase will be a nationwide movement along with all universities and NGOs, who are already involved in various forms of Green Revolution. The Philippines has taken it aggressively and made this project mandatory for all students. The saplings can be planted within the campus or a designated area created for the same.

The primary goal of this project is not just planting saplings but providing sustainable green environment by assigning one tree to each and every student of Karnataka. The second important goal is to enhance the intellectual energy of students by getting them involved in social activities.

4.3.8 Adoption of Lakes for Rainwater Rejuvenation

This is an initiative taken up by educational institutions to save water bodies as well as create awareness among students. The change in human lifestyle over the centuries has negatively impact the ecological balance. It is high time we wake up, protect, and rejuvenate our lakes and other existing water bodies. The students may follow the blueprints by the government and experts for the same.

4.3.9 Adoption of Heritage Center as Tourist Hubs

The "Adopt a Heritage: Apni Dharohar, Apni Pehchan" scheme is a key initiative of the Ministry of Tourism, in collaboration with the Ministry of Culture and the Archaeological Survey of India. Under it, public sector companies, private sector firms, and individuals are invited to develop selected monuments as heritage centers or tourist attractions across India.

Institutes can adopt one of the heritage centers in their region and involve students in maintaining monuments. This program will also make students aware of their history and culture.

4.3.10 Healthcare

One of the best social works we can involve our students in is telehealth in rural areas. Telehealth allows small rural hospitals to provide quality healthcare services at lower costs and in the local healthcare facility which benefits rural patients, since they are no longer required to travel long distances to access specialty care.

4.3.11 SEVA/Free Service in Charity Hospitals

Under this program, the medical students will offer free service in charity hospitals.

4.4 Conclusion

Doing good to others and sharing your knowledge with students unconditionally, without expecting any returns from them, is not easy as I preach!! It is definitely difficult. But the joy you get from this is phenomenal. The advantages of unselfish knowledge sharing are immense, which I have explained elaborately with mythological, spiritual, practical, and scientific evidences. Just practice, and I assure that you will start enjoying each and every minute of feeling the greatest satisfaction.

Vidhya daanam, maha daanam

In Indian culture, sharing knowledge is considered to be the most sacred. Of course, everyone learns for their own benefit, but when we are teaching others, we learn the most. Remember, when you do good to others, good will always return to you. One should not teach just for money and fame. In the long run, you will be unhappy and depressed in life if you share knowledge only for material gains.

One must realize that the happiness and satisfaction you earn from your unselfish work will not only benefit your students and the society but also drive you to reach the greatest summit of success. Work whole-heartedly and no one can stop you from achieving your dreams.

References

Balachandra Shetty, P., Kabadi, V. R., & Balakrishna Shetty, P. (2015). Foundational principles for teachers in Bhagavad Gita. *Indian Journal of Humanities and Social Sciences*, *3*(1), 1–5. ISSN 2347-324X. © GBS Publishers & Distributors (India). http://www.gbspublisher.com

Links:

Dr P Balakrishna Shetty, Vice Chancellor, Sri Siddhartha Academy of Higher Education – Best Practices in Higher Education – elets Jnana Sangama 2016 https://youtu.be/_gdo8U4mciU

Dr P Balakrishna Shetty, Vice Chancellor, Sri Siddhartha Academy of Higher Education – International Education Initiatives: Learning & Collaborative Opportunities – Elets' 7th World Education Summit' 16 https://youtu.be/CKSVox6Ms-g

Dr P Balakrishna Shetty, Vice Chancellor, Sri Siddhartha, Academy of Higher Education, Bangalore – Talks / Skill Development / University Industry Collaboration Employability – SIETIIE NATIONAL CONFERENCE 2019 https://youtu.be/2BIVQsybiv8

Dr P Balakrishna Shetty, Vice Chancellor, Sri Siddhartha Academy of Higher Education – Bringing Quality – eINDIA 2014 https://youtu.be/FDhY_Vfz8Sw

Chapter 5
Neuroscience-Influenced MOOC Content Integration in a Pre-service Course: A Case Study

C. Praveen

5.1 Introduction

Since June 2019, teacher educators across India were assiduously engaged in discussions related to the draft of the New Education Policy 2019. Highly critical statements in the chapter on teacher education such as "…the teacher education sector has been beleaguered with mediocrity…" (p.283) to forward-looking statements such as "Teacher preparation may itself leverage technology (e.g; through the use of online courses), but the quality of training must be of the highest quality…" (p.339) have prompted debates in several teachers' forums and the media.

The launch of MOOCs by leading universities has made learning possible 24X7. A survey by a leading provider of MOOC courses, Coursera, revealed that a majority of learners see "tangible educational benefits" (2015). With a view to providing quality content, the teacher educator-cum-investigator attempted to explore the possibility of integrating MOOC content to the regular secondary teacher preparation course.

5.2 Background and Challenges

With the recent launch of the 2-year teacher training programmes in India, recognized colleges of teacher education started offering both Master of Education (MEd) and Bachelor of Education (BEd) courses each academic year. But unlike in previous years, when only one batch each of MEd and BEd would have been in the campus every year, two new batches of students started joining. This meant

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during the same academic year, four batches of students were simultaneously studying in the same college, viz. two MEd and two BEd, one senior batch and one junior batch. In the state of Kerala, owing to an acute financial crunch arising from natural disasters, additional faculty was not recruited, and the teacher educators were assigned the task of engaging classes for the four batches simultaneously. This led to a pronounced rise in workload and became a challenge to be overcome especially because "quality education" was expected in teacher education institutions.

The investigator, a practising teacher educator, caught up in the unprecedented hike in workload, attempted to cope with the situation by drastically cutting down the multimode instructional strategy normally employed and also reduced time normally utilized for syllabus transaction. But such an approach, it was soon found, resulted in miscomprehension and poor learning of theoretical knowledge, which was expected to be utilized by the teacher trainee during practice teaching. So, towards the end of the first semester, the teacher educator-cum-researcher explored the possibility of integrating technology for curriculum transaction in a blended mode. For this, the investigator attempted a review of the MOOC content offered by leading providers such as FutureLearn, edX, Canvas, and Coursera using a self-prepared checklist (Appendix I). The choice fell on "Lesson Design and Assessment", a MOOC offered by Arizona State University in Coursera for the obvious reason that, at that point of time in the BEd course, the trainees were expected to plan and prepare lesson plans. Even the objective of the MOOC – "Learners will be introduced to designing lesson plans based on principles and knowledge of learning objectives, assessment plans, methods, materials, and learning activities" – matched the expected learning outcome of the BEd course.

The initial attempt to integrate the MOOC course on *Lesson Design and Assessment* by making the entire batch of English optional trainees of the academic year 2018–2019 register for the course in the audit mode was a complete failure. Though all the trainees, numbering five, registered for the course and were given infrastructure facilities (Digital Language Lab) with free Internet facilities and provided WhatsApp-based 24X7 teacher educator support for clarification of doubts, within a month of registering for the MOOC which had high-quality free downloadable resources, the interest fizzled out. Despite repeated instructions by the investigator-cum-teacher educator to submit assignments related to the first week of the course, not a single trainee submitted any assignment.

Onah et al. (2014) suggest that the reasons for dropout for MOOC courses could be due to no real intention to complete, lack of time, lack of digital skills or learning skills, unrealistic expectations, and difficulty to catch up. From hindsight, the researcher found that failure to complete may also result from disinterest in the course materials.

Cognitive psychology studies have provided clinical evidence of stress, boredom, confusion, low motivation, and anxiety to interfere with learning (Christianson 1992). Studying the challenges to participation in MOOCs, Hamtini (2008) observed that there is a high dropout rate because certain individuals lack the motivation and willpower to succeed in a self-study program. Zull (2011), attempting to apply neuroscience research to adult online learning, proposed a few strategies which among others included creating an environment for discovery, applying all available senses to learning, and allowing individualized paths to learning.

The investigator, through informal interviews with the trainees of the 2018–2019 batch, tried to find out problems experienced in pursuing a MOOC. Following this, once again, a review of MOOCs on teaching of English was conducted by the investigator. This time, the investigator found a lot of similarities with the theory papers prescribed for study by the English optional trainees in the BEd course syllabus with a set of six different courses entitled **Teach English Now** offered by Arizona State University in Coursera (Appendix II).

Guided by research findings of cognitive psychology and neuroscience mentioned above, the investigator-cum-teacher educator attempted to integrate six courses of the **Teach English Now** with the BEd English course (2019–2020 batch). This was followed by charting out a plan to utilize the course content of multiple MOOC courses related to the teaching of English offered by Arizona State University, utilizing a four-phase format: Access-Self-study-Assimilation-Presentation followed by teacher educator feedback.

5.3 Brief Review of Studies

Carlson and Gaido (2002, p.119) highlighted that ICT is not, and never will be, transformative on its own as it requires teachers who can incorporate its use into the curriculum to improve their teaching and student learning.

Studies have indicated that student teachers reported a statistically significant higher technology competency in learning activities with technology, thereafter integrating them with appropriate inquiry-based pedagogy in classroom instruction (Angeli 2005).

The quality of a MOOC can be studied, focussing on technical and pedagogical criteria. Regular users of a computer know that accessibility and technical platform support are factors that affect learning. Even if the technical aspects are properly taken care of, if the pedagogical aspect fails to meet learner expectations, it can affect learning. However, informed educators will be better equipped to make evidence-based decisions, foster the positive growth of this innovation, and adapt it for their own unique contexts (Onwuegbuzie et al. 2012).

The quality of the MOOC content is also a significant factor. Margaryan et al. (2015) evaluated the instructional quality of 76 MOOCs and concluded that they all scored poorly overall.

Grover et al. (2013) observed that the factors that limit MOOC participation included the lack of accreditation, lack of accessibility, differences in cultural norms and language barriers, technological and time zone challenges, information overload, and insufficient facilitation skills.

The potential of the massive open online course (MOOC) to reach a vast number of students has resulted in studies attempting to find its real usefulness. MOOCs were found to have an added advantage over traditional course materials, such as filmed lectures, readings, and problem sets, through the teaching assistants (McAuley et al. 2010).

A critical factor influencing learner satisfaction was found to be course quality (Sun et al. 2008). Studies have shown that facilitation is an important element in sustaining MOOC participation and engagement. The facilitator's behaviour conveys cues that motivate and shape students' experience (Mathieu et al. 1993). Further, studies have also shown the need for an active participation of the learner coach (Voogt et al. 2013). They emphasize that the teacher's job is to organize the classroom and give students more opportunities and control over learning.

In recent years, neuroscience has begun to influence educational thinking and practice across the world. Stevens and Goldberg (2001) report that our brains are not equally good at everything; each brain is unique. Studies have shown that there is a direct connection between the biology of the human brain and teaching and learning (Madrazo and Motz 2005).

Drawing on neuroscience research and applying them to adult online education, Zull (2011) proposed the following strategies to maximize learning (cognition) as well as learning how to learn (metacognition): (1) create an environment for discovery, (2) include modelling by experts, (3) provide challenges that require creative actions, (4) apply all available senses to learning, (5) promote joy from learning, (6) use practice and experimentation to extend memory for future problem-solving, (7) allow individualized paths to learning, and (8) promote ongoing development of learning skills or metacognition.

5.4 Research Questions

- Will the utilization of MOOC content benefit the learner in an Access-Self-study-Assimilation-Presentation mode?
- Will learners benefit from peer presentation of MOOC content interspersed with teacher educator scaffolding?
- Will self-study of MOOC content followed by presentation of the same raise confidence level of the BEd trainee?

5.5 Population and Sample

The population comprised BEd trainees, and the sample comprised six BEd trainees in the age group of 24 and 28 of the English optional (2019–2020 batch) in a government-run college of teacher education in Kerala State, affiliated to the University of Calicut.

5.6 MOOCs Employed for the Study and Its Adaptation

The MOOC employed for this study is the audited mode version of the *Teach English Now* online professional teacher training course for Teaching English to Speakers of Other Languages (TESOL) launched in 2019 by Arizona State University, a leading provider of top-rated courses in the United States.

The course is offered in two parts entitled *TESOL Certificate Part 1:Teach English Now*, comprising four courses to be completed in 5 months, and *TESOL Certificate Part 2: Teach English Now*, comprising four courses to be completed in 6 months. A participant has the option to do any one of the first three courses of each part in any order one likes but becomes eligible for a certificate only if the last (fourth) course of each part, which comprises a project, is undertaken after registering for all the four courses of each part by paying a fee to the service provider, which, in this case, was Coursera. But a unique feature of courses available on Coursera is that one can register for any course for free and opt to audit the courses. This means, without payment of fee, a participant can access all the available reading materials and video lectures and even download them absolutely for free, but will not be issued a certificate, as those auditing a course will neither be permitted to take the quiz at the end of each module or participate in the discussion forum.

The English language teacher educator-cum-investigator, through a close scrutiny of the syllabus of the TESOL certificate course mentioned above, found that the MOOC has several components prescribed for study in the English language teacher education programme of the BEd course of the University of Calicut (Appendix III). For instance, the titles of the courses mentioned below are self-explanatory of the content. In *TESOL Certificate Part 1*:

Course 1.Teach English Now! Foundational Principles
Course 2.Teach English Now! Theories of Second Language Acquisition
Course 3.Teach English Now! Lesson Design and Assessment

In TESOL Certificate Part 2:

Course 1.Teach English Now! Second Language Reading, Writing, and Grammar
Course 2.Teach English Now! Second Language Listening, Speaking, and Pronunciation
Course 3.Teach English Now! Technology-Enriched Teaching

In Kerala State, in recent years, strikes, natural disasters such as flood, and intervening festival-related holidays resulted in loss of several working days for the BEd programme. And with the mounting workload, the investigator found a time-saver in the freely available resources of the MOOC course, TESOL Certificate Parts 1 and 2. So the investigator charted out a plan to make his teacher trainees of the academic year 2019–2020 comprising a total of six to register for one each of the six MOOC courses offered by Arizona State University. The rationale was that the high-quality content in digital form, audio, video, text, and graphics can serve as additional self-study learning materials. The teacher educator in addition to teaching in the face-to-face mode could integrate components available in the six MOOC courses for own teaching and learning by the teacher trainees. The prime objective was to integrate the MOOC into learning through teacher educator assistance. The study also tried to explore the possibility of integrating high-quality MOOC content for self-learning and peer mentoring under teacher educator supervision, utilizing ideas drawn from neuroscience.

The expected learning outcome included:

1. Gaining of knowledge and understanding of the MOOC content
2. Acquiring the ability for self-study on the assigned MOOC content
3. Developing the ability to transact the self-learned MOOC content to peers

The duration of the study was dependent on the pace at which the trainees learn the MOOC content and share their understanding with the peers. It worked on the assumption that neuroscience-influenced strategy of utilizing high-quality MOOC content would help transform trainees into self-reliant learners.

5.7 Methodological Framework

At the very commencement of the BEd course, the trainee's educational background was ascertained by the teacher educator. This was followed by an orientation to the BEd programme during the first week, which included ice-breaking sessions and invitation to interact with own peers. The initial sessions made a profuse use of multimedia for familiarizing with different aspects of teaching and learning English as a second language. Next, a WhatsApp group was formed, and on a regular basis, following the face-to-face interaction with the trainees, the teacher educator started posing questions utilizing infographics and videos relating to the content taught in the class. Care was taken to pose questions on the WhatsApp group which necessitated the BEd trainees to surf the Internet to find answers. One obvious aim of such a strategy was to enable the teacher trainee to acquire and polish own digital literacy skills.

During actual face-to-face teaching of the prescribed content of the BEd syllabus, questions posed by the educator were ones closely related to the content of the MOOC course which the trainees were expected to register in the following month. By the end of the first month, the teacher educator had identified the most suitable course for each of the six trainees who had registered for the BEd programme for the academic year 2019–2020. The course on lesson planning was discreetly assigned to the trainee in the group who had completed a primary teacher training course prior to joining the BEd course.

The following month, a visit to the college-owned Digital Language Lab with free Internet facility was arranged. Once the trainees familiarized themselves with the initial formalities of booting the computer, switching on the Internet, etc., the teacher educator briefed the trainees about the work they were going to undertake, namely, registering for a single MOOC course which, in the normal pace, is to be completed in 6 weeks. Printed syllabus of each of the six MOOCs for the six trainees was made available for reference.

Next, using own email ID, the trainees were directed to register one each for the six MOOC courses offered by Arizona State University in the Coursera platform. This meant creating a login ID with a password. Then, with the assistance of the teacher educator, all trainees choose the "audit mode" of the MOOC course which enables one to read digital texts, watch videos, and download content without payment of fee. Next, all trainees were directed to read, view, and download the learning materials week-wise by numbering them and storing them in separate folders in the computer assigned to them.

For the next 3 weeks, the trainees were directed to attempt a profuse use of the free Internet facility available in the Digital Language Lab to download the available materials for each MOOC. They were also directed to study the content and seek teacher educator assistance for clarification. A schedule for presentation of self-learned content before the peers and the teacher educator was made ready, and accordingly, the trainees were expected to transact the content they had learned. The participants were also briefed on aspects for which they will be assessed during presentation. It was also made clear that their performance during presentation would count towards the overall semester-end assessment.

While the study was in progress, during the face-to-face interaction on regular working days, the teacher educator transacted the syllabus prescribed for study for the BEd course. During such sessions, when the content taught was found to be related to the content in the MOOC which was assigned to individual trainees, the teacher educator commenced posing more questions to those who were auditing the same content in the MOOC (Appendix III).

The procedure followed on weekends during trainee presentation of content before peers and the teacher educator is as follows:

- With a brief introduction, the trainee commences presentation of the module which was accessed, taken time for self-study, and assimilated.
- The teacher educator relates the topic presented with the content in the prescribed syllabus of the University of Calicut.
- The trainee lists down concepts learned and explains it to peers. For this, the trainee is encouraged to either display the video content included in the MOOC or use charts or self-prepared PowerPoint slides.
- The teacher educator fills in significant aspects left out by the trainee and relates the content presented with pedagogical content knowledge which is expected to be gained by a teacher trainee.
- The trainees take turn to present one module each. Once all the first modules of each course assigned are complete, the trainees commence preparation for peer presentation of the second module of the already assigned course.
- If more presentation time is required, the regular college instructional hours are utilized.

The data on the effectiveness of the Access-Self-study-Assimilation-Presentation mode was collected through informal interviews and self-observation. A Trainee

Assessment Schedule was specially prepared by the investigator for use during presentation of content learned by the trainee (Appendix IV).

5.8 Results

An analysis of the data collected through the Trainee Assessment Schedule and informal interview is listed below:

- Online engagement, sharing of content learned and 24X7 WhatsApp support of the teacher educator who served as a kind of facilitator, helped address several problems faced during the experiment.
- The use of MOOCs not only reduced the sheer burden of the teacher educator for transacting the BEd curriculum all by oneself but also ensured the possibility of making available quality content for the BEd trainees.
- The use of multiple MOOCs for English language teacher education curriculum transaction fulfils the proposal for integration of technology proposed in the New Education Policy.
- Peer assistance made available in the setting of the Digital Language Lab ensured ease in overcoming technical glitches which a single learner auditing a MOOC content normally fails to get while learning oneself. This is significant because studies have shown that technology skills are impediments to learning, given the wide variety of tools used in courses (Fini 2009).
- Informal inquiries revealed that during the initial stages of downloading and using high-quality content from the MOOC, trainees experienced slight difficulties since it was a new method of learning. But almost every one opined that constant peer support in the environment of a Digital Language Lab and complete flexibility in timing turned out to be a big help.
- A month following the commencement of the MOOC content learning, the trainees were found to become less dependent on the teacher educator for own learning. On occasions, they also displayed confidence in explaining to their peers the content they learned from the MOOC course. This to a large extent affirmed the fulfilment of the assumption on which the research commenced, viz. the trainees will become self-reliant.
- The findings suggest that neuroscience shaped the utilization of the highly rated MOOC content, which created an environment for discovery, allowing individualized paths to learning to help strengthen the knowledge, skills, and dispositions of the teacher trainees. It also promoted trainee growth and learning. The illustrative videos of the MOOCs not only helped in mastering the content but also critically analyse own understanding and ability and gain an enriched learning experience.
- Bali (2013) identified five reasons for use of MOOCs by teachers for professional development. In this study, the use of MOOCs for pre-service teachers helped in realizing two identified reasons: (1) learn something new in a structured way, and (2) find well-chosen (mostly free) resources on a topic or subtopic.

- The liberty to store a set of digital learning materials with own name in the folder in an assigned computer for exclusive use by a single participant, which was a prelude to compiling a Digital Library for use by future students, created in the learner a sense of self-worth.
- On an average, each trainee took 1 h for downloading the content of a week, 4 h for self-study and assimilation, and 45 min for presentation of the same. Each of these purposeful activities ensured the complete attention of the trainee, thereby ensuring a meaningful study of the MOOC content.
- The teacher educators' familiarity with the entire content of the MOOCs vis-à-vis the topics prescribed for study in the BEd syllabus helped to focus study and to reduce time and energy of both the teacher educator and the trainee.
- A major hindsight gained during the integration of the MOOC content with the regular BEd syllabus is that facilitator familiarity with the MOOC course content is crucial when suggesting to trainees to pursue an online course for their own professional development.
- The teacher scaffolding during presentations of the MOOC content which the trainee had attempted to study on his/her own was found to be particularly useful. This to a certain extent helped raise the confidence level of the trainees.
- As the expected learning outcome identified by the MOOC content producers and the expected learning outcome of the course content of the BEd syllabus were different, close and discreet monitoring at the time of self-study by each trainee and also during presentation by the teacher educator was detrimental in ensuring effective utilization of the MOOC content.
- A review of courses offered by Coursera will reveal that most of their courses are designed to help spread new concepts quickly and effectively. In this study, the BEd trainees could familiarize with a much known twenty-first-century skill such as technological skill included as technological pedagogical content knowledge (TPACK) in one of the MOOC assigned for study to a participant. Incidentally, TPACK does not figure in the BEd syllabus prescribed for study in the University of Calicut.

5.9 Discussion

5.9.1 Pedagogical Aspects

The depth of knowledge of content learned was regularly checked by the teacher educator-cum-investigator during presentation before the peers and the teacher educator. Focus was on the ability of the trainee to combine facts and ideas, explain, and synthesize knowledge, which made possible checking of higher-order thinking skills of the teacher trainee. Conversational interchanges among peers and the teacher educator made possible an improved and shared understanding of topics prescribed for study, which is usually tested only during the semester-end university examination. The use of an Assessment Schedule followed by immediate feedback benefited both the trainee and the teacher educator. Interestingly, Ryerse and Brookhart (2018) quoting a recent **OECD Policy Brief** affirmed that teachers who engage in formative assessment report a changed classroom culture, clarity regarding goals, varied instructional practices, and more positive interactions with students.

5.9.2 The Use of the MOOC Content

Misra's (2018) literature review revealed a wide range of issues and concerns related to MOOCs. These issues may be categorized under three heads: (i) learner issues, such as learner motivations; motivation to participate; values and expectations; personal, cognitive, or psychological barriers; learner dropout rates; and learners' participation and engagement patterns; (ii) pedagogical issues, such as pedagogical design, content and resources, learning material, learning activities, learner guidance and support, tutor and facilitator roles, and completion and retention; and (iii) technological issues, such as learning objects, instructional design, technologies used, assessment of learner performance, and learning analytics. In this experiment, the Access-Self-study-Assimilation-Presentation mode employed in a collaborative learning environment with peers and teacher educator scaffolding helped directly address learner issues, pedagogical issues, and technological issues normally experienced by a learner who registers for a MOOC.

- MOOCs offer a powerful platform for education and development with cost savings and greater efficiency (Florentine 2015). In government-run institutions, particularly in the State of Kerala, most students are recipients of financial assistance, and they seldom take the initiative to register for online courses which charge a fee. The use of high-quality MOOC in the audit mode helped realize the watchwords of "equity and access", which form the basis of current reforms in higher education in India.
- Chunks of information learned were expected to be shared by the trainee to peers in the presence of the teacher educator. This meant assimilation of content learned and choosing an appropriate strategy to present the content learned from the MOOC course. This helped the teacher educator to check for accuracy in learning. The trainees' attempt to utilize the high-quality MOOC course content which included illustrative video lectures meant gaining invaluable practice in explaining with digital aids. This served as an excellent prelude to practice teaching which was expected to commence in the third semester of the BEd course.
- The utilization of the MOOC content through a peer mentoring mode, along with scaffolding by the teacher educator, helped address a common problem highlighted in studies on the use of MOOCs, namely, the necessity for the facilitator to be "on duty" (Hiltz 1993). More significantly, the experiment shows that group learning of the MOOC content can considerably reduce the demand on a MOOC facilitator's time and energy in a virtual learning environment.

- The innovative use of the MOOC content-integrated teacher education programme has directly addressed the common criticism of synchronous mode of delivery of MOOC courses, which limits accessibility and flexibility (Daniel 1998).
- The experimental study to a fair degree succeeded in meaningful and effective utilization of the MOOC content, resulting in an enriched learning experience for the teacher trainee. But since the audit mode was chosen, the participants were unable to access the original assessment tests that follow each module of the course.
- Though the narrative of this innovative experiment appears to be a success story, it has certain obvious limitations. The study was conducted on a small sample of first semester BEd trainees, and the actual utility and effectiveness of the content learned, particularly the use of illustrative classroom videos will become fully clear only when the participants of the study, complete their teaching practice in the third semester of their BEd course. More significantly, the proposed learning outcome of the MOOCs and the expected learning outcome of the BEd programme had marked differences. So even though the MOOCs were accessed by the participants, the actual learning to a large extent was dependent on the original objective for which the MOOC materials have been developed.

5.9.3 The Use of Neuroscience-Influenced Strategies

The teacher educator-cum-investigator made use of certain neuroscience-influenced strategies while adapting the MOOC content. These include:

- Creating an environment of discovery: In addition to the regular bazaar guides the trainees depend on for preparation for their semester-end university examinations, top-class MOOC content was made accessible for study.
- Modelling by experts: The availability of illustrative video presentation in the course content of the MOOCs which included teaching of language skills, demonstrations of teaching during various stages of a class, and assessment practices in the classroom made learning of the MOOC content meaningful.
- Providing challenges that require creative actions: In addition to learning the MOOC content through self-study, the trainees had to transact the same in a lecture mode. This meant employing one’s imagination and creativity to make the presentation interesting and meaningful.
- Applying all available senses to learning: The course materials included both audio (with talk and music) and videos (with moving images and teacher talk). This ensured, to an extent, the use of more than one sense.
- Promoting the joy of learning: The presenters of each course were amicably addressed as “expert” of their assigned course. So the six “experts” in the class which studied six different courses included foundation expert; second language acquisition expert; lesson design and assessment expert; reading, writing, and

grammar expert; listening, speaking, and pronunciation expert; and technology expert. This indirectly boosted their self-esteem and brought in its wake a sense of joy in the trainees.

- Practice and experimentation: The theoretical aspects of the MOOC content learned were expected to be utilized during practice teaching of the BEd programme, and this lend the scope for practice and experimentation.
- Individualized paths to learning: Though the ultimate objective was to familiarize with the content of all the six MOOC courses, each trainee was assigned only one course. This was done discreetly by the teacher educator by identifying areas of interest in language education during the first 2 months of the 2-year BEd course.
- Promoting ongoing development of learning skills: The gap between presentation of each week and the final utilization of the theoretical content during criticism lessons and practice teaching by the trainee promoted development of learning skills.
- Scientific research has suggested that repeated exposure to cognitive or sensory stimuli could strengthen neural connections (Caroni et al. 2012). It has also been reported that connections weaken if they remain inactive for extended periods, making the information harder to retrieve (Kemp and Manahan-Vaughan 2007). In the study, there was a brief passage of time during each phase of knowledge construction by the teacher trainee. The chosen learning path comprised four phases: Access-Self-study-Assimilation-Presentation, followed by teacher educator feedback. In fact, during the study, there is very little scope for connections to weaken and remain inactive. The specially chosen learning path for the MOOC content appears to have fostered learning through the brain's ability to create, strengthen, and eliminate unwanted connections, which is believed to underlie the cognitive processes of memory required for learning.
- As per the hierarchical relational binding theory (hRBT) (Shimamura 2010), the stronger the connection between brain cells, the higher the chance of recalling the learning object. The hRBT theory also places emphasis on multiple pathways that form the networks of brain cells associated to a specific concept and thus the importance of review, repetition, and reinforcement for building robust networks (Jensen 2005; Wolfe 2006). Revisiting the learning object and attaching emotional significance made possible through peer approval and teacher educator appreciation during presentation are likely to have strengthened the connection of brain cells and thus helped in an improved recall of information about the learning object. Whatever theoretical knowledge the teacher trainee acquires from the MOOC content during the first semester of the BEd course is expected to be utilized during the third semester when sent to schools for practice teaching. It is assumed that if the learning of the MOOC content resulted in a strong network with well-connected brain cells, it would produce a robust mental representation of the learning object, which could be later recalled, modified, and extended through further learning experiences.
- Novelty is a factor that determines the direction of attention towards a desired learning object (Horst et al. 2011). It is the element of surprise associated with an

unexpected event, or an event that occurs out of context (Ranganath and Rainer 2003). New information should be novel in the sense that it contains a dimension unlike ones previously experienced by the learner. The participants of this study are postgraduate students who have freshly joined for a 2-year Bachelor of Education programme. The content they study as part of the course is novel, and teachers usually make use of the lecture mode. The MOOC content of Arizona State University employs video lectures and simulated teaching, occasionally interspersing with humour which is definitely a novel learning experience.

- The neuroscience theories provided the teacher educator-cum-investigator a theoretical lens to examine the MOOC content and adapt it to benefit teacher trainees to acquire pedagogical content knowledge.

5.10 Recommendations

- The strategy chosen by the teacher educator can in a way be perceived as one way of ensuring the optimum use of the MOOC content.
- Planned exploitation of the rich content of MOOCs by teachers not only empowers learners but also promises millions of learners, particularly in the developing world, access to better-quality content.
- The trainees fully utilized the MOOC content as the investigator-cum-teacher educator who served as facilitator ensured user-friendliness of infrastructure and provided continuous support. This perhaps is a clear indication that such an approach to the use of MOOCs can prevent student dropout.
- The prescribed BEd course input alone would provide only a limited knowledge base for the trainees. The integration of MOOC content of leading universities which the trainees learn in a collaborative mode, through peer input and teacher educator feedback, can foster self-reflection and meaningful learning. The use of such innovative strategies can help improve the quality of teacher education programmes.
- The recent spread of MOOCs demonstrates that technology continues to transform education in both traditional and online settings, and their introduction seems to have expanded its space for possible blended or hybrid course designs and experiences, especially in higher education (Bruff et al. 2013). The present study is an extended affirmation in its innovative use of the MOOC content for pre-service teacher training of teachers of English drawing on ideas from neuroscience. Studies that explore the possibilities for training pre-service teachers of other subjects utilizing MOOCs may be undertaken.
- This case study provides a detailed illustration of how the MOOC content is adapted for students undergoing a teacher training programme through a discreet utilization of neuroscience information. Though the insights gained from the study are localized with limited generalizability, it provides valuable considerations for research in the use of MOOCs for teacher education.

5.11 Disclosure Statement

The initial attempt to integrate the MOOC content for curriculum transaction was in February–March 2019. The second attempt was in July 2019. But in August 2019, the State of Kerala was ravaged by floods for a second consecutive year, resulting in suspension of classes and inability of participants of the study to make use of the Digital Language Lab with free Internet facility where the presentation-cum-feedback sessions were held. This lasted for almost a month, and when the classes resumed, it became necessary to find time to make up for missed classes, and the participants of the study were more keen on preparing the university examination that was postponed owing to the floods. This affected the smooth conduct of the present study.

Appendices

Appendix I

Checklist for Selecting MOOC Listed Down in Terms of Priority

1. Free access to materials
2. Scope for accessing content in audit mode
3. Availability of list of topics covered in each module
4. Mention of module-level learning objectives
5. Clear and measurable objectives which beginners can easily understand
6. Variety in resources (print, audio, and video)

Appendix II

Area Focus in Teach English Now Similar to BEd Optional Course in English

Area focus: Teach English Now (Total 06 excluding capstone project)	Course objectives: BEd-English (Total 03 excluding core courses on perspectives in education)
1. Foundational principles *7 basic language learning paradigms. *Familiarize with foundational principles as motivation, risk taking, and balancing the teacher profession 2. Theories of second language acquisition *Second or foreign language theories *Practices for teaching and assessing listening, speaking, and pronunciation	1. Theoretical bases of teaching English *To be competent in pedagogic knowledge and teaching skills in English language *To familiarize the feature of English language and its place and importance in Indian context *To familiarize the principles of teaching English and enhance language skills *To review the basic structure of English language *To understand the aims and objectives of teaching English at different levels *To understand the core teaching skills and implement them in classrooms *To understand the application of various theories of language learning

Area focus: Teach English Now (Total 06 excluding capstone project)	Course objectives: BEd-English (Total 03 excluding core courses on perspectives in education)
3. Lesson design and assessment *Design lesson plans based on principles and knowledge of learning objectives, assessment plans, methods, materials, and learning activities 4. Second language reading, writing, and grammar *Reading and writing courses and the integration of grammar instruction within those courses 5. Second language listening, speaking, and pronunciation *Aspects of listening and speaking that are challenging for students and teachers * Basic strategies to ease the acquisition and instruction of listening and speaking. 6. Technology-enriched teaching *Key concepts for effective integration of technology in teaching *Current and future trends in educational technology *Strategies for implementing trends in the classroom	2. Pedagogic practices in English *To apply various methods and approaches of teaching English *To familiarize different audiovisual aids in teaching of English *To analyse the course books in English. *To know the need and importance of planning of instruction *To understand the process of evaluation in English language *To acquaint with library resources 3. Professionalizing English education *To acquire knowledge, skill, and experiences to professionalize the profession *To understand the need of professionalism *To know the global demands of English teachers *To become aware of new careers in the global scenario *To understand and experience various language learning materials

Appendix III

Table showing essential content for study by BEd trainees identified by the teacher educator-cum-investigator from **Teach English Now** MOOC of Arizona State University matched with the related syllabus of the 2-year BEd course of the University of Calicut.

Arizona State University	University of Calicut
TESOL Certificate Part 1	

Arizona State University		University of Calicut	
Essential content for study by BEd trainees	MOOC title and module	Related content in the BEd course	Related paper and unit
*Teacher talk *Increasing student motivation * Scaffolding language	Foundational principles: module 1		
*Learning and acquisition *Accuracy vs fluency	Foundational principles: module 2	*Learning and acquisition	Theoretical bases of teaching English: unit 1
*Language learner *Strategies *Affective filter hypothesis	Foundational principles: module 3	*Krashen	Theoretical bases of teaching English: unit 3
*Language learning outside classroom *Learning online	Foundational principles: module 4	*Online teaching	Professionalizing English education: unit 3
*Teaching in a team	Foundational principles: module 5		
*Critical thinking	Theories of second language acquisition: module 1		
*Grammar translation *Direct approach *Berlitz method	Theories of second language acquisition: module 2	*Methods: grammar translation	Theoretical bases of teaching English: unit 4
*Reading and audio lingual approach	Theories of second language acquisition: module 3		
*Cognitive approach *Affective humanistic approach	Theories of second language acquisition: module 4	*Humanistic approach	Theoretical bases of teaching English: unit 4
*Comprehension approach *Communicative approach	Theories of second language acquisition: module 5	Communicative approach	Theoretical bases of teaching English: unit 4
*Instructional design theory	Lesson design and assessment: module 1		
*Objectives	Lesson design and assessment: module 2	*Learner objectives and learning objectives *Process objectives and product objectives	Pedagogic practices in English: unit 1
*Presenting instruction modelling	Lesson design and assessment: module 3	*Micro-teaching *Lesson plans for prose and poetry	Pedagogic practices in English: units 2,5
*Guided practice *Independent practice	Lesson design and assessment: module 4		

Arizona State University		University of Calicut	
*Assessing knowledge vs memory	Lesson design and assessment: module 5	*Evaluation criteria for various discourses	Pedagogic practices in English: unit 6
TESOL Certificate Part 2			
*Types of readers *Whole language vs phonics	Second language reading, writing, and grammar: module 1	*Whole language	Theoretical bases of teaching English: unit 4
*Extensive reading techniques *Intensive reading techniques	Second language reading, writing, and grammar: module 2	*Intensive and extensive readers	Pedagogic practices in English: unit 4
*Process writing	Second language reading, writing, and grammar: module 3	*Composition-guided and free	Pedagogic practices in English: unit 4
*Good writing from reading, speaking, and critical thinking	Second language reading, writing, and grammar: module 4	*Fourfold language skills: how to enhance	Theoretical bases of teaching English: unit 2
*Integrating grammar into reading and writing *Grammar problems	Second language reading, writing, and grammar: module 5	*Review of the grammatical aspects of English language	Theoretical bases of teaching English: unit 2
*Challenges to listening	Second language listening, speaking, and pronunciation: module 1		
*Listening strategies	Second language listening, speaking, and pronunciation: module 2		
*What makes speaking hard?	Second language listening, speaking, and pronunciation: module 3	*Phonetics	Theoretical bases of teaching English: unit 3
*Speaking strategies	Second language listening, speaking, and pronunciation; module 4		
*Barriers to pronunciation *Strategies for teaching pronunciation	Second language listening, speaking, and pronunciation: module 5		
*Tips for using technology	Technology enriched teaching: module 1		

Arizona State University		University of Calicut	
*Choosing the right technology *LMS *Nine categories of technology	Technology-enriched teaching: module 2	*Various IT resources	Theoretical bases of teaching English: unit 6
*Digital natives and non-natives *Engaging	Technology-enriched teaching: module 3		
*Technological pedagogical content knowledge *Substitution *Augmentation *Modification *Redefinition	Technology-enriched teaching: module 4		
*Tips for evaluating technology *Instructional design	Technology-enriched teaching: module 5		

Appendix IV

Trainee Assessment Schedule

Name of trainee:
Topic: Date: Duration:
Aids used:

Item	Rating scale 1 = Lowest 5 = Highest					Remarks
Understanding of concept presented	1	2	3	4	5	
Ability to explain concept with illustrative examples	1	2	3	4	5	
Use of aids such as chart paper/ PowerPoint/ videos	1	2	3	4	5	
Ability to synthesize facts and ideas	1	2	3	4	5	
Ability to connect topic to pedagogy	1	2	3	4	5	

Operational Definition of Key Terms

Blended Learning It combines face-to-face learning activities with online or computer-based learning activities. In blended learning, computer technology becomes another useful tool for enabling students to learn effectively (Wikieducator). In this study, it refers to the use of computers by the trainees of the English optional subject to access MOOC course materials both in an online and offline mode, followed by the use of the downloaded materials for self-study by the trainee and for instructional purpose by the teacher educator.

Coursera It is a leading provider of online courses. Coursera claims that every course offered by them is taught by top instructors from world-class universities, so that one can learn something new anytime anywhere. Hundreds of free courses which they offer give learners access to on-demand video lectures and community discussion forums. Paid courses with a sharable course certificate on completion and free courses are also available. This study made use of six MOOCs of Arizona State University offered on Coursera.

MOOC It is a short form for massive open online course which has open access and offers interactive participation by means of the web. MOOCs provide participants with course materials that are normally used in a conventional educational setting, such as lectures, videos, study materials, and problem sets (Techopedia). In this study, it refers to the six courses of TESOL Certificate: Teach English Now Parts 1 and 2 MOOC offered by Arizona State University on Coursera, save the final Capstone Project of Parts 1 and 2.

Neuroscience It is a multidisciplinary science concerned with the study of the structure and function of the nervous system. It encompasses the evolution, development, cellular and molecular biology, physiology, anatomy, and pharmacology of the nervous system, as well as computational, behavioural, and cognitive neuroscience (nature.com). Educational neuroscience is an emergent field in which researchers, teachers, and entrepreneurs are keenly applying neuroscience to education with the hope of improving teaching and learning. This study draws on findings of neuroscience and employs it for adapting MOOC content for a teacher training programme.

References

Angeli, C. (2005). Transforming a teacher education method course through technology: Effects on pre-service teachers' technology competency. *Computers & Education, 45*, 383–398. https://doi.org/10.1016/j.compedu.2004.06.002. Available at https://www.sciencedirect.com/science/article/abs/pii/S0360131504000946. Retrieved 17 Oct 2019.

Bali, M. (2013, July 12). 5 reasons teachers should dip into MOOCs for professional development. *MOOC news & reviews*. Retrieved from http://moocnewsandreviews.com/5-reasons-teachersshould-dip-into-moocs-for-professional-development-2/

Bruff, D. O., Fisher, D. H., McEwen, K. E., & Smith, B. E. (2013). Wrapping a MOOC: Student perceptions of an experiment in blended learning. *Journal of Online Learning and Teaching, 9*(2), 187–199. http://jolt.merlot.org/vol9no2/bruff_0613.htm. Retrieved 17 Jan 2014.

Carlson, S., & Gaido, C. T. (2002). *Teacher professional development in the use of technology* [Online]. Available at: http://www.ictinedtoolkit.org/usere/library/tech_for_ed_chapters/08.pdf

Caroni, P., Donato, F., & Muller, D. (2012). Structural plasticity upon learning: Regulation and functions. *Nature Reviews. Neuroscience, 13*(7), 478. https://doi.org/10.1038/nrn3258.

Christianson, S. A. (1992). Emotional stress and eyewitness memory: A critical review. *Psychological Bulletin, 112*(2), 284–309.

Coursera survey. (2015). *Coursera impact revealed: Learning outcomes in open online courses*. Available at https://www.slideshare.net/Coursera/coursera-impact-revealed-learner-outcomes-in-open-online-courses. Retrieved 30 Oct 2019.

Curriculum of Two Year Bachelor of Education (BEd) Programme: With effect from 2015–2016 Available at http://www.universityofcalicut.info/syl/BEd_2_year_curriculum_UO_Erratum_2015_admn_on09Nov2015.pdf. Retrieved 02 June 2018.

Daniel, J. (1998). Can you get my hard nose in focus? Universities, mass education and appropriate technology. In M. Eisenstadt& & T. Vincent (Eds.), *The knowledge web – Learning and collaborating on the net* (pp. 21–29). London: Kogan Page.

Draft National Education Policy 2019. Available at https://innovate.mygov.in/wp-content/uploads/2019/06/mygov15596510111.pdf. Retrieved 03 Aug 2019.

Fini, A. (2009). The technological dimension of a massive open online course: The case of the CCK08 course tools. *The International Review of Research in Open and Distance Learning*, *10*(5).

Florentine, S. (2015, September 28). *4 ways MOOCs are changing professional development*. CIO. Retrieved from https://www.cio.com/article/2986306/it-skills-training/4-ways-moocs-arechanging-professional-development.html

Grover, S., Franz, P., Schneider, E., & Pea, R. (2013). *The MOOC as distributed intelligence: Dimensions of a framework & evaluation of Moocs introduction and motivation*. Available at: https://web.stanford.edu/~shuchig/docs/Framework%20for%20Design%20&%20Evaluation%20of%20MOOCs-Grover-Franz-Schneider-Pea.pdf. Retrieved 17 Oct 2019.

Hamtini, T. N. (2008). Evaluating e-learning programmes: An adaptation of Kilpatrick's model to accommodate e-learning environments. *Journal of Computer Science, 4*(8), 693–698.

Hiltz, S. R. (1993). Correlates of learning in a virtual classroom. *International Journal of Man-Machine Studies, 39*, 71–98. https://doi.org/10.1006/imms.1993.1054. Available at https://www.sciencedirect.com/science/article/pii/S0020737383710540. Retrieved 17 Oct 2019.

Horst, J. S., et al. (2011). What's new? Children prefer novelty in referent selection. *Cognition, 118*(2), 234–244. https://doi.org/10.1016/j.cognition.2010.10.015.

Jensen, E. (2005). *Teaching with the brain in mind* (2nd ed.). Alexandria: ASCD.

Kemp, A., & Manahan-Vaughan, D. (2007). Hippocampal long-term depression: Master or minion in declarative memory processes? *Trends in Neurosciences, 30*(3), 111–118. https://doi.org/10.1016/j.tins.2007.01.002.

Madrazo, G., & Motz, L. (2005). Brain research: Implications to diverse learners. *Science Educator, 14*(1), 56–60.

Margaryan, A., Bianco, M., & Littlejohn, A. (2015). Instructional quality of massive open online courses (MOOCs). *Computers & Education, 80*, 77–83. Available at https://oerknowledgecloud.org/sites/oerknowledgecloud.org/files/1-s2.0-S036013151400178X-main.pdf. Retrieved 30 Oct 2019.

Mathieu, J. E., Martineau, J. W., & Tannenbaum, S. I. (1993). Individual and situational influences on the development of self-efficacy: Implications for training effectiveness. *Personal Psychology, 46*, 125–147.

McAuley, A., Stewart, B., Siemens, G., & Cormier, D. (2010). *Massive open online courses digital ways of knowing and learning*. Available at: http://www.elearnspace.org/Articles/MOOC_Final.pdf

Misra, P. K. (2018). MOOCs for teacher professional development: Reflections, and suggested actions. *Open Praxis, 10*(1), 67–77. https://doi.org/10.5944/openpraxis.10.1.780. Available online https://openpraxis.org/index.php/OpenPraxis/article/view/780#:~:text=Massive%20Open%20Online%20Courses%20(MOOCs,per%20their%20convenience%20and%20ease. Retrieved 19 Aug 2020. ISSN 2304-070X.

OECD Policy Brief. (2005 November). *Formative assessment: Improving learning in secondary classrooms*. Available at http://www.oecd.org/education/ceri/35661078.pdf

Onah, D. F.O., Sinclair, J., & Boyatt, R. (2014). Dropout rates of massive open online courses: Behavioural pattern. In *6th International Conference on Education and New Learning Technologies, Barcelona, Spain, 7–9 July 2014*. Published in: *Edulearn*14 *Proceedings*, pp. 5825–5834.

Onwuegbuzie, A., Leech, N., & Collins, K. (2012). Qualitative analysis techniques for the review of the literature. *The Qualitative Report, 17*(56), 1–28. Retrieved from http://www.nova.edu/ssss/QR/QR17/onwuegbuzie.pdf

Ranganath, C., & Rainer, G. (2003). Neural mechanisms for detecting and remembering novel events. *Nature, 4*(3), 193–202.

Ryerse, M., & Brookhart, S. (2018). *The research base for formative assessment* [Online]. Available at https://www.gettingsmart.com/2018/07/the-research-base-for-formative-assessment/. Retrieved 20 Aug 2020.

Shimamura, A. P. (2010). Hierarchical relational binding in the medial temporal lobe: The strong get stronger. *Hippocampus, 20*, 1206–1216. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.700.4654&rep=rep1&type=pdf.

Stevens, J., & Goldberg, D. (2001). *For the learners' sake*. Tucson: Zephyr Press.

Sun, P. C., Tsai, R. J., Finger, G., Chen, Y. Y., & Yeh, D. (2008). What drives a successful e-learning? An empirical investigation of the critical factors influencing learner satisfaction. *Computers & Education, 50*(4), 1183–1202.

Voogt, J., Fisser, P., ParejaRoblin, N., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge – A review of the literature. *Journal of Computer Assisted Learning, 29*, 109–121.

Wolfe, P. (2006). The role of meaning and emotion in learning. *New Directions for Adult and Continuing Education, 2006*(110), 35–41. https://doi.org/10.1002/(ISSN)1536-0717.

Zull, J. E. (2011). *From brain to mind: Using neuroscience to guide change in education*. Sterling: Stylus Publishing.

Websites

https://www.coursera.org/
https://www.coursera.org/specializations/tesol
https://www.coursera.org/specializations/tesol-certificate-2
https://www.techopedia.com/definition/29260/massive-open-online-course-mooc
https://wikieducator.org/Blended_Learning

Chapter 6
Applications of Neuroscience in Education Practices: A Research Review in Cognitive Neuroscience

Moses Satralkar, Jose Cherian, and Kennedy Andrew Thomas

6.1 Introduction

The human brain is the most complex and mysterious organ in the body responsible for learning. Many different facets of the brain like anatomy, circulation, neuronal growth and the like have been arenas of study by researchers (Cercone 2006). Applications of neuroscience and genetics need to be comprehended to modulate teaching and learning practices in education. Chronobiology is another science of the study of the effects of time and rhythmical phenomena on life processes, which has emerging applications in education practices. There is essential research information that goes unnoticed by the educational fraternity or is not well understood and needs to be simplified. The paper "Brain-Based Learning" authored by Kathleen Cercone et al. in 2006 provides a detailed overview of cognitive neuroscience with few fundamental practical implications for application in teaching and learning. Education helps in fostering holistic development in learners, and neuroscience aids in understanding the mental processes that lead to growth and learning. Hence, neuroscience complements educational research by eliciting a scientific temperament into it (The Royal Society 2011). Cognitive enhancement is a term used to refer to increased mental prowess in terms of problem-solving skills or memory. Such enhancements in mental abilities can easily be achieved through the use of drugs or sophisticated technological tools. However, when compared with these means, education seems the most broadly and consistently successful cognitive enhancer of all

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(The Royal Society 2011). Lawton et al. (2006) propounded that improving one's mental faculties is a comprehensive process that requires one to incorporate specific changes in habits, diet, lifestyle and behaviour, which can help flex grey matter in the brain to get the best out of the brain cells. Given the scope for application of advanced sciences in educational practices, this paper simplifies and reviews ten critical research findings relevant for teachers, professors, parents, students of all age groups and the academic fraternity at large.

Brain-based learning, which is a biologically driven process, refers to learning in congruence with the brain's natural mechanism to retain and process information (Cercone 2006). To gain a deeper insight about brain-based learning, it is imperative to have a rudimentary understanding of the anatomy of the human brain. The brain is made up of fatty tissue with billions of enmeshed neurons or specialised cells responsible for learning. A neuron consists of filamentous dendrites that receive signals from other neurons for transmitting electrochemical signals via chemicals called neurotransmitters. The dendrite of a single neuron is capable of receiving 10,000 synaptic connections from other neurons, making the brain a highly complex structure influenced by both intrinsic and extrinsic stimuli. The brain responds to stimuli by developing new circuits to connect further information to current or past knowledge. Hence, learning can simply be comprehended as the process in which novel neural connections and networks are formed in the brain (Cercone 2006). It is necessary for us to realise amazing scientific facts to understand the growing relevance of cognitive neurosciences, genetic studies and circadian rhythms for modulating educational practices in both schools and universities.

6.2 Subjects and the Brain

The human brain is divided into two cerebral hemispheres connected by the corpus callosum. Capacities such as visual and spatial attention, language and motor coordination are controlled by one of the two hemispheres (Gotts et al. 2013). Although nothing in the brain is entirely lateralised, one hemisphere takes precedence over the other in performing certain functions. In this respect, the left hemisphere is specialised for processing language and producing speech, writing, arithmetic and carrying out sequential processing of information, focusing attention and inhibiting negative emotions. The right hemisphere is specialised for simultaneous processing of data, attending broadly or diffusely, forming and using spatial maps and expressing intense emotions (Rogers 2003). The right and left hemispheres of the brain control various functions of the body and mind. Different subjects taught in schools affect and influence the left and right half of the brain, and this is shown below (Fig. 6.1).

Traditionally, schools and colleges encourage left modes of learning more than the right ways of learning. Academic subjects influencing the left brain bring out logical thinking, analysis and accuracy. Subjects influencing the left brain learning include Math, Science, Language and Computer Science. Academic subjects influencing the right brain bring out aesthetics, emotions and creativity. These subjects

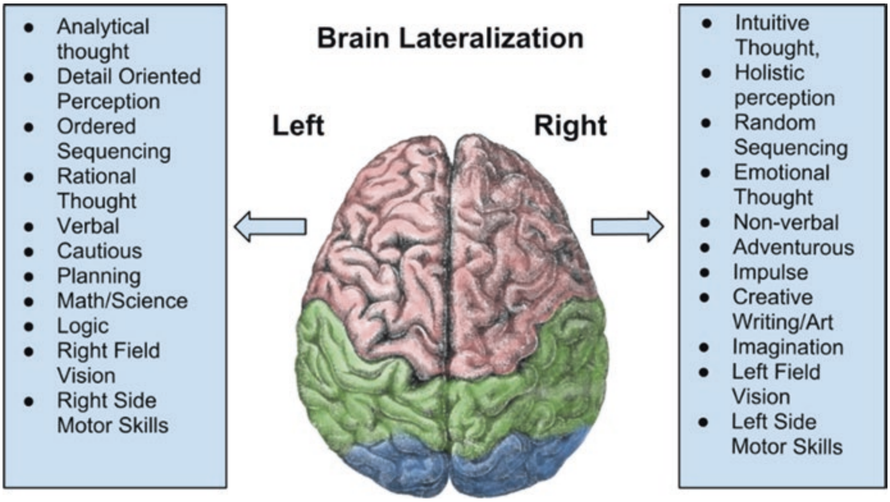

Fig. 6.1 Differentiating the right and left brain halves

include Arts, Music, Sports, Theatre, Social Sciences and Drama. Left-brain users play safe, are logical and focus on the past and present, whereas right-brain users are risk-takers and imaginative and focus on the future. Most people exhibit a combination of subject preferences for learning. Hence, personality and thinking develop as a result of subjects taught in the right variety at school. Subjects taught actually help a child think in a certain way and develop an attitude and unique personality. An imbalance may result if certain subjects are not taught in school or focus is limited to a few subject areas. As for instruction, teachers can increase their classroom's right-brain learning activities by incorporating more patterning, metaphors, analogies, role-playing, visuals, project-based learning, outdoor excursions, expeditionary learning and play. Educators must develop new forms of assessment that merit right-brained talent and promote a more accurate whole-brain-centred evaluation of student learning.

6.3 Sensory Preferences for Cognition

"Sensory preference" refers to the preference an individual possesses concerning information acquisition through sensory stimuli (i.e. visual, auditory, olfactory, taste, touch/kinaesthetic). This includes the type of sensory data that registers most quickly through seeing, hearing, tasting, smelling or touching. These five sensory preferences impact the way an individual acquires information, the comfort level in learning a subject and how an individual stores information or develops memory systems. By the age of 5 or 6, the brain begins to identify with one sensory system over the other two, although what triggers the selection isn't well understood.

Generally, one type of sensory stimuli will register most quickly in the brain than another. A meticulous understanding of one's sensory preferences would aid in devising suitable learning strategies conducive to the same. Learning styles play a significant role in the lives of learners in that they would be able to integrate the most suitable learning style into their academic arenas, which in turn would promote faster, successful and easier learning. Students also become effective problem-solvers when faced with adversities, making them independent and in control of their own lives (Biggs 2001 as cited in Awla 2014). Sensory preferences for general academic work can be classified into visual, auditory, kinaesthetic/interactive, reading and writing. In visual learners, the optimum level of learning takes place by observing images, videos and graphs that utilise a variety of colour combinations. Auditory learners increasingly begin to exhibit preferences for spoken messages or languages which can be their own voices or that of others. Their focus would be on the pitch, tone and pace of the speaker (Awla 2014). Kinaesthetic or interactive learners best learn what they ought to by doing. They incorporate limb movement and physical activity while learning. Reading and writing are the most traditional forms of learning, wherein the learners learn better while reading a text or writing linear or outlined notes. Awareness of the various learning styles mentioned above would facilitate a better understanding amongst teachers, so as to customise lesson plans in congruence with the learners' preferences. This is of utmost importance when teachers have to cater to children who are typically slow learners. On the contrary, mismatching might help quick learners experience new methods of learning, so as to incorporate novel ways of thinking by introspecting on their own styles (Tuan 2011 as cited in Awla 2014). Hence, it is essential to use multiple modal stimuli for sensory processing that triggers all biochemical pathways for learning. Lectures, audiovisuals/LCD, hands-on practical work/experimentation, group activities, worksheets, games and outings should be used in balance by teachers. Estimates of sensory preference were found through a general survey in schoolchildren shown below, and the majority of children preferred visual learning (Fig. 6.2).

Hence, it would be ideal if instructors utilise a wide array of pedagogical techniques and accommodate various learning styles (Cercone 2006). Moreover, Howard Gardner's theory of multiple intelligences has been critical in reviewing the methods for learning, teaching and assessment in educational institutions across the world. He proposed a total of nine or ten intelligences, and children or adults manifest one intelligence predominantly in life. Thus, Gardner propounded that these intelligences are critical for them to utilise to create interest areas, vocations and careers in life.

6.4 Gender Differentiation in Learning

In recent years, the age-old question of nature versus nurture has sprung up in neurobiology. Individuals differ significantly in their response to education, and both gene-environment interactions contribute to these differences (The Royal Society

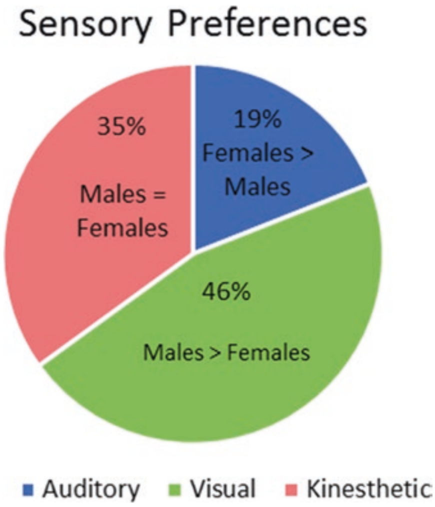

Fig. 6.2 Sensory preferences for learning

2011, p. 3). Are boys' brains different from girls' and do they learn differently? Neuroscientific research has shown there are apparent variations in the structure and thereby function of male and female brains. These physiological variations include cerebral volume differences, distribution percentage of grey and white matter, cerebral region size and thickness variations in the brain. By adolescence, a girl's corpus callosum is 25% larger than a boy's. They have fewer attention span problems, faster transitions between lessons, more robust neural connectors, better listening skills, more detailed memory storage and better discrimination amongst the tones of voice. Enhanced vital neural connectors and a larger hippocampus provide more generous use of sensory memory details in speaking and writing assignments. Girls' prefrontal cortex develops earlier and is more extensive than boys'. They have more serotonin secretion and make fewer impulsive decisions than boys. Thicker corpus callosum enables girls to multitask better. With more cortical areas devoted to verbal functioning, girls are better at sensory memory, sitting still, listening, tonality, mental cross talk and the complexities of reading and writing.

On the other hand, the male brain is different; the more cortical area is devoted to spatial-mechanical functioning and half as much to verbal-emotive functioning. The male brain is better suited to symbols, abstractions and pictures; hence, boys usually learn math and physics better than girls. Boys do well with kinaesthetic activities, sports and outdoor excursions. Boys also prefer video games, depicting physical movement and destruction. Boys also get into more trouble for not listening, moving around, sleeping in class and incomplete assignments. Hence, strategies need to be developed to differentiate instruction for boys and girls intelligently. The book by Michael Gurian, PhD, and Patricia Henley, with Terry Trueman – *Boys and Girls Learn Differently!* CA: Jossey-Bass 2001 – covers the essentials on this topic and also delves into the principle of androgyny, which is emerging as an essential leadership trait in the new century.

6.5 Learning Windows of Opportunity

Erstwhile, scientists believed that the rigidity of the brain escalated with age. As research progressed in neurosciences, the brain is now known to be extremely dynamic and flexible across the lifespan of an individual; hence, new neuronal growth takes place at all ages including the latter stages of life. Hence, learning is facilitated at all age groups. Kathleen Cercone calls this neuroplasticity of the brain (Cercone 2006). Our routine activities like sleeping, talking, interacting and learning are inadvertently changing the wiring of our mind for a short or prolonged period. This ability of the brain to adapt quickly to changes is known as neuroflexibility. This extraordinary ability allows the brain to accommodate changes from the environment on a day-to-day basis (The Royal Society 2011). However, there are sensitive and crucial brain developmental periods during which learning occurs more efficiently and effectively. Development is a complex process encompassing a sequence of physical, emotional, linguistic and cognitive changes in human beings over a period of time. There are a series of time periods, ages or stages in a child's brain development cycle which are optimal for mastering particular concepts or academic learning conceptually. These periods are also called cognitive learning windows. These learning windows narrow as the child grows. Brain neurons multiply rapidly during childhood years, making it easier to grasp concepts and understand during this phase of development. There are designated windows for learning various skills like motor control, vision, emotions, language and the like. These windows of learning should be best utilised before the age of 10 as the rate of neuronal growth or neuronal proliferation is rapid during earlier years of life during childhood. This does not imply that children stop learning after the optimal period. It just means that it becomes difficult to master concepts and learn after the age of 10, as the rate of neuronal growth slows down. A good example is language development. Language is the first subject to be learned by infants as the Broca and Wernicke's areas responsible for decoding and encoding sounds is the first region of the brain to develop in the midbrain. Students who are introduced to second languages before adolescence have a greater chance of mastering speech, encoding sounds and picking up new words to enhance vocabulary (The Royal Society 2011). Little children find it much more comfortable than adults to acquire a second or third language spontaneously. Adolescence is a crucial period, wherein the brain undergoes various changes in terms of areas that control skills and abilities like self-awareness, internal control, emotional responses like guilt and embarrassment and so on (The Royal Society 2011). These critical periods of brain development illustrate the importance of creating an enriched environment and age-appropriate subject teaching during the early years. Continuous training needs to be given at crucial junctures to foster brain development in children. The neuronal connections can be strengthened only through continued usage. Repeated usage of these neuronal connections supports the networks and leads to further growth. Thus, the age-old saying, use it or lose it, is opposite to this situation (Cercone 2006). When critical windows of opportunity for learning are missed, it does not mean that the child will never be able to learn that specific skill; it just means that it will take comparatively much more effort and time to realise that particular skill. Delayed gratification through emotional control, sensory control or development of a qualitative virtue known as patience at the age of 4 was shown by the classic "marshmallow experiment" by Walter Mischel at Stanford University. This research study had tremendous significance in the progression of personality from childhood to adulthood. Few children when asked to wait for a period of time to eat a marshmallow kept in front of them actually did so, thus overcoming temptation. These children were then rewarded by a double portion; this demonstrated delayed gratification. In fact, the same set of children when evaluated after 17 years during teenage years demonstrated better SAT scores, better body mass index and much better relationships. After additional experimental processes, it was concluded that there was a direct and obvious link between delayed gratification of needs and proficiency in higher education, lesser probability of drug abuse and obesity, better stress responses and practical social skill development (Saxler 2016). Self-regulation is a long developmental process that commences from childhood and lasts until adulthood, wherein it attains full maturity (Saxler 2016). Similarly, as discussed earlier, there are optimal ages during which children can learn certain subjects effectively. The diagram below shows how age and subjects may be correlated, thus illustrating concept of learning windows of opportunity in childhood (Fig. 6.3).

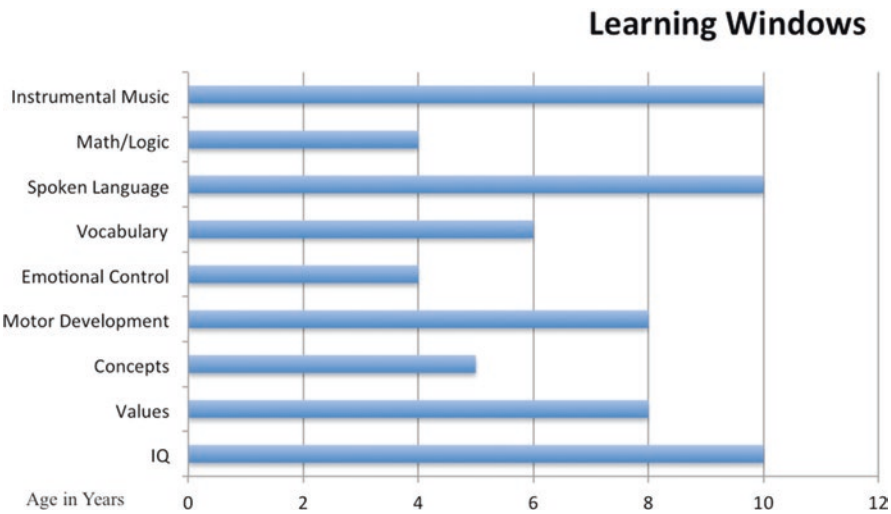

Fig. 6.3 Learning windows of opportunity

6.6 Circadian Rhythms and Biocognitive Cycles

Chronobiology is the science of the study of the effects of time and its influence on life processes. Circadian rhythms are physiological rhythms (Latin circa = approx. and diem = a day), which are periodic or repetitive as cycles over a day or a 24-h period. Living organisms can perform all their activities over a 24-h cycle due to the presence and effective functioning of this biological clock which is also present in bacteria, plants, animals, fishes, insects and all life forms (Caliyurt 2017). Human beings demonstrate a regular rhythmic series of changes in body temperature, heart rate, respiration and metabolism over a 24-h time period, which is cyclic in nature. Examples include locomotor activity, temperature, sleep-wake cycle, secretion of hormones, secretion of neurotransmitters, cell cycle, etc. The biological clock or body clock is scientifically known as the suprachiasmatic nucleus (SCN or "pacemaker" or "master clock") and is located in the anterior portion of the forebrain. A zeitgeber is an external environmental cue or stimulus that "entrains" or synchronises the internal biological clock in living organisms to the environmental cues on the Earth (e.g. bright light, temperature, humidity, photoperiod, exercise, etc.).The master clock thus helps living beings to adapt to the Earth's rotations, revolutions, seasonal changes and likely environmental vagaries (Schmidt and Bao 2017). Synchronisation is thus crucial for cognitive processes. The brain provides a temporal platform necessary for perception or attentional modulation. When desynchronised, the period of the investigated rhythm could jeopardise brain function and associated health outcomes (Bao et al. as cited in Schmidt and Bao 2017). When investigated at genetic level, molecular clock genes, such as "timeless, cryptochrome and period" amongst several others, were discovered. These genes were actually responsible for the generation of the circadian rhythms (Caliyurt 2017).

Time affects the learning process and even memory (Golombek and Cardinali 2008). The human brain is influenced by these biocognitive or peak cycles of learning associated with the body clock. Circadian systems adapt slowly to changes in sleep-wake schedules (Golombek and Cardinali 2008). For example, few children may be classified as "owls", while others may be "larks". The owls can stay up late and study but are unable to wake up early in the mornings. The larks have the capability to wake up early for study but cannot stay up late at night. The scientific process behind our sleep-wake schedules is as follows: During the night, special photoreceptors positioned in the retina feed information via the optic nerve into the SCN and pineal gland, which in turn secretes melatonin into the bloodstream. This thwarts the production of serotonin by the reticular activating system (RAS). Hence, the "exogenous zeitgebers" play a crucial role in regulating our sleep. It is 2 h before the bedtime that melatonin levels increase, resulting in low mental alertness. It is during this point, known as the "sleep gate", that the urge to sleep escalates (Broadbent 2018). Adolescents in particular have drastic and abrupt changes in their sleep schedules shuttling between early morning awakening owing to school timings and late bedtimes during the weekdays (Golombek and Cardinali 2008). Forcing children to switch their regular body clock is possible. Still, it may not have desirable effects as it may create hormonal imbalances which can lead to developmental and/or mental disorders. Other circadian rhythm dysfunctions due to shift work, jet lag or old age may result in insomnia, ailments, etc.

Memory has also been shown to vary by the clock. In the morning hours, literal memory functioning is better, whereas in the afternoon and evening, inferential memory functioning prevails. Hence, the timetable in educational institutions has to be carefully planned to keep this in mind. During the morning hours, subjects such as Languages, Math, Science and Computers should be scheduled, whereas, in the afternoon, Art, Drama, Theatre, Music and Sport are appropriate for learning. When we refer to the "state of mind", we refer to brainwaves (there are four brainwave types, i.e. alpha, beta, theta and delta). The delta or slowest waveform is prevalent at night during sleep, whereas the others are prevalent during the day. A student has to be in the "right state of mind" for in-depth reading. Frances Rauscher, a psychologist at the University of Wisconsin, along with her colleagues, established that children who listened to Mozart had better mathematical and spatial reasoning (Lawton et al. 2006). Research by Daniel Levitin has shown that light soft, slow music enables a learner to focus better and orchestrates brainwaves and sound waves to create optimum conditions for developing a degree of focus, attention span and retention span. Certain music boosts brainpower because it calms the mind while simultaneously stimulating it. Listening to stories also produces similar effects, according to research studies (Lawton et al. 2006). In this manner, the implication of biocognitive cycles has a profound impact on human cognition. Sleep studies using wrist actigraphy are also critical in evaluating wellness and treatment of insomnia, jet lag and shift work.

6.7 Food and Nutrition

The brain is an energy-guzzling fatty tissue organ that makes up only 2.5% of the body mass but utilises almost 30% of the body's energy (700 Cal) to function optimally every day. This energy comes from the consumption of a balanced and wholesome diet, rich in nutrients like zinc, iron, sugars, carbohydrates, thiamin (Vitamin B1), essential fatty acids, vitamin A, calcium, protein, fibres, vitamin C and folate, which are vital for optimal physical and cognitive growth of children (Sorhaindo and Feinstein 2006). Glucose acts as a catalyst in supplying the brain with the requisite fuels. Neurons are highly specialised brain cells located in the brain, a majority of which are responsible for learning and memory. Neural networking, synaptic connections and dendritic growth occur as a result of food, diet, rest, exercise, hormonal secretion and metabolism. Neurotransmitters are chemicals transmitting information, which are found zapping like electricity through neurons in the brain. These chemicals are biomolecules which are responsible for cognition (learning) and metacognition (higher-order thinking). These neurotransmitters or chemical messengers are quite often the byproducts of digestion. Hence, food and nutrition play a vital role to modulate optimum levels of neurotransmitters responsible for learning at all age groups, at different stages in life. It is essential to understand the food stuffs that are responsible for enhancing cognitive abilities in humans. One of the most critical brain-rich chemicals is the docosahexaenoic acid (DHA) or omega-3 fatty acid, which is found in fish, salmon, kiwi and walnuts. This chemical directly benefits cognition and increases memory power, degree of focus and learning efficiency to develop a razor-sharp mind. Breakfast is the most important meal of the day for learners in particular and should ideally comprise of proteins, fats and sugars to provide enough energy for our day-to-day activities and for physical or mental work.

On the other hand, a breakfast of just starch and sugar will sustain a child for only about 2 h. Popular research studies show that children who increasingly consumed fizzy drinks and sugary snacks performed poorly at attention and memory tests. Barbara Stewart from the University of Ulster, UK, discovered that toast and beans were a better alternative than sugary food, since it proved useful in increasing students' abilities in a variety of cognitive tests. However, breakfast with high-protein beans worked best, as the difficulty level of the tests progressed. Research has shown that fibre significantly improves cognitive abilities, and beans are rich in fibres. Vitamin B, which is a brain booster, is a significant component in yeast extract present in the bread (Lawton et al. 2006).A smart choice for lunch is an omelette, white meat and salad. Eggs are rich in choline that produces the neurotransmitter acetylcholine. Salads are high in antioxidants which consist of beta-carotene and vitamins C and E. These antioxidants combat free radicals harmful for the brain. Curds and yoghurt are rich in the amino acid tyrosine. During the night, it is best recommended to consume strawberries and blueberries or fruits and boiled vegetables that further develop coordination, concentration and short-term memory. An absence in iron and zinc can adversely affect neuropsychological functions, leading to mental retardation, reduced immunity and subsequent susceptibility to diseases. Iodine deficiency results in brain damage and mental retardation in children (Sorhaindo and Feinstein 2006). Halterman et al. found that deficiencies in iron content lead to dismal standardised test scores. This was the case especially with math scores. "One study found that 5th-grade students with less nutritious diets performed worse on a standardised literary assessment (Florence et al. 2008 as cited in Stuber 2014, p. 2). Another study discovered that 5th-grade students who ate more fast food fared worse on math and reading" (Li and O'Connel 2012, as cited in Stuber 2014, p. 2). A study in the UK established that 14% of secondary school-going children who skipped breakfast exhibited dismal academic performance especially in tasks that required the utilisation of working memory (Centre for Educational Neuroscience 2016). Learning outcomes are hence directly correlated with diet and nutrition in children and adults. The paper "Ten Steps to a Better Brain" by Kate Douglas et al., in 2006, summarises this concept and other pertinent areas relevant to cognitive enhancement succinctly.

6.8 Sleep and Exercise

Sleep is a quintessential prerequisite for a healthy brain. It is an active, essential and involuntary process that allows the brain to relax and rejuvenate (Broadbent 2018). For centuries, sleep has been described as a poignant behavioural process that fosters the development of a good brain and a healthy body. The importance of sleep can be summed up in the fact that it is responsible for memory formation. This way rest enhances new learning and skill and memory acquisition especially in the critical developmental stages in children (Svingos et al. 2018). Optimal duration of sleep varies according to age groups. Children between the age groups of 3–5 ideally require 10–13 h of good sleep, while teenagers require a minimum of 8 h for optimal cognitive functioning (Dawkins 2018). School-going children display a parsimonious tendency in sleeping patterns, possibly owing to their busy academic schedules, leisurely activities or even mental disorders like depression or severe anxiety that can have debilitating effects on children's daily functioning and sleep patterns. Sleep problems amongst children can also crop up due to sleeping disorders like parasomnia which are dissociated sleep states such as somnambulism (sleepwalking) or dyssomnia when there is difficulty in initiating sleep such as in chronic insomnia (Stormark et al. 2019). Proper restitution is a prerequisite for neurocognitive and emotional functioning. When we sleep, the brain cells are reactivated. Rest is essential for fine-tuning mind-body coordination. This helps learners to recap day-to-day learning and rehearsal of episodes and facilitates the conversion of short-term memory to long-term memory. Systematic sleeping patterns help learners study better through improved concentration and attention spans, augment and hone their creative abilities and result in improved mood, stamina and energy to function productively during school hours (Broadbent 2018). Skipping sleep can do dreadful things to the brain, negatively affecting problem-solving, organisational skills, alertness, concentration, planning, memory and consciousness. “If you have been awake for 21 hours straight, your abilities are equivalent to someone legally drunk”, says Sean Drummond from the University of California, San Diego. Sleep is thus necessary for mental as well as physical wellness.

The Greeks have, since time immemorial, established the correlation between a physically active body and an intellectual mind (Rasmussen and Laumann 2012). Taking account of the innumerable and indispensable benefits that daily exercise has on children, most schools in countries across the world have incorporated physical education periods in their timetable schedules. Experimental studies have proven that regular exercise has a positive effect on the brain in that it induces structural changes and functional advantages (Mandolesi et al. 2018). In children, PE is shown to improve task orientation, self-efficacy, moods and awareness along with reducing the susceptibility to depression and anxiety disorders amongst children. This is because of the secretion of the stress-relieving hormone called endorphin, which, via interaction with the brain receptors, reduces the perception of pain. Research has shown that students who simply walk for half an hour three times a week improve abilities such as abstract reasoning, concentration and learning by 15%.

Umpteen studies have established the correlation between physical exercise and academic performance amongst students. This is because during exercise, a happy hormone, known as endorphin, is secreted in the bloodstream. This hormone combats the effect of cortisol, the biomolecule responsible for stress conditions. Correlational studies conducted across schools have proven the positive relationship between physical training activities in schools and academic performance (Rasberry et al.). Rasmussen and Laumann (2012) have established that, after physical activity like walking on a treadmill, children performed significantly well in academic achievement tests, in contrast to a resting session. Angela Balding from the University of Exeter, UK, has found that schoolchildren who exercise three or four times a week get higher than average exam grades at age 10 or 11. Neurogenesis or creation of new brain cells is stimulated when learners engage in physical exercise, which further boosts learning and memory power. Endorphins positively influence learning, and it is an alarming fact that this hormone is not found in optimal levels in several children largely because of lack of physical activity amongst school-going children. Physical exercise is plummeting with every passing year, especially in developed countries, due to obsession with gadgets and technology. One hour of exercise every day can boost metabolism and is highly recommended by the National Exercise Guidelines in the United States. According to estimates, only 20% of young children engage in regular exercise with a vast majority forgoing it on account of having busy schedules or simply due to dwindling motivational levels. As a consequence, children as young as 2 have obesity. According to the Centers for Disease Control and Prevention, 17% of children in the age group of 2 suffer from obesity (Reynolds 2018). Lack of sleep and exercise reduces creativity and increases risks of all kinds of ailments. Thus, implications of chronobiology have had a tremendous impact on health psychology.

6.9 Special Educational Needs

The tools of cognitive neuroscience offer exciting possibilities for educational practices. Neuroscience conducts studies in conjunction with disciplines like neurology, psychology, physiology and biology (Muller 2011). The development of brain imaging techniques like positron emission tomography (PET), functional magnetic resonance imaging (MRI) and electroencephalography (EEG) opens a plethora of opportunities to study the cognitive functioning of the human brain. Parts of the brain which are implicated during a wide variety of cognitive tasks can be studied comprehensively. Researchers in the arena of Special Needs Education can use brain imaging for comparing different patterns of neural activities in children with learning disorders, learning disabilities or genetic problems (Muller 2011). Early diagnosis of special educational needs is necessary for the monitoring and comparison of the effects of different kinds of educational input on learning disorders. Neuroscientific studies not only validate the effectiveness of specific interventions but also shed light on why these interventions are effective. Brain-based studies are increasingly using brain imaging to diagnose and remediate specific learning disabilities like dyslexia. Experts have learnt from these studies that not all children with reading difficulties suffer from similar problems (Muller 2011). Brain activity that can be recorded while performing tasks through neuroimaging provides scientists and researchers with a unique opportunity to visualise and comprehend the neural circuits that are formed during reading acquisition and mastery (Tandon and Singh 2016). Early detection of disorders like dyslexia aids educators in providing specialised instructional programmes in reading and writing (Tandon and Singh 2016).

Music as an interventional therapy plays an integral part in terms of responses such as pulse, rhythm, breathing and movement, influencing a wide range of emotions. Disability and illness do not deter these connections from forming. Music therapy has hence made inroads into the field of special education, wherein counsellors and psychologists help children with learning disabilities, stress and mental illnesses through music. Interactive music experiences help in addressing cognitive, developmental and emotional needs (Zhang et al. 2017). "Music therapy is now a form of psychotherapy wherein musical experiences are used as measures of interventions to promote the health of patients by the therapist" (Bruscia 1998 and cited in Zhang et al. 2017). Disorders like ADHD have been effectively resolved through "music therapy" at various schools in the past, where slow, soft classical music synchronises the brainwaves to soothe and calm hyperactive behaviour. Loud and fast music with distorted sounds and harsh lyrics increases brainwave frequency and may give rise to disturbing, aggressive and delinquent behaviours, especially observed in teenagers. Music provides patients with disorders like ADHD a self-regulatory system that helps to synchronise their internal timing with that of the external timing (Antonietti et al. 2018). In developing children, the amygdala (emotional senor in the brain) activation is linked to the processing of emotional and social signals. Mirror neurons are a set of neurons that replicate and mimic the same behaviour in humans and are associated in understanding emotional states. The connectivity hypothesis in autism spectrum disorders (ASD) has shifted their focus of study from single brain structures to the more complex neural networks. According to this hypothesis, ASD occurs as a result of critical differences in both the quantity and quality of neural networks in the brain, which are involved in transmitting information within and between local or distal neural systems. Currently, brain studies are also carried out through imaging techniques like DTI, which are efficacious in measuring the structural integrity of white matter that facilitates mapping of connections and communications between various regions in the brain (Mundy 2016). EEG and MRI studies suggest that children with autism, who experience significant challenges in the area of social cognition, show no or limited activity in mirror neurons or particular areas of the brain. However, targeted interventions have been shown to help students with autism decode emotions. Fear and anxiety have known to destroy brain cells in the amygdala or the emotional control centre in the brain. Hence, love, care, affection, humour and positive reinforcement work better than reprimand, insults, beatings, punishment and constant criticism towards students. A SEN classroom comprises of diverse children in terms of learning needs and behavioural differences that the teacher needs to pay careful attention to each of these learners. The Education University of Hong Kong in collaboration with the Department of Electronic Engineering has made a breakthrough by developing and launching a portable multiuser brainwave recording and analysis system that can simultaneously monitor the learning experiences and emotional responses of around 40 SEN children. Students are required to wear Bluetooth sensors that allow the brainwave recorder to measure brainwaves in real time which is then transmitted to a computer via a data collecting system to measure attention levels and emotional status (Special World 2018). Such interventions by neuroscientists in the educational contexts are proving to be beneficial to educators, therapists and parents. They also channelise new research to formulate special intervention programmes for children with special needs.

6.10 The Medium Is the Message

This concept was published by Marshall McLuhan in his book *Understanding Media: The Extension of Man* in 1964. He suggested that any form of a message (print, visual, musical, etc.) determines how that message will be perceived by the mind. McLuhan argued that modern electronic communications (including radio, television, films and computers) would have far-reaching sociological, aesthetic and philosophical consequences, to the point of actually altering how we learn, process information and experience the world. How information is communicated has more of a profound effect on the mind of the person receiving the information than the data itself. The cognitive theory of multimedia learning propounds that information, which is processed either via verbal contexts such as text, the spoken word and auditory events or visual information like diagrams, animations and photographs and non-verbal processing systems, can function independently. However, there are cross-linkages between the two. Thus, recall of the material is a function of the medium through which it is presented. So each person may have a particular type of media which suits them better and allows people to recognise, retain and recall specific types of information. This may be further affected by individual differences (Alty et al. 2006). In his esteemed report titled “Communication in Africa”, Leonard Doob tells of one African who regularly and keenly listened to the BBC news, though he could not understand anything. Yet, he took great pains to hear just to be in the presence of those sounds at 7 P.M., ordinary day. “His attitude to speech was like ours to melody – the resonant intonation was meaning enough” (McLuhan 1964, p. 9). Technology has become an important term in the twenty-first century since it has made inroads into the arena of education. This is because technology has become a medium or a highway to transfer knowledge in many countries. Innovations in technology have transformed our thought processes, work-life and lifestyle (Grabe 2007). The introduction of new media brings with it massive social, psychological and structural upheaval that has mass impact and shapes mass thinking especially in educational establishments by acclimatising students to live in what is popularly known today as the “knowledge society”. A few examples of the evolution of society were the invention of the radio, the television and the Internet. Even if the same information were presented, the effect of that information (the message) is transformed by how it’s delivered (the media). Therefore, it can be concluded that it is not the message per se but the medium itself that has shaped and controlled human associations and actions.

In the educational context, ICT integration refers to the teaching and learning process that utilises technological resources to enrich the process. Students learn better with technical aids, due to their familiarisation with the same (Ghvifekr and Rosdy 2015).When correlated with classroom learning, this perspective has ramifications in shaping educational practices. When students refer to digital media like laptops, computers, iPads, smartphones, kindles, digital tools, etc., they engage in “surface reading”, usually skimming through information on such gadgets, thereby building opportunity for concept thinking. Parents and teachers have impeccable faith in technology and its positive influence on the academic attainment of students to which the big financial commitments stand as testimony. Many students feel motivated to learn with technological aids due to the sheer novelty of the equipment (Neal 2005).

Numerous studies conducted to explore the apparent dichotomy between print and digital texts have increasingly begun to conclude that print-based books lead to better comprehension and recall when compared to digital texts. Many research studies have concluded that students could grasp the main ideas in a text, regardless of the type of text. However, they tend to remember the trivial details in a text only when they read printed books (Ross et al. 2017). Studies which have focused on metacognitive learning or higher-order thinking have proved the efficacy of print media in contrast to digital platforms of learning. Navigation, display and scrolling are identified as possible factors affecting reading comprehension (Ross et al. 2017). In a study, students in countries like the United States, Germany and Japan believed that if print and digital media cost the same, they would prefer hard copies of books for academic work. Ninety-two per cent of the students sampled said that they would choose a hard copy to read lengthy texts. Digital reading encourages students to multitask, and this could lead to distractions. Eighty-five per cent of the American students sampled in the study admitted that they were more likely to multitask while reading digital texts (Niccoli 2015). Hence, when the students refer to print/paper media such as books, magazines and newspapers, the opportunity for in-depth reading, deep reading, deep thinking and critical thinking arises. Digital learning is, however, not devoid of benefits to learners, but both are recommended in educational settings. Instructions by educators using useful teaching aids like projectors and other audiovisual devices make learning more interactive and can easily sustain students’ attention in the digital age. Visual learning through videos and pictures supplement the teacher’s explanation of concepts in a classroom and helps students internalise concepts better, and they remain in their minds for longer. Hence, there is a pressing need to find a balance between digital and print-based learning. It is essential to utilise both digital and print media in education since the "medium serves as the message" and the mind and personality of the reader also shapes along with the medium he or she is referring to on a long term. An imbalance will not augur well for the holistic outlook of an individual.

6.11 Neurocognition and Genetic Wellness

Neurocognition is increasingly being recognised as a significant factor in determining a person's quality of life. The ability to perform brain functions at high efficiency is vital to learning and leading a healthy and productive lifestyle. The science of neurogenetics presents scientific research that contributes to a better understanding of the DNA variations of abnormal and normal functions of the nervous system. It is now possible to learn how to fix our brain according to our DNA makeup. Our brain chemistry, more precisely neurotransmitters, affects our mood, behaviour, social attitude, degree of focus, learning abilities, memory, etc. Thus, our genes influence our neurotransmitters pathways and allow us to find out how to fix these. We are also able to improve our short- and long-term brain functioning and overall health and personalise our list of brain support supplements unique to our genetics. Many psychiatric conditions have been linked to some degree of neurocognitive impairment. Deterioration can contribute to ADHD, bipolar disorder, substance abuse/alcohol addiction and depression/anxiety. Changes to the frontal lobe, for example, could lead to difficulty in deciphering right from wrong, overriding socially unacceptable behaviour and understanding future consequences of our actions or impairments commonly associated with psychiatric disorders.

In recent years, genetic testing looks at genes impacted explicitly by customised diet, nutrition and exercise to give clear guidelines as to what is needed to optimise genetic expression. For example, there are several areas genetic testing focuses on as described by the Merritt Wellness Centre (in Austin Texas) to give you an overall idea on what individual genetic makeup looks like. These are:

- Exercise type
- Vitamin B metabolism (including MTHFR)
- Cholesterol metabolism
- Phase 1 detoxification
- Phase 2 detoxification
- Antioxidant function
- Bone integrity
- Glucose balance
- Inflammatory response
- Salt sensitivity
- Alcohol metabolism
- Exercise recovery

In summary, one could analyse his/her genetic profile and then make efforts to raise overall lifestyle genetic score in consultation with a "genetic counsellor" who is a qualified healthcare practitioner who will provide inputs on how one can modify individually genetic makeup ethically, by appropriate external interventional strategies, like optimised diet, nutrition, exercise, therapy and even intake of accurate medication to avoid future hereditary diseases or lifestyle complications.

6.12 Conclusion

The field of education, in conjunction with that of the neurosciences, opens umpteen arenas and possibilities for research. A comprehensive and multifaceted understanding of the neurological roots of learning could prove instrumental in equipping teachers, parents and educational administrators with the requisite knowledge to understand, respond and overcome challenges that arise in the academic context with resilience. Knowledge of the brain's anatomy, chemistry and neural connections can be translated into brain-based learning strategies (Cercone 2006). Neuroscience in education can hence be characterised as a tool for science-based education policy and even public policy. Better results can be yielded if neuroscientists cultivate more robust links between and within the research community and emphasise practical applications for educators within the broader education system.

References

Awla, H. A. (2014). Learning styles and their relation to teaching styles. *International Journal of Language and Linguistics, 2*(3), 241–244. https://doi.org/10.11648/j.ijll.20140203.23.

Antonietti, A., Colombo, B., & DeRocher, B. R. (2018). *Music interventions for neurodevelopmental disorders* [E-book]. Springer Publishing. https://link.springer.com/content/pdf/bfm%3A978-3-319-97151-3%2F1.pdf

Çalıyurt, O. (2017). Role of chronobiology as a transdisciplinary field of research: Its applications in treating mood disorders. *Balkan Medical Journal, 34*(6), 514–521. https://doi.org/10.4274/balkanmedj.2017.1280.

Centre for Educational Neuroscience. (2016 March 15). *Diet makes a difference to learning*. http://www.educationalneuroscience.org.uk/resources/neuromyth-or-neurofact/diet-makes-a-difference-to-learning/

Cercone, K., Korsgaard, E., & Muruchu, D. (Eds.). (2006). Brain-based learning. In *Enhancing learning through technology* (pp. 293–320). Information Science Publishing. https://pdfs.semanticscholar.org/3195/8adb8e10b292d5bacdf2ad5a3a597a6f9d1a.pdf?_ga=2.239347843.1225516853.1599137799-102233311.1599137799

Dawkins, R. (2018). *The importance of sleep for kids – Johns Hopkins All Children's Hospital*. John Hopkins Medicine. https://www.hopkinsallchildrens.org/ACH-News/General-News/The-importance-of-sleep-for-kids#:%7E:text=Studies%20have%20shown%20that%20kids,pressure%2C%20obesity%20and%20even%20depression

Evans, M. D. R. (2020, September 17). *Identifying the best times for cognitive functioning using new methods: Matching university times to undergraduate chronotypes*. Frontiers. https://www.frontiersin.org/articles/10.3389/fnhum.2017.00188/full

Golombek, D., & Cardinali, P. D. (2008). *Mind, brain, education and biological timing*. California: International Mind, Brain and Education Society and Blackwell Publishing.

GradIOSH, & Broadbent, L. (2018). *Sleep: A basic introduction into the neuroscience of sleep and the effects of sleep deprivation on health, safety and wellbeing*. GradIOSH. https://iosh.com/media/4030/sleep-a-basic-introduction.pdf

Harvard Graduate School of Education, & Saxler, P. (2016). *The Marshmallow test: Delay of gratification and independent rule compliance*. Harvard Library. https://dash.harvard.edu/handle/1/27112705

Lawton, G., George, A., & Holmes, B. (2006, September 4). *Top 10: Steps to a better brain*. New Scientist. https://www.newscientist.com/article/dn9968-top-10-steps-to-a-better-brain/.

Mandolesi, L., Polverino, A., Montuori, S., Foti, F., Ferraioli, G., Sorrentino, P., & Sorrentino, G. (2018, April 27). *Effects of physical exercise on cognitive functioning and wellbeing: Biological and psychological benefits*. Frontiers. https://www.frontiersin.org/articles/10.3389/fpsyg.2018.00509/full

McLuhan, M. (1964). The medium is the message. In *Understanding media: The extensions of man* (1st ed., pp. 1–18). MIT Press. https://web.mit.edu/allanmc/www/mcluhan.medium-message.pdf

Muller, E. (2011). *Neuroscience and special education*. inForum. https://nasdse.org/docs/72_f2f7f9b7-ff92-4cda-a843-c817497e81e4.pdf

Mundy, P. C. (2016). *Autism and joint attention: Development, neuroscience, and clinical fundamentals* (1st ed.). The Guilford Press. https://books.google.co.in/books?hl=en&lr=&id=UdXHCgAAQBAJ&oi=fnd&pg=PP1&dq=neuroscientific+treatments+for+autism&ots=lTeh4TDutj&sig=RKx7Hs50w3NZ3uGPeM8c4R4MbcE#v=onepage&q=neuroscientific%20treatments%20for%20autism&f=false

Neal, G. (2005, December). *Student reflections on the effectiveness of ICT as a learning resource* [Paper Presentation]. AARE Annual Conference Parramatta, Paramatta, New South Wales, Australia. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.118.5711&rep=rep1&type=pdf

Niccoli, A. (2015, September 28). *Paper or tablet? Reading recall and comprehension*. EDUCAUSE Review. https://er.educause.edu/articles/2015/9/paper-or-tablet-reading-recall-and-comprehension

Rasmussen, M., & Laumann, K. (2012). The academic and psychological benefits of exercise in healthy children and adolescents. *European Journal of Psychology of Education, 28*(3), 945–962. https://www.researchgate.net/publication/257488559_The_academic_and_psychological_benefits_of_exercise_in_healthy_children_and_adolescents.

Reynolds, G. (2018, February 14). *A before-school exercise program may help children thrive*. https://www.nytimes.com/#publisher. https://www.nytimes.com/2018/02/14/well/move/a--before-school-exercise-program-may-help-children-thrive.html#:%7E:text=A%20supervised%20exercise%20program%20that,dozen%20elementary%20and%20middle%20schools

Rogers, L. J. (2003, October 1). *Seeking the right answers about right brain-left…*. Dana Foundation. https://www.dana.org/article/seeking-the-right-answers-about-right-brain-left-brain/

Ross, B., Pechenkina, E., Aeschliman, C., & Chase, A.-M. (2017). Print versus digital texts: Understanding the experimental research and challenging the dichotomies. *Research in Learning Technology, 25*(0), 1–8. https://doi.org/10.25304/rlt.v25.1976.

Schmidt, C., & Bao, Y. (2017). Chronobiological research for cognitive science: A multifaceted view. *PsyCh Journal, 6*(4), 249–252. https://doi.org/10.1002/pchj.203.

Sorhaindo, A., & Feinstein, L. (2006). *What is the relationship between child nutrition and school outcomes?* (No. 18). Centre for Research on Wider Benefits of Learning. https://discovery.ucl.ac.uk/id/eprint/10015414/1/WBLResRep18.pdf

Svingos, A., Greif, S., Bailey, B., & Heaton, S. (2018, March 1). *The relationship between sleep and cognition in children referred for neuropsychological evaluation: A latent modeling approach*. PubMed Central (PMC). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5867492/#:%7E:text=In%20healthy%20children%2C%20sleep%20disturbance,29%2C30%2C31%5D

Tandon, P. N., & Singh, N. C. (2016). *Educational neuroscience: Challenges and opportunities*. PubMed. https://pubmed.ncbi.nlm.nih.gov/27647954/

The Royal Society. (2011). *Neuroscience: Implications for education and lifelong learning*. The Royal Society. https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2011/4294975733.pdf

Wilder Research. (2014). *Nutrition and students' academic performance*. https://www.wilder.org/sites/default/files/imports/Cargill_lit_review_1-14.pdf

Zhang, F., Liu, K., An, P., You, C., Teng, L., & Liu, Q. (2017, May 2). *Music therapy for attention deficit hyperactivity disorder (ADHD) in children and adolescents*. PubMed Central (PMC). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6481398/

Chapter 7
Effective Learning: A Neurological/Mental Process

L. N. Mittal

7.1 Background

This text has been written based on more than five decades of teaching and research experience of the author in the field of technical and vocational education, as well as consulting appropriate literature mentioned in the references including discussions which the author used to hold with one of his senior colleagues late Professor PD Kulkarni at NITTTR, Chandigarh. The author enjoys writing and sharing his experiences on the subject of learning, which in fact is connected with God-gifted neurological/mental system of learning. This has been written in the context of higher education which requires “intentional-conscious learners” to develop acquisitive, adaptive, operative, innovative, and ultimately business development competencies [discussed later]. The chapter is based on mental process of learning to imbibe new learning based on existing knowledge of each learner in the neurological system of all humans for furtherance of knowledge. While imparting instructions, majority of teachers in higher education don’t pay desired attention of existing knowledge of students for learning knowledge.

There is lot of educational terminology which may cause hindrance to readers, but conscious reading will make the text easy to understand because meaning of each unknown word/term is clearly spelled out. Teaching and learning are interconnected aspects which require clear understanding of domain-specific concepts, principles, and procedures, coupled with appropriate exposure of the world of work in the concerned domain, and clarity of mental learning procedures by all the teachers

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for effective learning at the part of learners. In the process of learning, it is important to understand the difference between teaching and learning.

Teaching is the process of imparting factual information by the teachers to the learners based on the objectives of instruction. It is considered as teacher-centered learning. This may be teaching of concepts, principles, procedures, or practices. In teaching, teachers are active and students are passive listeners. It is considered as traditional method.

Learning is the mental process of acquiring knowledge/information, skills, and attitudes based on the educational objectives so that the learners may use or apply in later situations and under conditions different from those of instruction. Therefore, in learning students are active and teachers are passive. Learning is performance based. It is student-centered learning. Teaching has no meaning if students are not able to perform as per instructions imparted. Therefore learning is change in the behavior of students for achieving desired performance.

Therefore, teachers are expected to select appropriate **teaching strategies** and **teaching methods** which advocate active participation of learners during instruction, which tends to minimize the use of lecture method, in which students are relatively passive, and promotes the choice of more learner active methods such as tutorials, laboratory/workshop sessions, seminars, self-instructional packages, industrial experiences, project work, problem-based learning (PBL), etc.

Teachers are also expected to use teaching tactics which are specific ways that one chooses to implement a particular method in a particular case/situation to cause better learning to bring about desirable change in the behavior of the learner to work effectively in the world of work. It is brought about by using teaching strategies, methods, and tactics to achieve desired educational/instructional objectives.

In the ancient days learning was a matter of speculation for philosophers and theologians. Later in the early twentieth century, learning was taken out of the purview of philosophers and taken over by scientists. Human beings learn in two ways. In one, they notice stimuli from the environment and respond impulsively to satisfy their basic needs like hunger and thirst and then go on to satisfy their other needs like physical security, maintaining a sense of social belongingness, and self-esteem. These were the areas studied by early behaviorists. In their theory, there was no role played in learning by neurological/mental events of a learner. Later, social cognitive theorists accepted that all learners who observe and imitate a model behavior make use of memories to retain images of the behavior similar to that of a model. It was here for the first time that **conscious aspect of learning** was noticed by the researchers.

When all deficient needs mentioned above were fulfilled, the learner resorted to self-actualization. Self-actualization means trying to improve one's own knowledge and skills consciously in order to perform well in the society. This aspect of conscious learning was picked up by cognovits who developed further theories called **information processing, constructivism, and contextual learning** by focusing their attention on neurological/mental events of a learner. In today's context, people have to think before they act. Hence cognition is becoming a dominant perspective in the educational research. In view of its dominance in higher education, this chapter is trying to introduce more of mental process of learning in detail, based on author's study, practice, and gaining experience in this domain.

7.2 Information Processing View of Learning

The information process theory explains how learner uses his memory system comprising of sensory registers [SR], working memory [WM], and long-term memory [LTM] to receive new information from the environment, store it temporarily in working memory to process it for understanding, and organize new information and store it permanently in LTM. LTM processes this integrated new information for retrieving it for later use. Later they developed the concept of **metacognition,** which means knowing the process of learning both incidentally and consciously. Using this knowledge, the learner knows how to convert himself/herself into an **intentional learner,** which means an intentional learner is expected to take control of his/her own learning, monitor the learning, and maintain motivation to continue learning for the entire life.

The cognovits have made further advances in the areas of **nature of knowledge,** i.e., factual concepts, schemas, scripts, personal theories, and world views in an individual and also scientific and professional knowledge acquired collectively by researchers and professionals. It is important to distinguish between the personal **idiosyncratic** [individual/distinctive] knowledge and scientific knowledge because the formal higher education is intended to make the student from his/her idiosyncratic knowledge to the scientific knowledge. Figure 7.1 provides details regarding neurological/mental information processing view of learning.

As mentioned earlier, information processing theory is based on the use of a leaner of three memory systems – sensory registers [SR], working memory [WM], and long-term memory [LTM].

7.3 Part I – Long-Term Memory [LTM]: Storage of Information

- Sensory registers [SR], i.e., eyes, ears, smell, taste, and kinetic movements, receive new information from the environment through seeing, hearing, touch, taste, smell, and actions (see Fig. 7.1 under SR). This information is normally held for just 2 s.
- This information moves from SR to WM where it is held for a longer time (2–20 s) and consciously for understanding by linking the new information to what is already stored in LTM. This helps the learner to make the raw information received from SRs more differentiated, elaborated, and organized [discussed later].

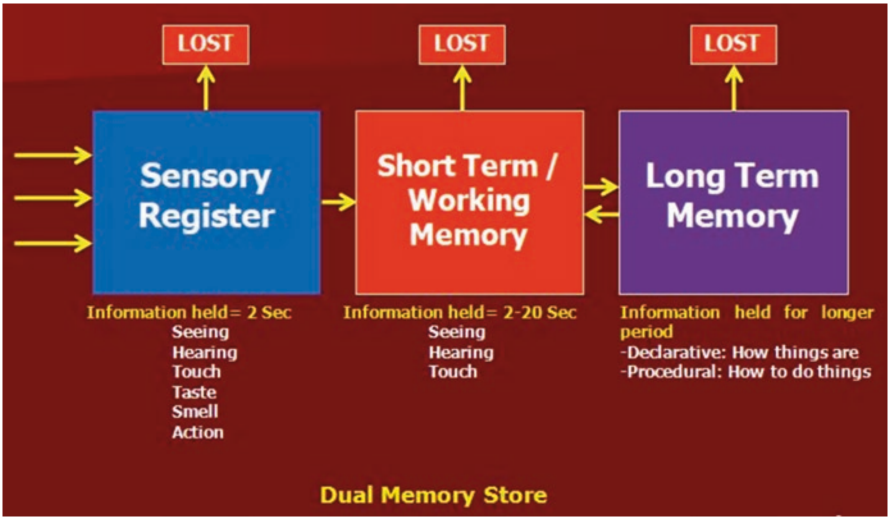

Fig. 7.1 Mental information process through dual memory system

- Such organized knowledge is now moved to LTM for long-term storage and easy retrieval for later use (like Ohm's law).
- This process is now repeated as another set of new information impinges the sensory registers and stored through WM to LTM (like modulus of elasticity).

It is important to note that each type of memory has its own particular feature like **capacity, form, and duration** of stored information.

Sensory register holds unlimited information (capacity) in different sensory registers in the same form as it is received by each of them, but it stays only for less than a second (duration). All information is not attended to by WM. Based on previous knowledge, only part of it moves to WM for further processing.

Working memory can hold only 5–9 units of information in the form of visual, auditory, and touch form and to a lesser extent smell and taste as they play minor role in information processing. WM can hold information for a period between 2 and 20 s depending upon the time required for processing different pieces of information.

WM focuses its attention on information in SR in two ways:

- Attention is automatically drawn to the information in SR when it has moving objects, object of usual size and intensity, novelty, incongruity, and objects and events which are likely to evoke emotions.
- When such information moves to WM, it is held for longer period for cognitive processing. Attention focuses only on some aspects of information held in WM, draws it, and converts it into a meaningful picture.

Long-term memory [LTM] stores knowledge of two types:

- Declarative (how things are)
- Procedural (how to do things)

Its capacity is much large; in fact the more information is stored in LTM, the more it can store.

Declaration knowledge is stored in three forms: **symbolic** (symbols, words, and language), **iconic** (images – visual, auditory), and **enactive** (actions, behaviors, and responses).

Some knowledge in LTM is implicit which is acquired during execution of daily activities, also called incidental activities. This implicit knowledge is not accessible to the conscious processing, but it strongly affects behavior. What is consciously processed and acquired is explicit knowledge and it can be retrieved. In LTM, every piece of information is interrelated.

There are educational implications for all teachers to note. Whatever information teachers wants to pass on to a learner, the learner alone control his/her learning. Learner uses his/her memory to select what he/she thinks is important based on his/her prior learning about the subject. Since initially student's attention is diverted by the nature of information teacher presents, teacher must maintain student's interest in the topic by bringing variety in his/her presentation (change intonation, intermittently asking questions, monitoring student's attention, making them reflect on their past knowledge, etc.). In addition, the teacher has to organize student's learning in such a way that the learner can store and retrieve information in LTM successfully.

Let us now study the process of organizing learning for LTM storage of knowledge, nature of knowledge finally stored, and process of retrieval of stored knowledge.

7.3.1 Construction of Storage

We have seen in the previous section that learner's WM attends only part of the sensory inputs and makes it meaningful based on his prior knowledge about a topic. Thus the learner constructs his/her own knowledge from the partial sensory input he/she notices. This constructed knowledge may not be the same which the teacher wants to convey. Similarly, the learner is likely to interpret any vague information in more than one way. Thus in the ultimate analysis, students do not retain the same information which the teacher has passed on but only that student's mind has constructed.

7.3.2 Storage Process

WM employs six learning processes which facilitates storage of declarative knowledge in LMT: selection, rehearsal, meaningful learning, internal organization, elaboration, and visual imagery which are briefly discussed below.

Selection As already explained before, the learner always selects only that part of sensory input which he/she considers important based on the prior knowledge about the topic the teacher teaches. While the teacher maintains the same speed of presenting information, the learner ultimately listens to only one fifth of the total presentation. The more familiar is the presentation to the learner, the faster is the rate of selection.

Teachers should take care to regulate the pace of presentation so that the leaner selects major portion of his/her presentation. Another way to build redundancy in the presentation is by repeating the same concept in more familiar terms.

Rehearsal Since mental processes for meaningful understanding take time, the new information should be held in WM for some time. This is done by repeating verbally the same information over time. Another way is by elaborative rehearsal, i.e., by trying to explain the new information by linking it with what the learner already knows. This prevents new information from fading from WM. Elaborative rehearsal also prevents rote learning by the learner.

Meaningful Learning This is a very important process in learning. Here the learner neurologically/mentally/cognitively processes the new information by relating his/her existing knowledge stored in LTM. When the new information is in the nonverbal form such as pictures, sound, smell, taste, and touch, it is first given a "label" which provides meaning to the nonverbal information.

Internal Organization Relating new information to the information already stored, as is done in meaningful learning, is called "external organization." But any new information also has its own internal structure. For example, new concepts are organized into hierarchy of subordinate concepts like animals are classified into "vertebrates" [like fish, mammals, birds, reptiles, amphibians] and "invertebrates" [like mollusk, insects, creepy-crawlies, etc.]. Short sentences can be organized into a proportional network which is interdependent on the agent, object, and relationship, e.g., Mary has an uncle. Mary is the agent, and object is uncle has relation and then converted into proportional network.

Elaboration When learner receives new information, say a concept word, the whole meaning is not clear. Learner tends to impose meaning by adding statements based on his/her prior knowledge. Thus, the leaner tries to make his/her understanding of the ambiguous information more precise. But these statements must be accurate and in tune with scientific assumptions. If the assumptions on which it is based are accurate and in tune with scientific assumptions, this is the better way of understanding new but vague information, and the understanding is also improved when the additional statements the learner uses are precise. Such elaborated new information is effectively stored in LTM.

Visual Imagery Visual imagery is a mental picture of how objects and events look like. Visual image supports understanding of verbal information/material. For example, the label "chair" is better understood when it is visualized as a picture showing four legs supported by a seat and a back. Similarly, event labels are better understood such as "visits to a restaurant" by visualizing activities one engages in a restaurant. Such combination of verbal text with its visual image helps effective storage of the text in LTM.

7.3.3 How Procedural Knowledge Is Acquired

A teacher does not teach merely declarative knowledge. He/she also teaches procedural knowledge. However, the process of learning procedural knowledge is different. Most of the procedural knowledge like driving a car and reading textual material for understanding is a complex combination of psychomotor skills and physical and mental activities. Only simple physical processes are learned in terms of actual behavior, e.g., riding a bicycle. But learning complex behavior requires a combination of physical and mental activities. The learner has to learn mental components as declarative statements that are learning information about how to organize mental activities. These verbal statements are required to be learned as explained above, i.e., by meaningful learning, internal organization, elaboration, and visualization and thus are stored in memory first. These elaborated statements are then used by the learner to mentally guide actual execution of procedures.

Since all this knowledge is to be acquired consciously, a lot of space and attention is consumed by WM. This slows down the speed of learning actual procedures. However, continued practice initially under guidance of declarative statement increases the speed of learning procedures. The use of declarative statement gets reduced till the procedures are learned to the level of automaticity. At this stage, the use of declarative statements fades completely. Further live demonstrations of procedures, illustrations, and visual imagery speed up the mastery of procedures.

7.3.4 Factors Affecting LTM Storage

Having understood how to learn complex declarative and procedural knowledge with the use of WM and cognitive processes, one should note the factors which may reduce the effectiveness of learning. These are listed below.

7.3.5 Use of WM

Storage of new information is effective when it is related to the learner's prior knowledge. The process of relating has to be done properly. WM must first retrieve the related previous information from the LTM and hold it simultaneously with the new information and search for accurate relationship. When the learner cannot do it, the teacher should guide him/her to retrieve and hold both and final relationship between them. Thus teacher is no more considered as mere information giver but a facilitator of learning by a student.

7.3.6 Influence of Prior Knowledge

Prior knowledge has great influence on understanding of new information. Learner must have therefore accurate prior knowledge. Knowledge containing misconceptions distorts the understanding. If such misconceptions are noticed, then teacher should take immediate corrective actions before presenting the new information, and the teacher should compel students to make explicit what he/she knows about the new topic already. Teacher should at this stage note any misconceptions and correct them.

7.3.7 Expectations

Learner generally, based on his/her prior experience of the subject matter, expects what he/she is going to listen or read or observe. If these expectations are not accurate, he/she misinterprets new information. Teacher should alert students what he/she is going to present is not repetition of the past trend, especially when teacher uses terms which are not closely related to learner's prior experience.

7.3.8 Verbalization

As already mentioned, in learning complex procedural knowledge, the use of verbal statements speeds up the learning. Teachers should encourage students to verbalize and self-instruct and guide execution of procedural knowledge. This enhances effective storage of both declarative and procedural knowledge in LTM.

7.3.9 Enactment

It means a learner is engaging in overt psychomotor behavior, i.e., actually doing something in some way that actually reflects what is being learned, for example, drawing geometry, drawing of a sketch of a neuron to study how nervous system works, etc. This is called enactive form of learning which reinforces understanding of the concepts.

7.3.10 Repetition and Review

Review and practicing information and procedures over a period of weeks, months, and often years improve retention of information and performance. Pay attention to the information during each review to review concepts, schemas, scripts, personal theories, and worldviews, and reflect over it. Such reflections involve additional elaborations, different contexts, and more associations. Such continued practice promotes atomicity in storage and retrieval of information from LTM. Teacher should encourage such frequent reviews and practice in the classroom.

7.4 Part II – Long-Term Memory: Nature of Knowledge

Declarative knowledge is stored in two forms in the LTM.

Episodic memory contains memories of one's personal life, and **semantic memory** contains general knowledge about the world independent of personal experience. Episodic memory resides in the parietal lobe and semantic memory in the frontal lobe of the brain, which is the seat of thinking. **Procedural knowledge** also resides in episodic memory and semantic memory, while responses in various parts of the brain in the motor cortex.

7.4.1 How Information Is Encoded in LTM?

Same information is represented or encoded in different forms primarily in images in various sensory cortices – visual, auditory, touch, motor, smell, and taste – but while learning in the classroom we use more of visual images. Visual images are the result of perception which does not record aspects of real objects. Hence image represents partial reality.

7.4.2 Encoding in Terms of Symbols

It is encoded in terms of symbols, words, numbers, or any other pictorial symbols. No symbol has any similarity with actual objects, events, touch, smell taste, or emotions but represents them in terms of their meaning. These remind them if properly associated during learning just like seeing construction of a road. The most common symbol in the classroom is verbal codes.

7.4.3 Encoding in Terms of Meaning

Propositions are small units of information containing a subject, object, and relationship between them. Each proposition may be true or false. For example, look at this sentence: Mary's uncle, whom she adores, owns a Ferrari which is red. It consists of four propositions

- Mary has an uncle.
- Mary adores her uncle.
- The uncle owns a Ferrari.
- Ferrari is red.

Each proposition has a meaning because it describes a particular relationship between the subject and the object or each proposition may be true or false. Thus people store information in terms of proposition. This is yet another way of organizing verbal knowledge.

7.4.4 Encoding in Terms of Actions Which Are Also Called Productions

Learner's physical or mental activities are encoded in terms of procedural knowledge. In a verbalized form these are all in the form of IF and THEN statements. For example "IF I want to speed up bicycle, THEN I should paddle faster. Thus IF part specifies the conditions under which action takes place, THEN statement specifies which action takes place. Such verbal statements are integral parts of procedural knowledge. It integrates behavioral and mental activities. Learner has to learn these production statements consciously in which WM plays an important part as a supervisor and guides overall execution of procedures.

All these four codes are interconnected. Bringing a verbal code in WM enables WM to pull all other codes like images, propositions, and productions, creating a total picture of a concept represented by that verbal code.

Teachers and students should note that words and sentences are primarily means of communication with another. Every sentence then becomes meaningful, if the verbal code can retrieve all other codes with it and contribute to the total meaning of all words. Each word is then called a **concept**.

7.4.5 Concepts

The word "concept" indicates a class of objects and events having similarities (also called characteristics, attributes, or features). Concepts are of two types: concrete and abstract.

Concrete Concepts are easily identifiable by physical and observable characteristics of objects and events they represent. Learning is required to learn how to classify these objects and events by responding to their observable features such as size, color, shape, and touch. Only later, these features are given labels. The word MILK is recognized as something which is white and has a particular taste. The word RED refers to a particular color of certain wavelength. These concrete concepts are learned easily.

In contrast, **abstract concepts** do not have observable characteristics, for example, intelligence, charisma, work, cousin, stress, strain, etc. They are, therefore, learned by formal definitions. Generalizations while learning abstract concepts do not occur by responding to concrete stimuli as in the case of concrete concepts.

Concepts are learned by examination of **instances.** Instances are examples of objects and events referred to by the concept level. Instances are of two types: positive instances and negative instances. Positive instances contain all features of a concept class which also follows rules of combination – simple, conjunctive, disjunctive, and relational "you and I" are positive instances of the concept "person."

Negative instances contain all features which are not part of a given concept. "You and I" are the negative instances of the concept "cow." For exact understanding of a concept, a learner must have to identify both positive and negative instances of a given concept.

Teachers should teach a concept first by defining features of a given concept and must provide numerous positive instances of a concept class and also negative instances of what the concept is not.

Failure to recognize all negative instances leads to undergeneralization (when some positive instances are not classified as a concept member), and failure to recognize negative instances leads to overgeneralization (when even some negative instances are considered as positive instances).

7.4.6 Schemas and Scripts

Concept is the simplest way to organize the knowledge of the world around, but the actual world is not that simple but is large and complex. Humans learn to grasp this complexity through schemas and scripts and personal theories.

Schemas are a connected set of concepts and facts related to specific objects and events. An example of schema is say about "FACULTY OFFICE" in an institute. Such schema affects how we perceive and remember new situations. When we visit a faculty office, we look around through the connected network of concepts such as desk, chair, and shelves. Scripts are schemas about events such as what goes on in a restaurant or in dispensary.

Schemas and scripts reduce information overload on WM by focusing on things according to schemas and scripts when they process objects and events. Schemas and scripts also help people to organize their experiences and use it to predict and interpret in the future.

7.4.7 Personal Theories

People use different ways of understanding the world around. One way is to understand in the ways useful to them by aligning themselves with day-to-day observations of physical, organic, and social environment and develop theories about how objects and events behave and are related to each other. He/she knows that a physical object can be converted from a coffee pot to a bird's feeding pot, but one cannot convert a rabbit into a mouse.

Concepts people form are influenced by such personal theories about how the world works. When people come to develop personal theories about the social world, they develop theories which help them to deal with the social groups in order to survive. One such theory currently dominant in education is the general assumption that learning and teaching can be learned by practicing on the job. It still persists, even though there is criticism about the quality of education because it suits the educationists as they can carry on their activities smoothly and without debate.

In general personal theories are about physical, organic, and social world based on their observation of their usefulness in carrying out their daily/routine activities smoothly, but they may not be in line with the real scientific theories.

7.4.8 World Theory

People's personal theories are restricted to a particular domain, i.e., physical, organic and social world. People's worldviews in contrast are a general set of beliefs and assumptions about reality on a wide variety of phenomena. For example:

- Life and universe came into being through random acts of nature or as part of divine plan and purpose.
- Objects in nature like rocks and trees have some degree of consciousness or are incapable of consciousness.
- People's success and failures in life are results of their own actions or divine intervention or random occurrence.

Worldviews are culturally transmitted through adult's day-to-day interaction with one another. These are integral part of one's life and taken for granted. Hence this knowledge is implicit but it influences the behavior.

However, there are many worldviews that impede learning of the classroom subjects. For example, a learner who assumes that his success in examination depends on God's help alone prays to God instead of working systematically applying scientific principles of learning. When the teacher notices these worldviews, he/she should strive to bring about conceptual change in both personal theories and worldviews.

7.4.9 Challenge to Promote Conceptual Change

The conceptual change is a challenging task for both the teachers and the students because:

- People are comfortable with existing beliefs and always look for information that confirms their existing beliefs and ignore contradictory information.
- Many beliefs are integrated into a coherent set of beliefs with many interrelationships among them. Changing any misconceptions involves changing an entire body of organized knowledge, for example, changing earth-centered view of the earth, sun, and stars revolving round the earth.
- Often these beliefs are integral part of one's culture and religion and hence almost impossible to change due to emotional involvement.

7.4.10 Promoting Conceptual Change

To bring about conceptual change, the teacher should:

- Determine students' current beliefs about the topic taught by informally asking him/her or by administering pretests.
- Teach scientific knowledge more meaningfully by bringing in it contradictions with students' old knowledge and process in depth.
- Provide them with evidence that blatantly contradicts their existing beliefs thus creating cognitive dissonance. Such dissonance can be created by organizing new experiments, demonstrations, hands-on experience, and better explanations by the teachers, allowing students to think and promote self-reading habits, discussion and debates, seminars, etc.
- Help students to bring their existing beliefs and new scientific knowledge simultaneously in their WM for conscious comparison.
- Monitor students' understanding of new knowledge and skills throughout the year.

7.5 Part III – Long-Term Memory: Retrieval and Forgetting

Students should learn to retrieve stored information systematically. Retrieval works in certain ways. Retrieved knowledge from LTM can only be selective and not exhaustive. One cannot search the whole knowledge from LTM for finding a particular portion of that knowledge one wants to use for making new information meaningful. The prerequisite for this in the first instance is to store knowledge in an organized form of network of concepts.

Having done this, make use of retrieval cues. Where to find cues are hints about desired information in LTM. There are four types of cues, namely, identity cues, associate cues, frame cues, and contextual cues.

- Identity cues are labels which are identical to the labels one has used for storing information.
- Associate cues are generally category words that relate themselves to the specific word one is looking for. For example, a concept word "clothing" brings to the mind specific items like hat, shoes, shirt, and trouser, and one might be looking for "shirt."
- Frame cues are organizational structure which guides to search for information and provide numerous cues. Where natural organization structure is not available as in the case of isolated facts, the structure is imposed by employing mnemonics. For example: F/Y = E/R = M/I, i.e., F, Y, E, R, and M are parts of bending equation. The equation can be learned and stored as For Your Easy Remembrance Mug it.
- Another example may be regarding minerals. Minerals can be metal and stones. Metals may be rare, common, and alloys. Stones can be precious and for masonry, and similarly this can be further extended, stored, and retrieved.
- Contextual cues are cues which refer to the physical environment in which the knowledge is originally acquired. For example, divers remember things better when they are under water rather than when on shore because they learn many things when they are under water.

7.5.1 Construction and Retrieval

Students must remember that during retrieval they only retrieve a small portion of knowledge and the rest they themselves fill up by what seems logical or consistent with their existing knowledge and beliefs about the topic. Hence students are required to be careful to check the accuracy of the retrieved knowledge and avoid distortions. There are external ways to ensure accuracy of the retrieved information as explained later regarding this.

7.5.2 Forgetting

Information stored in LTM gets more difficult to retrieve if students tend to forget what was stored in LTM. Students tend to forget because of several reasons. It simply decays if not used for a long time. Often information is stored with few connections. There is a tendency to repress information that creates anxiety and is never therefore retrieved. Finally some information never gets really stored in the first place or if stored was never consolidated by repletion and review. It is therefore necessary to bear in mind to keep on revising from time to time the stored information for its application at appropriate time.

7.5.3 General Principles of Retrieval During Instruction

- Teachers are expected to present information in an organized form – hierarchy, propositional network, cause and effect relationship, and concept maps. Students are required to store this information in similar form.
- Teachers should bring to students' attention the right way to retrieve information about any topic.
- Teachers should ensure that general concepts and principles should be related to various situations in which students are likely to use these in their daily life.
- Teachers should help students to devise various external cues such as maintaining information in diary calendar, for example, writing appointments, meetings, and also revising weekly. Also they should keep on reminding them regarding the assignments.
- It is important to conduct review of the knowledge previously learned by asking students both lower-level and higher-level questions.
- Teachers should remember that retrieving information for answering higher-level questions needs time. Give time to students to search for information and solve the problems. Such exercises should be conducted from time to time.
- Classroom assignment/seminars after every 2–3 weeks at undergraduate level encourage students to review and reflect on information learned.

7.5.4 Metacognition, Self-Regulated Learning, and Study Strategies

Meta cognition is the students' knowledge about their own learning process/style such as: how they learn in stimulus-response situation, by observations and limitations, use of cognition for perception of environment, processing of information using memory for acquiring new information, development of knowledge such as declarative and procedural, to store and retrieve this knowledge for use in their daily lives, to control emotions and feelings during the process of learning, and to keep motivation to continue learning for one's entire lifetime.

Educationists now believe that students should be taught about this metacognitive knowledge along with their subject teaching. They believe that this knowledge will help students to take control of their learning. Taking control of their own learning means learning to set their own goals and standards and to control their motivation to learn and emotions to maintain continuity of learning, attention control, self-monitoring of learning process, seeking external help when needed, and self-evaluation of results of learning.

Such self-regulated learning develops when students get opportunities to study independently and get exposure to self-regulatory models like teachers, parents, and peers. Teachers must help students to set their goals, focus attention, choose learning strategies, and monitor progress. Over a period of time, students become self-regulated learners.

The students must know what exactly is meant by "strategy." It is intentional use of one or more cognitive processes to accomplish a particular task. Effective learning strategy includes:

- Meaningful learning and elaboration
- Internal organization of new material
- Note-taking
- Identifying important information from instructions and reading materials
- Summarizing
- Comprehension monitoring by frequently asking low- and high-level questions
- Employing mnemonics to organize isolated information

However, adopting such techniques of an intentional learner by students often is delayed, or even obstructed, if they develop inaccurate beliefs about the sources of knowledge. These beliefs are called epistemological beliefs. Such beliefs are always two dimensional:

- The certainty of knowledge imparted by the teacher or experts [either certain or uncertain]
- Simplicity of knowledge structures [knowledge is either discrete or complex and integrated]
- Sources of knowledge [either teachers or experts or constructed by the learner]
- Speed of learning [knowledge is learned quickly or gradually]
- Nature of learning ability [learning ability is fixed at birth or learning ability is in learner's control and can improve with practice]

7.6 Effects of Epistemological Beliefs on Learning

- **Beliefs regarding certainty of knowledge:** students, who believe that the information received by them from a teacher is final, jump to the conclusions based on this knowledge. Those who believe that even expert's knowledge is subjective learn critically and meaningfully and are ready to undergo conceptual change.
- **Belief regarding simplicity of knowledge and its structure:** students, who believe that knowledge consists of discrete facts, learn knowledge in a rote fashion. Those who believe that knowledge is complex and integrated learn it meaningfully and organize it internally and elaborately during the study.
- **Beliefs regarding the source of knowledge:** Learner who believes that knowledge exists outside him/her and resides in experts will remain a passive listener. Those who believe that knowledge is ultimately acquired by the leaner himself/herself become an active learner and learn new information meaningfully.
- **Beliefs regarding criteria for determining the truth:** A learner who believes that the knowledge of experts contain the ultimate truth will generate passivity. Those who believe even experts' knowledge is subjective treat the knowledge with a critical mind.
- **Belief in the speed of learning:** Students who believe that one can learn quickly are satisfied with a single reading. In the event of failure to understand, gives up reading or dislike the topic/subject/course of studies. Those who believe that learning is essentially gradual continue their efforts to understand.
- **Belief in the learning ability:** Those who believe that learning ability is fixed at birth give up challenging tasks. Those who believe that learning ability is in their control pursue a variety of learning strategies, till they master the subject.

To sum up, students with advanced epistemological beliefs believe that knowledge is complex, learning is gradual, and learning ability is in their control. They make high-level achievement in the class, bring even more advanced view of learning and knowledge, acquire advanced integrated set of ideas, and continue to search for the truth.

7.6.1 A Case Study

In one of the class session of 'Structural Design', teacher solved a problem and arrived at the quantity of steel required in a beam and converted the amount of steel required in to number of bars as well as working out section of the beam for a particular loading condition. One student asked the teacher that sir, if we use only one bar equal to total number of bars in the centre of the beam, will beam fail? Teacher said that beam may fail or not but you will fail. After getting snubbed, the student asked that sir excuse me, if we don't add steel how the beam will fail? Teacher asked the student to get out of class. These are the situation of discouragement when teachers themselves have never conducted actual research in the laboratories.

It is a long story.

Interestingly what is true of students is also true of teachers. Many teachers believe that knowledge and abilities are fixed, teach and assess students accordingly, ask lower-level questions in testing and assignments to prepare them for qualifying a paper pencil test to solve five questions out of eight for the award of a degree, which is the glamour of the society.

7.6.2 The Intentional Learner

Truly, effective learning is intentional. It involves intentional use of cognitive processes and engagement in cognitive and metacognitive activities directed at thinking and learning something, setting goals and objectives, and setting many learning strategies. The learner is thus in a driver's seat with the teacher by his/her side with a roadmap and considerable knowledge about how to drive a car.

7.6.3 A Case Study

> This author was pursuing his M.Tech. in civil engineering at Punjab Engineering College Chandigarh. There was a subject called 'Foundation Designing'. This subject was to be taught by Late Professor KL Bhanot. He was a teacher and researcher who would involve students in the self-directed process of learning. He wanted that students should have conceptual understanding of concepts, principles and procedures to shape them as intentional learners. When the class of Foundation Engineering came up, he told the students (15 in number) that he is not going to teach until each student solve 35 problems of undergraduate level. He told that we need not to come to him at study at our own level to find solution to the given 35 problem as prerequisite to undergo a course in Foundation Engineering at Post-graduate level. Those who solve these problems in total may see him for conducting a pre-test. We were allowed to consult each other to find solutions to the given problems. Moment 6 or 7 students approached him regarding their understanding of these problems; he will ascertain individually whether students understand the concepts and principles involved, he will now assign a task to conduct soil investigation of a live building to determine safe bearing capacity of soil by all students. When students would have completed this assignment, he would ask for work out design for the foundation of a column as per loading conditions. He will provide hints/guidance wherever students felt the difficulty. Through this process he ensured that students develop clear understanding of concepts, principles and procedures in the students coupled with self learning and problem solving skills in almost all students. Such a strategy became instrumental that learning becomes permanent part of LTM.

Intentional learning also involves learning many basic processes as explained in above case study at the level of automaticity, such as retrieving word meaning and connecting ideas to similar ideas in LTM, but overseeing the process is carried out by a conscious goal-directed learner using a variety of learning.

And study strategies, deciding what to focus on and how to make sense of new information, drawing references for use in his/her own life circumstances.

Intentional learning is especially important when conceptual changes are needed which involves

- Attending to and thinking about new information; notice discrepancies between it and his prior knowledge.
- Making considerable effort to acquire mastery of new subject matter as explained in above case study.
- Bringing to table a variety of learning and study strategies that maximize changes of revising the current beliefs and bring students in line with scientific concepts.

7.7 Why Students Are Not Motivated to Learn?

There are so many reasons in respect of this. One of the most important aspects is that higher education is teacher centered whereby nobody is interested in developing students are lifelong learners. Observations reveal that the focus is on passing the information to qualify an examination and not on learning/development of students as professionals by a large number of institutions offering undergraduate/postgraduate courses. Most of the faculty lack domain-specific knowledge and skills as well as understanding of pedagogical principles highlighted in this chapter.

Students are also casual. It has been experienced that 10–20% of students on a daily basis are found absent because they don't find teaching-learning process meaningful and motivating. Neither faculty nor students are not focus directed to achieve competencies to develop cognitive, psychomotor, and affective domains.

Barring some institutes of national importance, Head of Institutions and Senior Professors mostly seen sitting in their offices, more or less having no concern about what is happening in the classes. Practical work is not given desired seriousness because of the emphasis of evaluation in the current scenario. Students therefore get bored in such a scenario.

- Besides above, some of the pedagogical aspects are either uninformed or misinformed about effective strategies of learning.
- They have epistemological beliefs that lead them to underestimate or misrepresent a learning task.
- Students often have mistaken belief that they are already using effective study strategies.
- Often students have little prior knowledge of the subject from which they can draw meaningful learning.
- Often teachers do not give learning task that lend the students' use of sophisticated learning strategies by asking them only lower-level questions.
- Majority of students somehow have a goal of passing examinations as mentioned above.
- It is also true that most of the students think that sophisticated thinking like solving open-ended problems or an attempt to undertake a live problem as project

work or innovative something, etc., requires too much time and energy and is not worthwhile.

There are so many other reasons like lack of proper planning of curricular, cocurricular, and extracurricular activities at macro and micro levels for overall personality development of students. This is also because majority of students and faculty are residing outside the campuses and only attend the institutions from a specified time of instruction.

7.8 Theories of Knowledge Construction

7.8.1 Levels of Development

Knowledge is constructed/developed by individual learner, community of researchers, and team members at the workplaces at individual, level, and workplace level which is entirely dependent on existing knowledge in LTM which is briefly touched below:

Individual level: At the individual level the knowledge constructed/developed by the learner is an **idiosyncratic/individual competency** and may not be in tune with what the teachers want to convey. If the student persists in maintaining misconceptions, then he/she will not learn scientific knowledge. When students pass his/her examination somehow, he/she forgets his/her knowledge. Therefore, teacher should examine student's prior knowledge, detect his misconceptions, and correct these.

Collective level: At the collective level, the researchers discover laws of nature and invent new products and processes. This knowledge is publically shared by all researchers and passed on to the younger generation as a more valid and reliable knowledge.

Local level: At the local level at the workplaces, the teams develop its own knowledge about their own products, and services developed by team members are not shared publically.

It is necessary for both teachers and students to know that the nature of knowledge developed at each level has its own role to play. What however more important is to know that all these levels employ principles of learning described in the chapter.

7.9 Promoting Effective Learning in Higher Education

Promoting effective learning in higher education depends on the competency of faculty in domain-specific knowledge and skills, relevant industrial/field experience, understanding of educational objectives, neurological/mental process of learning, and use of appropriate instructional strategies. These aspects are briefly discussed below.

7.9.1 Role of Faculty in Effective Learning of Learners

The author based on his experiences considers that the faculty in higher education, particularly in the case of technical education, is required to be clear in respect of following effective instruction to conceptual change and conscious learners.

- Clarity/mastery of discipline/domain-specific concepts, principles, procedures, and applications both in theory and in practice. Without these domain-specific competencies, what is described in this chapter may not be converted into action. Besides this, the faculty is required to possess appropriate industrial/field exposure to relate teaching-learning process with actual workbench requirements, i.e., world of work. Further, he/she is required to supplement experiences gained to offer consultancy to the industry in the respective areas of specialization for developing sophisticated/higher-order problem-solving/innovative skills in the students. This will help the teacher to relate the instructions with actual requirements.
- Practice for mastering subject matter must be continued on an ongoing basis.
- Faculty must be clear about Educational Objectives sated by Bloom and others. Educational objectives lay considerable emphasis of developing learners in cognitive, psychomotor and affective domains. These have been further analyzed in the development of acquisitive skills, adaptive skills, operative skills, and innovative skills for making the learners effective in the world of work which are briefly described below

  – **Acquisitive capabilities:** The capability to acquire knowledge of technologies depends on the ability to search for, assess, and transfer technologies for effective functioning in various functional areas like R&D, design and drawing, planning, shop floor management, quality control operations, repair and maintenance, marketing and sales, etc. To acquire acquisitive capabilities, students primarily require learning-to-learn skills, some aspects of which are:

    Willingness to learn continuously and grow in the identified domain
    Doing self-analysis to assess one's strengths and weaknesses
    Setting learning goals for oneself
    Scanning for and access learning resources from various sources
    Organizing one for self-learning and achieving the goals
    Not to be satisfied with what one knows
    Have the urge to learn continuously

- **Adaptive capabilities:** This relates to the ability to modify existing processes or product design so that the process is better adapted to local factors and the product reflects local market preferences. In addition to making use of new machines and technologies, this will necessitate computer handling skills. Presently, technical education is lagging far behind including new technologies, processes, and equipment in the teaching-learning process. In addition, students must be proficient in the following:

  Use of available graphic tools like AutoCAD
  Use of software to make effective computer-based presentations
  Familiar with and use of various patented softwares and programming language
  Use of the Internet effectively to gather information and exchange information with others

- **Operative capabilities:** This involves shop floor know-how, knowledge of codes and standards, management techniques, industrial engineering, diagnostic skills, communication, and interpersonal skills.
- **Innovative skills:** This involves the ability to anticipate future demands and to develop new designs, prototypes, processes, and technologies. This will require problem-solving skills which will require understanding of the following aspects:

  Clarity of domain-specific concepts and principles.
  Recognize various parameters related to the problem.
  Find innovative solutions based on the root cause of the problem.
  Evaluate alternate solutions and implement the solution for evaluating its impact.

• Clear understanding of "pedagogical principles" discussed above for planning and delivery of instructions in a logical way, converting teaching into learning by making use of appropriate strategies. Students learn more effectively when appropriate strategies are put to action within the context of any subject matter and specific learning tasks. For this purpose it is essential that teachers are required to understand the implication of various learning experiences to develop appropriate competencies in the students as per educational objectives (see Fig. 7.2).

It is observed from above diagram that student-centered learning experiences like well-planned tutorials, laboratory/workshop sessions, seminars, industrial training, and project work lead to convert teaching into learning for conceptualizing concepts, principles, and procedures taught in the classroom by lectures which become instrumental in developing intentional learners.

Further, teachers must also understand that instructional process is not a one-way traffic. Continuous teaching becomes boring. The rate of learning and cumulative learning is a nonlinear function. The maximum attention span of an adult learner is about 15–20 min. See Fig. 7.3 for details.

Desired Learning Outcomes	Learning Experiences that can be used to achieve desired learning outcomes					
	LECTURE	TUTORIAL	LABORATORY, WORKSHOP	SEMINAR	INDUSTRIAL TRAINING	PROJECT WORK
1. Knowledge/Remembering	●			●	●	●
2. Comprehension/Understanding	○	●	●		●	●
3. Applying	○	●	●		●	●
4. Analysis/Problem Solving	○	●	●		●	●
5. Evaluating			●		●	●
6. Creating			●		●	●
7. Learning to Learn				●	●	●
8. Report Writing			●		●	●
9. Psychomotor Skills			●		●	●
10. Communication Skills				●	●	●
11. Interpersonal Skills					●	●
12. Attitudes & Values	○		●		●	●

Legend ○ Partly achievable ● Fully achievable

Fig. 7.2 Relationship between learning outcomes and learning experiences

Instead of continuous teaching beyond 20 min, variations of stimuli like asking questions, giving demonstrations, etc., are essential to maintain the attention and interest of students. Teachers are expected to ensure that the entire teaching should be based on existing knowledge of students required to impart new knowledge. Matching eye with also students and recapitulating the teaching from time to time are also important aspects.

- Appropriate communication skills (written, oral, listening, body language), i.e., ability to communicate, presentation skills in a variety of formal and informal situations for creating appropriate environment and drawing attention of the students during the presentation, blackboard writing skills for developing the subject logically for proper comprehension by the students, and motivational skills for creating a climate of better learning and promoting confidence and optimistic attitudes in the students are other competencies of effective instruction.

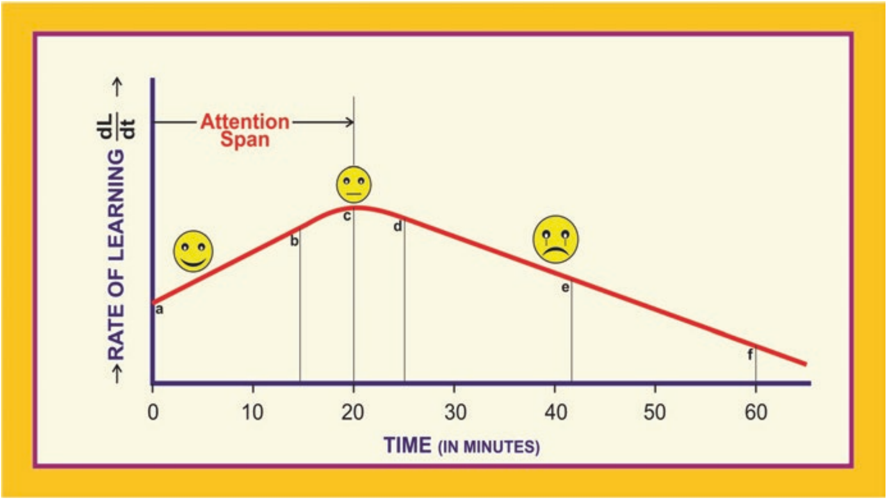

Fig. 7.3 Rate of learning

- Research methodology/problem-solving skills for generating new ideas, developing prototypes, and motivating students toward discovery learning are other requirements of higher education toward meaningful learning, internal organization, elaboration, and visualization. Teachers are also expected to examine beforehand the epistemological beliefs of students and try to change those beliefs that impede learning.
- Maintaining punctuality, planning and time management skills for effective functioning, and playing a role model before the students for their professional and personal growth are others parts of teachers' responsibility.
- Principals and professors have other additional responsibilities besides teaching. They need different set of skills like institutional management, research methodology, curriculum processes, etc.

7.9.2 A Case Study

The author was working as Director Quality Improvement to train students and teachers in systematic learning with the aim of producing professions possessing lifelong learning skills by adopting appropriate strategies by adopting planned procedures. There were some successes and failures to. It was observed that teachers were filling the formality to plan lessons, maintain desired information. When coming to actual situation, no such strategies mentioned in this chapter (though transmitted/taught) to the faculty during actual teaching learning process because teachers and students are tuned to cover the course of studies with the aim of qualifying a paper pencil test to achieve maximum pass percentage of students for the purpose of advertisement to general public for greater admissions and not with the aim of producing professionals having appropriate competencies to design new products, prototypes, systems as per requirement of the world of work or community. One of the reason for such a shortcoming in the system of higher education that Head of Institutions

> and Heads of Department in majority of institutions take teaching-learning process very lightly and are also not competent in field of Educational Technology.
>
> Readers will be surprised to note that project work being so important is not given desired attention to produce self/intentional learners. One project was given to all the students, 55 in number under the guidance of only one teacher to conduct a normal task, not utilizing even 5% knowledge imparted to organize execution of project work. Some students who were active prepared a Project Report and other students had a copy of the project report well bound, with even knowing the title of the project assignment.
>
> This is happening in majority of institutions to complete a formality for award of degree qualification, for which the society has glamour.

Higher education thus needs overhauling. This has been considerably debated while formulating the New Education Policy 2020 for revitalizing higher education in India.

The All India Council for Technical Education has also evolved a mandatory "Comprehensive Training Policy for Technical Teachers" comprising of eight modules, namely:

- Orientation Towards Technical Education and Curriculum Aspects
- Professional Ethics and Sustainability
- Communication Skills, Modes, and Knowledge Dissemination
- Instructional Planning and Delivery
- Technology Enabled Learning and Lifelong Self-Learning
- Student Assessment and Evaluation
- Creative Problem-Solving, Innovations, and Meaningful R&D
- Instructional Management and Administrative Procedures

It is expected that senior administrators take this policy for the development of faculty to produce appropriate technical manpower.

7.10 Conclusion

People working within and outside the system of higher education require changing their mindset toward teaching-learning in higher education which is currently focusing on attaining a degree qualification by passing an examination only. Students, teachers, and educational managers consider that their knowledge about learning and teaching is derived from their experience on the job. Unfortunately, very few of these beliefs are publically debated. Thus the educational practices thrive on the belief that the skills described in this chapter come to them automatically while practicing on the job. They are not aware of the scientific basis of how learning occurs as a neurological/mental process of conscious learning. Very few educationists can be convinced today that they need to make an effort to learn first and then teach students how to learn. New steps are being taken by the Ministry of Education and All India Council for Technical Education in this direction, as briefly described above.

Bibliography

AICTE. (2019). *A comprehensive training policy for technical teachers*. New Delhi: AICTE.

Bloom, B. S., et al. (1956). *Taxonomy of educational objectives-cognitive domain*. New York: David Mckay Co.

Bloom, B. S., et al. (1979). *Taxonomy of educational objectives-affective domain*. New York: David Mckay Co.

Bowden, J., & Marton, F. (1985). *The university of learning*. London: Kogan Page.

Flavell, J. H. (1985). *Cognitive development* (2nd ed.). Englewood Cliffs: Prentice Hall.

Kulkarni, P. D. (2012). *Overview of contemporary theories of learning applied aspects of educational technology*. New Delhi: S. Chand & Company Ltd.

Merrill, M. D., et al. (1992). *Educational technology publications* (2nd ed.). Englewood Cliffs: Educational Technology Publications.

Mittal, L. N. (2018a). Character of national university – A conceptual frame framework. *Tattva-Journal of Philosophy*, *10*(2), Christ University, Bengaluru. ISSN 0975-332X.

Mittal, L. N. (2018b). *Mitigating deficiencies of technical education*. Nashik: Cognifront Publishers.

Ormrod, J. E. (2008). *Human learning* (5th ed.). Columbus: Person/Merrill Imprint of Harper Collins.

Chapter 8
Starting from the Roots of Teacher Education: Inclusion of Educational Neuroscience in Teacher Training in India

Sruthi Suresh, Joseph Varghese Kureethara, and R. Vijaya

8.1 Introduction

Teacher training refers to the process by which students enrolled in the course are taught how to teach. In India, one of the courses that offer this training is Bachelor of Education, which forms the necessary qualification to become a teacher in most schools. This 4-year, 2-year, or 1-year course teaches students various subjects, including aspects of the teaching-learning process, understanding the nuances of handling different children, and India's educational system's foundational elements. They are also trained practically in the field through internships.

With the recent introduction of technology into education, there has been an increase in research into online learning or e-learning. Further, with the current COVID-19 situation, most educators have been forced to learn and adapt to the online learning environment. The India Report-Digital Learning, which was released by the MHRD in June 2020, has also indicated several initiatives taken by the government to train teachers and students to use digital learning technology. Therefore, the previous need to examine training in this field has reduced. In light of this, the next step is to investigate the role of neuroscience in learning.

Educational neuroscience is the field that deals with applying neuroscience concepts to the field of education, both in practice and through policies. Using educational neuroscience, techniques to enhance the teaching-learning process are developed based on research findings on brain mechanisms. It further aims to

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broaden one's understanding of the process of learning for students with different abilities (Thomas et al. 2018). One such component of educational neuroscience is social-emotional learning (SEL). It refers to a holistic approach to a child's development focusing on the five core competencies, viz., self-awareness, self-management, social awareness, relationship skills, and responsible decision-making (CASEL n.d.).

The next question that arises: is the inclusion of neuroscience in education necessary? Miller and Tallal (2006) aptly summed up the answer to this question as:

1. There have been significant breakthroughs in the field of neuroscience.
2. The power of technology has been increasing and so has its influence in the field of education.
3. There is dissatisfaction with the current e-learning approaches.

Therefore, it indicates that there is also an increasing need for more effective teaching methods with learners' growing needs.

Recent national and international policies also stress on the inclusion of multidisciplinary approaches and training in the latest advances in the field to improve the standard of education. In the 2030 Agenda for Sustainable Development (2015) the SDG 4.7 is to "ensure all learners acquire knowledge and skills needed to promote sustainable development, including among others through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development" by 2030. The Annual Report 2019: transforming twenty-first-century learning spaces, through the collaboration of UNESCO with the Mahatma Gandhi Institute of Education for Peace and Sustainable Development (MGIEP), acknowledged the importance of neuroscience in education to meet this goal by stating that, "The seat of all learning is the brain." Further, reviews and assessments have been conducted by UNESCO MGIEP in 2018 and 2019 to measure and monitor the progress toward achieving the target SDG 4.7. These reviews highlight the importance of holistic development for children and imply the use of social-emotional learning (SEL) in fulfilling SDG 4.7.

The National Educational Policy (2020), brought out by the Ministry of Human Resource Development, Government of India, also recommends, in the point 15.4, the collaboration of B.Ed. programs with other departments, including neuroscience. Further, the UNESCO document on the First Meeting of the International Commission on the Futures of Education (2020) recommended that "more thinking could be devoted to the possible forms that bottom-up change and calls to action could take." This statement suggests that future research should focus on developing plans of action through an evidence-based approach. Therefore, the path forward is clear; conduct more research on educational neuroscience and use the results to formulate relevant plans of action.

8.2 Need for the Study

Some of the latest national and international policies point out the need to improve the standard and goal of education, thereby encouraging the inclusion of multidisciplinary approaches to education. One of these approaches is educational neuroscience. To promote the use of educational neuroscience concepts in education, it is necessary to bridge the gap between laboratory research and application in a classroom setting. Scientists can not use educational neuroscience techniques in real classrooms, and educators cannot do so appropriately due to the lack of training. Therefore, it is suggested that experts trained in the field of neuroscience and education need to work together. An example of such a program is BrainU, where teachers are trained in the neuroscience learning concepts and apply the concepts flexibly as per the requirement of their students (Dubinsky et al. 2013). Due to the easy accessibility of knowledge, it can be effortless for someone to be an Internet-educational neuroscience expert. However, in order to effectively apply and test educational neuroscience techniques, proper training is required.

In order to do so, the most effective pathway would be to include educational neuroscience concepts in the teacher training curriculum, thereby ensuring that the upcoming generations of teachers are well equipped to meet the needs of future learners. As rightly pointed out by the Indian Human Resources Development (HRD) Minister Ramesh Pokhriyal Nishank, “Teachers are the pillars of the society, but it is important to upgrade their skills and ensure that they are trained in the best way. This is only possible in collaboration with teacher education institutions, which play a key role in their actual transformation.” (“HRD ministry” 2019). Furthermore, it will also provide a foundation for future collaborative research to investigate the real-life effectiveness of these concepts. Resultantly, there is a need to understand the awareness and openness of current B.Ed. students toward educational neuroscience. It is also essential to consider their opinions on the inclusion of these concepts and their relevance in the teacher training syllabus and their classrooms.

8.3 Review of Literature

Miller and Tallal (2006) has aptly summed up the need for neuroscience in education. The requirement to examine the existing literature on strategies, interventions, and evidence is helpful in this context. Such a study was conducted by Cherrier et al. (2020), which investigated the effectiveness of using neuroscience-based interventions on school performance among adolescents. These researchers developed the Neuroscience and Strategies in Education (NeuroStratE) intervention tailored-made for adolescents, focusing on cognitive and executive functions tied to educational success. The study used pre- and post-test evaluations to compare the intervention group to a control group, who learned the same content but using different approaches. The results of this study did not indicate any significant differences in both the groups; however, it did indicate that the NeuroStratE intervention contributed to the self-reliance and self-knowledge of the learners. One of the drawbacks of this study, however, was that the teachers themselves were learners, and hence their implementation of the intervention could have influenced the results.

The results of this study show that such interventions can be useful, but the teacher's training or expertise also plays a role. In order to guide the training of teachers in these strategies, Zadina (2015) outlined the role of educational neuroscience, based on existing evidence, in informing curriculum choices and informing professional development and classroom strategies. Based on her analysis, she suggested that although this field "may not yet tell us how to teach per se, it does inform teaching, learning, and school reform." Further, she says that there may be difficulties faced when bridging disciplines; however, by building these bridges effectively, neuroscientists and educators can work together toward transforming the teaching-learning process.

When these professionals work together, the next step to be examined is how scientific strategies can be tested out or implemented in a classroom setting. This concept was discussed by Thomas et al. (2018) under "future prospects and policy implications" of educational neuroscience. They pointed out that new strategies derived from randomized controlled trials tend to be prescriptive. This nature can restrict the teacher's autonomy and ability to adapt techniques to individual learners, consequently reducing the resulting uptake. Hence, there is a need to enable the teacher to understand these concepts, which will promote better implementation of these strategies. This strengthens the argument that it is important to include educational neuroscience in teacher training and education.

The "Teacher Education" (as cited in Nautiyal and Sinha 2015) document brought out by the Indian ministry of HRD stated that teacher education is a crucial component to improving the learning achievements of school children. In order to train teachers, the twin strategy to be adopted is to (a) prepare teachers for the school system (pre-service training) and (b) improve the capacity of existing school teachers (in-service training). Therefore, educational neuroscience would best be taught in teachers' pre-service training, as its implementation requires thorough training.

Tan and Amiel (2019) conducted a case study in British Columbia to explore the role of teacher professional development in applying neuroscience to teaching instruction. They found that the teacher professional development programs not only acted as the apt platform to confront neuromyths but also encouraged better understanding and effective implementation of educational neuroscience techniques. Although the generalizability of the results is limited, this research and its conclusions can act as a guiding light to focus on new research and conduct relevant teacher professional development sessions.

In light of these studies, there is an indication that neuroscience can be beneficial in education. Teachers must be trained and have sufficient knowledge of the field to implement these techniques and evaluate their effectiveness. Further, there is a need for more research to help build relevant policies. This study aims to cater to this need by collecting relevant information from student-teachers, i.e., pre-service teachers.

8.4 Method

This study focuses on the awareness, opinions, and openness of student-teachers toward educational neuroscience concepts and techniques. This study uses a qualitative survey methodology to obtain in-depth information on the topic.

8.4.1 Objectives of the Study

The objectives of this research are as follows:

- To assess the awareness of student-teachers about the concept of educational neuroscience
- To determine the awareness of student-teachers about the techniques of educational neuroscience
- To understand the opinion of student-teachers regarding the utility of these concepts and techniques in the classroom setup
- To understand the view of student-teachers regarding the utility of these concepts and techniques for teaching their subject
- To know the interest of student-teachers in learning concepts and techniques of educational neuroscience
- To obtain the opinion of student-teachers regarding the current training and future suggestions for training in the field of educational neuroscience

8.4.2 Sample

The snowball sampling technique was used, and the researchers reached out to the network of contacts to collect data for the study. The study included 83 students (student-teachers) who joined the Bachelor of Education (B.Ed.) program in India in 2018, 2019, and 2020. Samples consisted of individuals from different subject backgrounds, states, qualifications, and with a different number of years of teaching experience.

Inclusion Criteria The inclusion criteria of the study are:

- Students of Bachelor of Education (B.Ed.) program
- Students who joined the course in 2018, 2019, or 2020
- Students who are studying in India

Exclusion Criteria The exclusion criteria of the study are:

- Students who have not provided consent to participate in the study
- Students who have not answered all the questions

8.4.3 Method

The data was collected using a Google Form developed by the researchers. The survey form included the following sections.

Informed Consent Form This section informed the participants about the study and sought their voluntary consent to participate in the study.

Demographic Details In this section, the participants' general details were collected, including gender, age, highest qualification, subject specialization, location in India, teaching experience, syllabus in which they taught, and the year they joined for the B.Ed. program.

About Neuroscience in Education This section stated the definition of educational neuroscience and measured how well the participants understood the definition and if they had heard about the concept before.

Techniques of Educational Neuroscience Four educational neuroscience techniques were introduced in this section. Participants were asked to indicate whether they were aware of these techniques and knew that these techniques came under the purview of educational neuroscience.

Educational Neuroscience in B.Ed. Training In this section, participants were asked about the utility of educational neuroscience techniques in general teaching and its relevance to their specific subject. Further, they were also asked to indicate their thoughts on whether these concepts were currently included in the B.Ed. program or if it should be included, along with the supporting reasons. There was this final question that was asked to the participants: "Who do you think is responsible for ensuring B.Ed. students are trained in educational neuroscience?"

Feedback for the Survey The final section asked the participants how far they felt the survey was informative and enjoyable. In the end, participants were also given a few links if they were interested to know more about educational neuroscience.

8.5 Data Analysis and Discussion

The data collected were both quantitative and qualitative, based on the individual questions of the survey. A total of 86 respondents participated in the survey. Of these responses, one response was removed as the participant did not provide consent, and two responses were removed as they did not indicate the year in which they joined the B.Ed. program. The remaining data of 83 participants was compiled and evaluated.

8.5.1 Demographic Details

In the demographic section of the questionnaire, specific details of the participants were collected. These questions served different purposes, such as:

1. To ensure only participants who had joined B.Ed. in the years 2018, 2019, and 2020 were included in the study.
2. To understand the participants' general characteristics such as gender, age, highest qualification completed, number of years of teaching experience, and location in India.
3. To collect information about the syllabus taught and subject specializations to inform the utility of educational neuroscience techniques across subjects and syllabi.

In the information provided in Table 8.1, most of the participants were females and postgraduates, and were in the age group of 21–24. This information indicates that the participants were well educated and young and could be more aware of the upcoming trends in their field. Further, only two participants had more than 4 years of experience, which suggests that the majority were just being inducted into teaching. This phase is apt for teachers to be introduced to the concept of educational neuroscience, as they will be the ones to teach future students, and they are more likely to be up-to-date with technological advances. Therefore, these sets of teachers can be trained in the next upcoming field of educational neuroscience.

As indicated in Fig. 8.1, the maximum number of participants were from Kerala, Tamil Nadu, and Karnataka. However, the study also included participants from Maharashtra, Goa, Rajasthan, Delhi, Himachal Pradesh, Uttar Pradesh, Bihar, Odisha, and Nagaland. All the same, the syllabus for the Bachelor of Education (B.Ed.) program is regulated by the National Council for Teacher Education and follows a similar structure throughout India. Consequently, the training and education received through the B.Ed. program will also be similar for all the students throughout India.

Out of the 83 participants who responded to the survey, only 26 participants had work experience; however, students undergo a teaching internship during the B.Ed. program; thereby, 64 participants have indicated their teaching experience in each

Table 8.1 Gender, age, highest qualification (completed), and number of years of teaching experience of the participants ($N = 83$)

Demographic	No. of participants	Percentage of participants
Gender		
Male	17	20.48
Female	65	78.31
Prefer not to say	1	1.21
Age group		
21–24	47	56.62
25–30	31	37.35
31–34	5	6.03
Highest qualification (completed)		
Undergraduate	31	37.35
Postgraduate	52	62.65
No. of years of teaching experience		
0	57	68.67
1–3	24	28.92
4–6	2	2.41

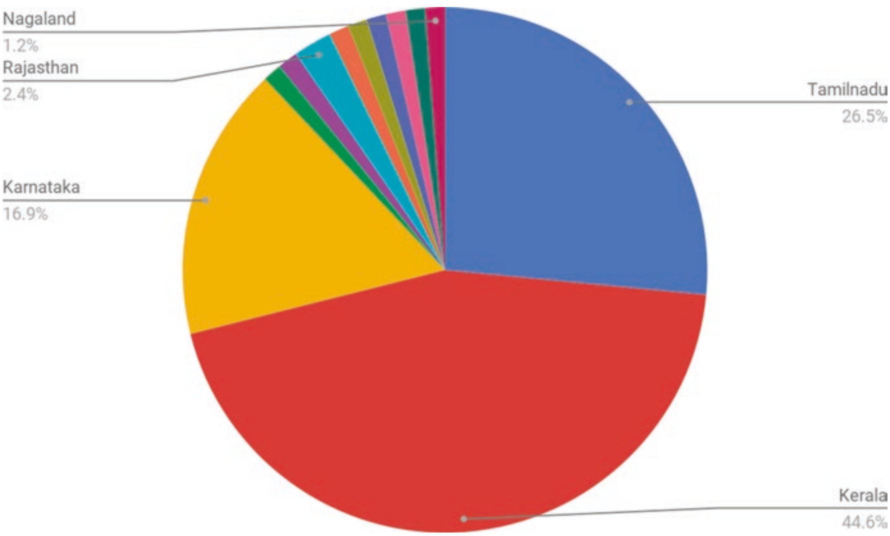

Fig. 8.1 Percentage of participants from different states in India ($N = 83$)

syllabus. Furthermore, some participants also had experience of teaching in more than one syllabus.

Through Fig. 8.2, it is evident that most participants had experience in teaching the State Board Syllabus. It can also be noted that the study has obtained participants who have experience in all the current syllabi being followed in India. Thereby,

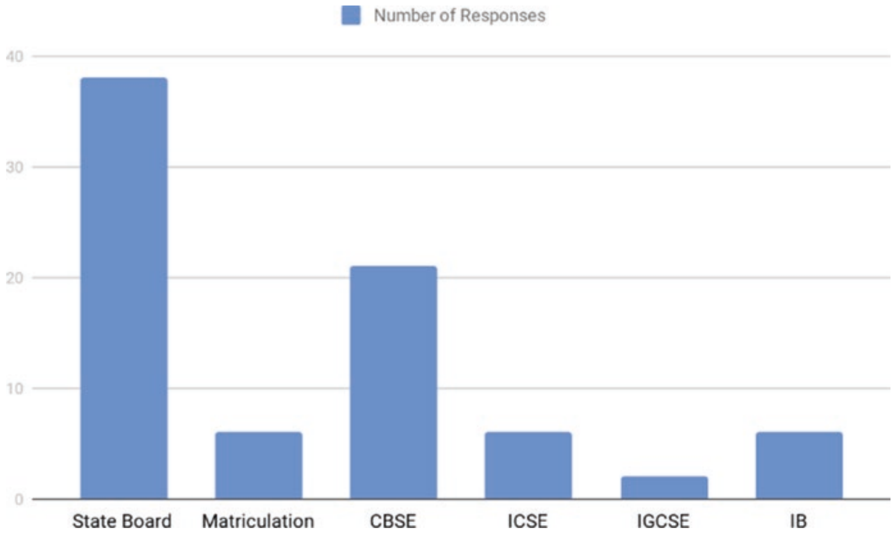

Fig. 8.2 Number of participants who had teaching experience in each syllabus ($N = 64$)

it helps us generalize the applicability educational neuroscience to all the prevailing syllabi, keeping in mind the relevance and utility of the same in each syllabus.

Figure 8.3 indicates that the participants in the study come from a wide range of disciplines. Some participants had more than one subject specialization as well. A majority of the participants were from English and Mathematics, followed by Botany, Chemistry, Zoology, Physics, and Psychology. These subjects are the most common ones found in schools, and hence the target group of the study is the right one to be made aware of and trained in the concepts of educational neuroscience. It also indicates that the group is heterogeneous, both in subject specialization and in the syllabus taught, which improves this study's generalizability to the target population of B.Ed. student-teachers.

8.5.2 About Neuroscience in Education

In order to understand the awareness the participants had about educational neuroscience, a definition of the concept was provided followed by two questions:

How well did you understand the definition of educational neuroscience? To be responded to on a 5-point scale of "did not understand at all (1)" to "understood completely (5)." A majority of the participants (49.4%) chose 4, indicating that most of them understood the definition to a certain extent.

Have you heard about educational neuroscience before? To be responded to from the options, yes, no, or maybe. Most participants (50.4%) responded with a "no" stating that they had not heard about this concept earlier.

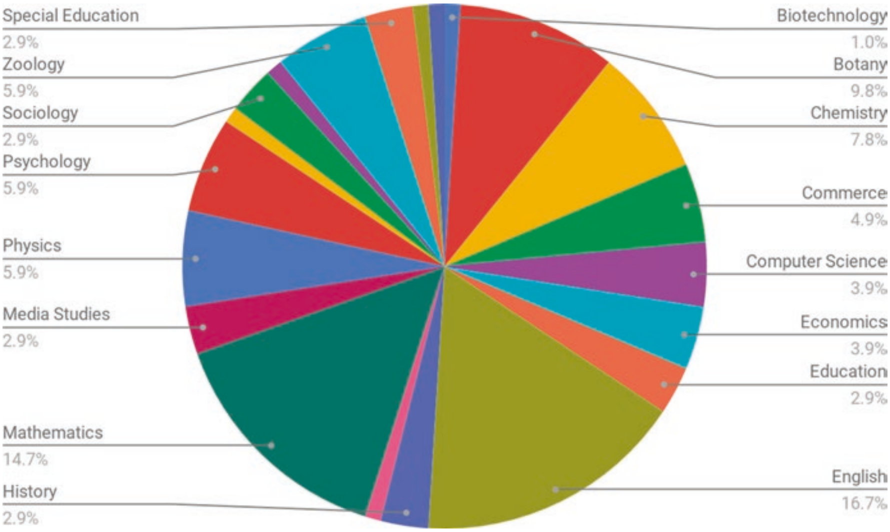

Fig. 8.3 Percentage of participants from each subject specialization ($N = 83$)

8.5.3 Techniques of Educational Neuroscience

To further understand whether the participants were genuinely unaware of these concepts, in this section, four examples of neuroscience techniques were provided, and participants were asked to rate their awareness of these techniques on a 5-point scale, where 1 indicated "I have never heard of this" and 5 indicated "I know this well." The examples given were:

1. Using real-world examples will help students understand concepts/ideas better.
2. Connecting a new concept with what the student already knows will help them learn better.
3. When students engage with each other in learning tasks, they remember the material better.
4. Repeatedly practicing/revising/revisiting what is learnt will help the students remember better.

In contrast to the lack of awareness indicated by the participants in the previous section "About Neuroscience in Education," most of the participants (an average of 56 participants) showed that they knew the concept well.

The participants were also asked, "Have you heard about these techniques before?" The options provided to respond were "Yes and I know it is educational neuroscience," "Yes, but I did not know it is educational neuroscience," and "No, and I can't recollect it." The results obtained are indicated in Fig. 8.4.

By comparing the results of this section with that of the previous section, it can be pointed out that although most of the participants were aware of such techniques

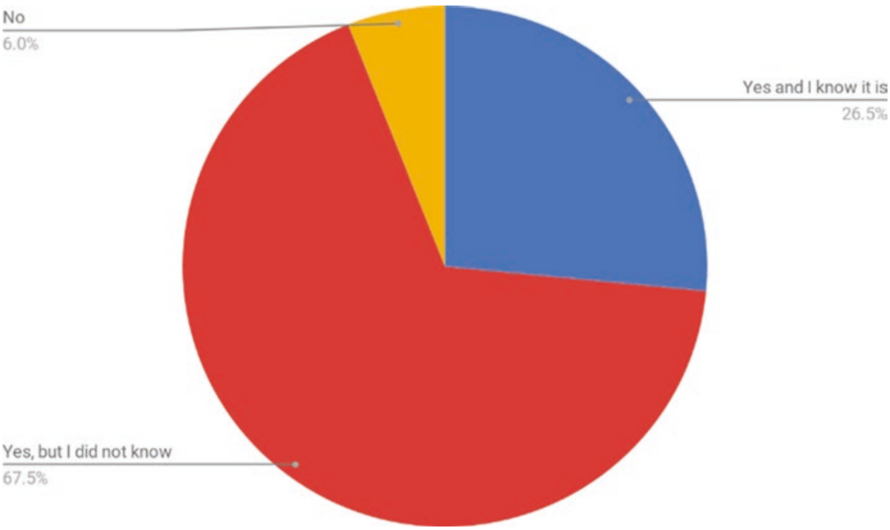

Fig. 8.4 Awareness about techniques of educational neuroscience ($N = 83$)

and concepts, they were unable to connect it to the field of educational neuroscience.

8.5.4 *Educational Neuroscience in B.Ed. Training*

In this section, participants were asked to rate the usefulness of these techniques, how interested they were to learn such techniques, and the relevance of these techniques to their specific subject. They were asked to respond to each of these questions on a 5-point scale ranging from "not at all useful/interested/relevant (1)" to "very useful/interested/relevant (5)." An average of 56 participants (67.5%) chose the higher end of the scale, indicating that they found these techniques very useful. They were very interested in learning these techniques and stated that these techniques were very relevant to their subject specializations.

The participants were also asked if educational neuroscience was currently included in the B.Ed. program, and if it wasn't, should it be included. The results obtained are indicated in Fig. 8.5.

The results in Fig. 8.5 indicate that most participants (45.8%) were not sure whether educational neuroscience concepts were included in the B.Ed. program, closely followed by 41% of participants who thought it was currently included. However, among the 76 participants who responded to the second question (Fig. 8.6), 84.2% stated that it should be included in the syllabus.

In order to follow up on this question, to understand why they wanted this inclusion, participants were given an option to state their reason. Out of the 38 reasons

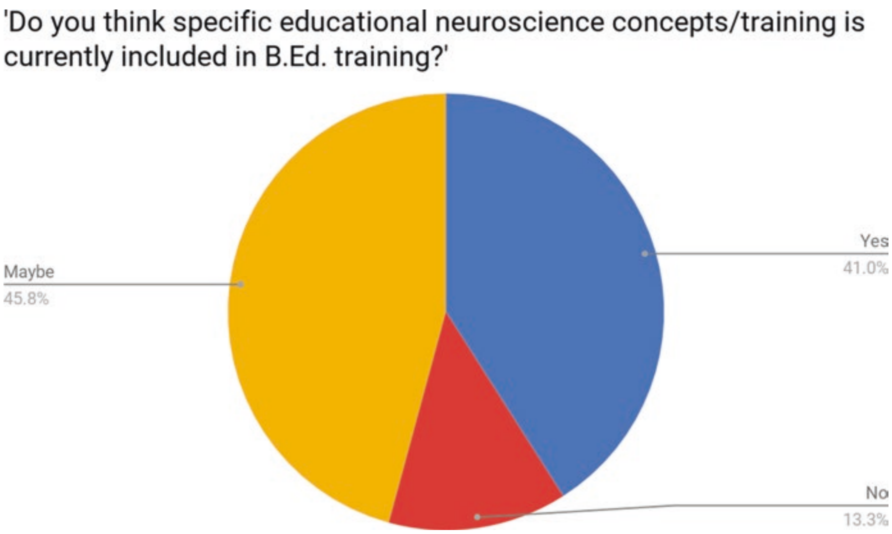

Fig. 8.5 Current inclusion of educational neuroscience in the B.Ed. program ($N = 83$)

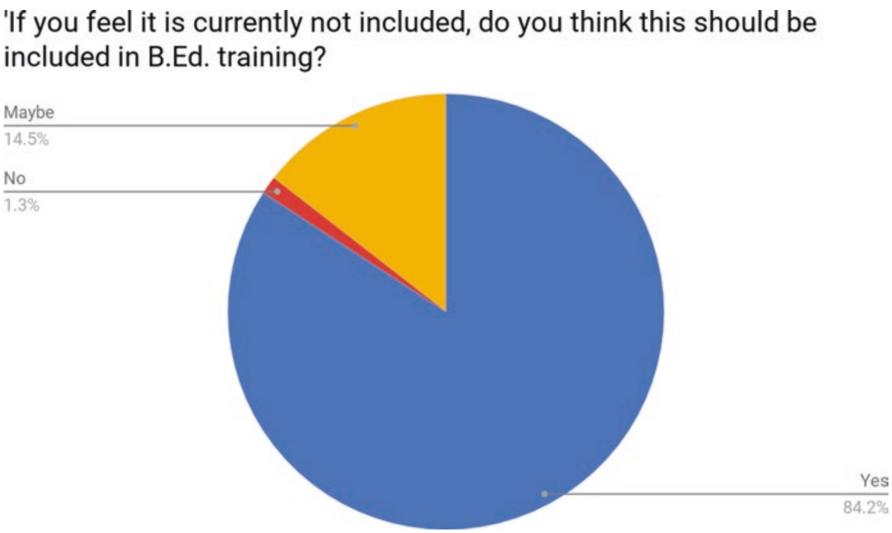

Fig. 8.6 Need for inclusion of educational neuroscience in the B.Ed. program ($N = 76$)

given in the response, the primary ideas were that inclusion of educational neuroscience techniques would help the student learn better, enable the teacher to teach more effectively, and improve the entire teaching-learning process.

The next question posed to the participants was regarding who should be responsible for the inclusion they had suggested. In this question, participants were free to choose any number of options. Based on the responses graphed in Fig. 8.7,

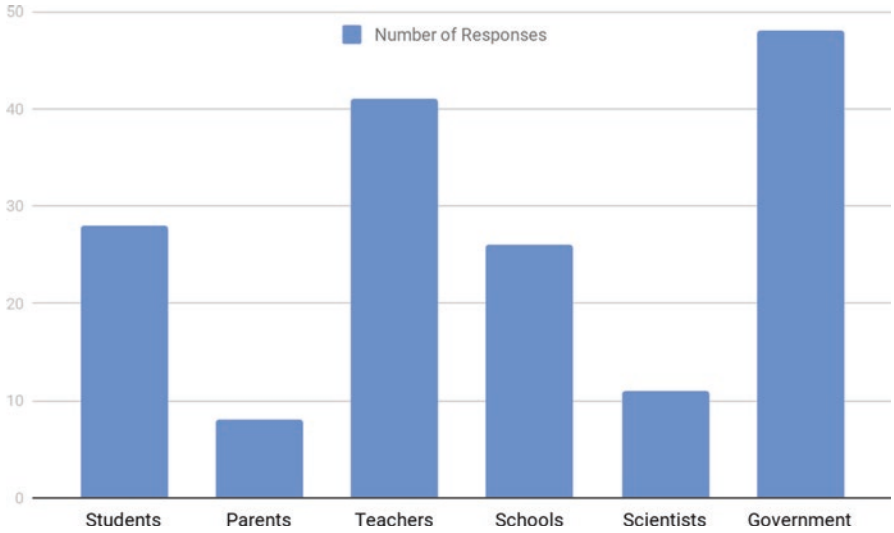

Fig. 8.7 Response to "Who do you think is responsible for ensuring B.Ed. students are trained in educational neuroscience?"

participants have entrusted the majority of this responsibility to the government and teachers.

The study obtained responses of 83 student-teachers throughout India. Although the number of participants is low, the representativeness is high due to the participants' diverse characteristics. It has been seen that despite being aware of educational neuroscience techniques, participants were unaware that it was related to the field of educational neuroscience. Further, participants indicated that they were keen to learn these techniques, which would be relevant for classroom instruction. Finally, there is a suggestion that the government and teachers of B.Ed. programs need to take the responsibility of including these concepts in the B.Ed. program.

8.6 Key Findings

The key findings obtained from this study can be summarized in the following points:

1. More than half of the participants (67.5%) indicated that they were well aware of the given educational neuroscience techniques, but only 26.5% of participants were aware that these techniques were part of educational neuroscience. According to Tan and Amiel (2019), professional development programs can help combat this lack of awareness about educational neuroscience as well as reduce the spread of false information or "neuromyths" among teachers.

2. More than half of the participants (67.5%) stated that they found these educational neuroscience techniques very useful, relevant to their subject specializations, and were keen to learn more about educational neuroscience. The common reasons given by the participants for suggesting the inclusion of educational neuroscience techniques were that it would help the student learn better, enable the teacher to teach more effectively, and improve the entire teaching-learning process. These findings are congruent with the indication that educational neuroscience promotes student self-reliance and self-knowledge (Cherrier et al. 2020).
3. Most participants (45.8%) expressed that educational neuroscience concepts were not currently included in the B.Ed. program, and a majority of participants (84.2%) stated that educational neuroscience should be included in the B.Ed. program. These results back up the suggestion by Zadina (2015) and Thomas et al. (2018) that educational neuroscience and teaching-learning need to work together hand-in-hand. Further, it shows that student opinion is also in line with the NEP 2020 brought out by the GoI, stating that B.Ed. program should work in collaboration with other departments, including neuroscience.

8.7 Conclusion

This study shows that a representative sample of student-teachers from India finds educational neuroscience techniques useful and urges the decision-makers to include this into the B.Ed. program. As the participants come from different subject backgrounds and have taught in the different syllabi followed in India, it can be deduced that educational neuroscience concepts are essential and can be useful across subjects and syllabi.

Based on these results, a suggestion is that an optional paper on educational neuroscience can be introduced into the Bachelor of Education curriculum. Previously, the ICT component in teacher education was included to meet the technological advancements in education. This inclusion was in line with the UNESCO's Planning Guide for ICT in Teacher Education (2002). It was later emphasized in India's National Council for Teacher Education (NCTE) in its National Curriculum Framework for Teacher Education (2010). Similarly, a step can be taken to include educational neuroscience to meet learners' and teachers' future needs.

To enable this inclusion, future researchers can focus on the role of educational neuroscience, specifically in India, due to the vast diversity present in the country. Further, the current usage of such techniques in the country and its effectiveness can also be investigated. Other avenues for research include the subject-specific utility of these techniques and the application of educational neuroscience in teaching gifted children and special children.

References

Annual Reports. (n.d.). UNESCO MGIEP. Retrieved from https://mgiep.unesco.org/annual-reports

Cherrier, S., Roux, P. L., Gerard, F., Wattelez, G., & Galy, O. (2020). Impact of a neuroscience intervention (NeuroStratE) on the school performance of high school students: Academic achievement, self-knowledge and autonomy through a metacognitive approach. *Trends in Neuroscience and Education, 18*. https://doi.org/10.1016/j.tine.2020.100125.

Department of School Education and Literacy, Ministry of Human Resource Development, Government of India. (2020). *India Report- Digital Education.*

Dubinsky, J. M., Roehrig, G., & Varma, S. (2013). Infusing neuroscience into teacher professional development. *Educational Researcher, 42*(6), 317–329. https://doi.org/10.3102/0013189X13499403.

Goal 4 | Department of Economic and Social Affairs. (n.d.). Retrieved from https://sdgs.un.org/goals/goal4

HRD ministry to launch programme to train over 4.2 mn teachers across India. (2019, August 18). *Business Standard. Retrieved from* https://www.businessstandard.com/article/pti-stories/hrd-ministry-to-launch-programme-to-train-over-42-lakh-teachers-across-india-on-aug-22-119081800008_1.html

Miller, S., & Tallal, P. A. (2006). Addressing literacy through neuroscience. *School Administrator, 63(11). Retrieved from https://eric.ed.gov/?id=EJ757404*

Ministry of Human Resource Development, Government of India. (2020). *National Education Policy 2020.*

Nautiyal, V., & Sinha, R. (2015). Teacher education in India: Engagement of student teachers in online learning. *IOSR Journal of Humanities and Social Science, 20*(7), 7–13.

Review and Assessments for SDG 4.7. (2018). UNESCO MGIEP. Retrieved from https://mgiep.unesco.org/review-and-assesments-for-sdg4-7

Tan, M. S. Y., & Amiel, J. J. (2019). Teachers learning to apply neuroscience to classroom instruction: Case of professional development in British Columbia. *Professional Development in Education*. https://doi.org/10.1080/19415257.2019.1689522.

Thomas, M. S., Ansari, D., & Knowland, V. C. (2018, October 22). Annual research review: Educational neuroscience: Progress and prospects. *The Journal of Child Psychology and Psychiatry, 60*(4), 477–492. https://doi.org/10.1111/jcpp.12973.

UNESCO. (2020). *First meeting of the International Commission on the Futures of Education. Retrieved from* https://unesdoc.unesco.org/ark:/48223/pf0000372674.locale=en

What is SEL? (n.d.). CASEL. Retrieved from https://casel.org/what-is-sel/

Zadina, J. N. (2015). The emerging role of educational neuroscience in education reform. *Psicología Educativa, 21(2), 71–77.* https://doi.org/10.1016/j.pse.2015.08.005.

Chapter 9
Pedagogical Challenges and Neurocognition in Education for the 21st Century

K. Anand and K. Chellamani

9.1 Introduction

The fastest changes in educational advancement and information technology attempt to give an enhanced education to these twenty-first-century learners. They are otherwise called New Millennium Learners, familiar with digital technology on learning. Preparing them for the future is the aim of policy makers at global level. OECD in its Education Policy Outlook 2015 says, 'In our fast-changing knowledge economies, with globalization, heightened competition, changing labor markets and employment instability, citizens have to learn skills for the jobs of today, tomorrow and the years to come'. OECD's 21st Century Learning (2008) and UNESCO's Future Learning (2015) report insist on various skills and competencies that are deemed necessary for present society. Hence, they recommended that formal education must tackle the complex global challenges ahead.

Multiple sources identified variety of skills such as critical thinking, creativity, collaboration, problem-solving and communication as necessary for the twenty-first century. These skills are termed as survival skills because they are tailored to one's career development, livelihood and employment. To develop such skills at schools, teacher education needs new pedagogical approaches, and the main focus is on inculcating self-awareness among the learners by tuning their thinking. It can be possible by activating the neurocognitive functions such as Attention, Perception, Thinking, Memory, Reflection, Analysing and Empathising through Neuro-Cognitive Strategy Application (NCSA). NCSA is providing experiential learning

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among the learners. Some of the notable NCSA are in concept mapping approach, flipped classroom approach and constructivism approach. The significance of constructivism philosophy and flipped classroom strategy blended with neurocognition has been insisted in teaching by educational scientists. Therefore, it is mandatory for teacher educators to have knowledge in neurocognition and should incorporate in their transactional strategy.

9.1.1 Twenty-First-Century Pedagogy

The application of learning strategies is not limited to classroom and school but through peers and community relationships. Leadbeater and Chittka (2008) emphasise that learning may occur outside of the school such as community centres, museums and libraries. Saavedra and Opfer (2012) opine that the twenty-first-century pedagogy must employ innovative and research-supported teaching strategies, learning technologies and real-world applications. The constructivist pedagogy is now known as 'Pedagogy 2.0', which supports learners in mastering twenty-first-century skills and competencies.

Twenty-first-century pedagogy aims to develop the skills and competencies with relevant knowledge in learners. It facilitates environment for the learners to interpret and use the information in their real-life situation. Hence, twenty-first-century pedagogy is a challenging task for teachers as they are to find out the latest competencies that learners need to develop. In traditional methods, the knowledge is transmitted from teacher to learner by memorisation, repetition, drill and so on. It has fewer opportunities for skills such as critical thinking, creativity, decision-making and problem-solving, whereas the twenty-first-century pedagogy gives prominence to higher-order skills by engaging the learner in meaningful learning from their real world and collaboration. It also consistently points out the needs and strengths of learners to develop individual potentiality to face the complex task ahead. By providing a variety of learning experiences, twenty-first-century pedagogy addresses new challenges to learners in terms of skills such as creativity, critical thinking, problem-solving and communication through negotiation and collaboration.

The learning experiences must be incorporated with learning tasks where learners participate totally. Therefore, pedagogy must provide a better learning environment in which learners dedicate time for interacting with peers and applying newly acquired skills. In this context, Neuro-Cognitive Strategy Application (NCSA) in constructivist pedagogy is a helping tool to nurture these skills and competencies.

9.1.2 Twenty-First-Century Learning

Twenty-first-century learning means acquiring the necessary skills for facing the demands of global life. Twenty-first-century learners are familiar in the use of digital technology on acquiring knowledge and skills, and therefore, attaining the competencies and skills for sustainable life is fundamental in twenty-first-century learning.

Over the last two decades, several frameworks and commissions listed twenty-first-century skills and competencies with its challenges in detail. The International Commission on Education for Twenty-first Century – The Delors Report explained the visions of learning as ‘competencies for life and competencies for action’ (Delors 1996). It helps to identify significant competencies for twenty-first-century learning. Personalisation, collaboration, communication, productivity and content creation are key to the overall vision of the twenty-first-century learning (Mcloughlin and Lee 2008; Redecker and Punie 2013).

The Future of Education and Skills: *Education 2030* (OECD 2018) states that ‘Learners will need to apply their knowledge in unfamiliar and developing circumstances. Hence, the learner should have a wide range of skills, including 1) cognitive and meta-cognitive skills such as critical thinking, creative thinking, learning to learn and self-regulation; 2) social and emotional skills such as empathy, self-efficacy and collaboration; and 3) practical and physical skills such as using new information and communication technology devices’. The ways of thinking, the ways of working, tools for working and skills for living in the world are the four broad categories of twenty-first-century survival skills (Griffin et al. 2012). These skills are intended to nurture the potential in individuals to face the challenge in the workplace.

The Center for Curriculum Redesign and OECD, 2012, report states to minimise the less relevant knowledge and embed the new competencies and skills by using meta-layering and personalised learning approaches. However, there is no single model explaining the strategies for developing the needed skills that have differences in their complexity. Yet each one is advantageous for the specific context for which it was developed.

Learning in the twenty-first century is expected to be a system that includes skills in the curriculum. The curriculum obviously connects these skills and competencies along with teaching-learning approaches and technologies. Therefore, the learning methods and the curriculum design should emphasise blended learning with more direct forms of instruction to build knowledge, understanding, creativity and other twenty-first-century skills. Learning happens within the learner. It is the learner who has to tune his mind and engage totally in the process of learning. Therefore, the learner variables such as Attention, Perception, Thinking, Memory, Reflection, Analysing and Empathising are to be dealt in the pedagogy chosen for the learner to actively participate. The researchers envelop the above components and designed Neuro-Cognitive Strategy Application (NCSA) in the pedagogy being operated in their experimental research.

9.1.3 Transforming the Dynamics of Teacher Education

At global level, in the recent past, the perception of teachers and their dynamism in their performance has got a new outlook. They are expected to have expertise not only in their subjects but also in work values and personality traits. They need to possess communication skills; show enthusiasm, excitement on teaching dynamics and motivation towards learning; have a friendly approach; possess creativity and humour; provide emotional support; promote student-centredness; update essential information; manage classroom and student behaviour; and be competent and ethical. The teacher must collaborate with other experts and work with colleagues, institutional authorities, assistants and counsellors around them to get expertise in their subject. The teacher provides guidance to students, facilitates learning process and becomes a role model to inspire students. Apart from this, they play a key role on building rapport among parents for the welfare of the students and produce dynamic citizens that will honour society.

Becoming a teacher demands specific skills and competencies to deal with students. Self-mastery skills encompass subject mastery along with other skills; information critical literacy skills and technology skills are helping to update the latest information and pedagogical practices for attaining mastery. Soft skills competence including social and behavioural skills, social competence, self-compassion, communication skills and interpersonal communication (IPC) provide a positive relationship and academic peaceful environment. Cognitive skills such as higher-order thinking skills, analytical skills, hypothetical-creative, reasoning skills and reflective practices are enhancing the considerable quality of the teacher (Estrada and Mariam Rahman 2014). All the above skills are necessary for professional development of a teacher.

In accordance with the international bodies, the researchers listed out several skills necessary for survival. Among them, eight skills – (1) creativity, (2) critical thinking, (3) problem-solving, (4) decision-making and learning, (5) communication, (6) collaboration, (7) information literacy and (8) citizenship, personal and social responsibility – are focused majorly (Anand and Chellamani 2019). Especially, in teacher education, these eight skills are necessary for effective learning and pedagogical practices in the twenty-first century. Survival skills are techniques that individuals perform to sustain their professional living. To accomplish these eight-survival skills through classroom pedagogical practice, we need to think about the learning process. Hence, connecting mind (cognition), brain (neuro) and education, these skills can be nurtured using neurocognition in neuroscience. The increased connectivity among these disciplines brought growth in communication and information in the global world.

Today, scientists are tracking the sources of knowledge with the powerful tools of neurocognition and analysing the relations between thinking and survival skills among the different levels of learning and memory (Anand and Chellamani 2019). There emerges neurocognition and neurocognitive philosophy in teaching and learning. Neurocognitive philosophy is the field of neuropsychology and cognitive sciences which construe the relationships between cognitive activities and cranial nerves using advanced technology (Brown et al. 2018). Neurocognition evolves depth of information processing, and it stresses how information is organised in memory and adapted to a changing environment. Its functions include attention, perception, remembering things, processing information, learning, speaking and understanding.

Universally, education is aimed at preparing future citizens to the world of work and equipping them with necessary survival skills to face undefined challenges. This is in the hands of the teachers. Accordingly, the teacher education policies of various countries focus on the development of skills for survival in modern digital lives. Therefore, Teacher Education Institutions (TEIs) of today have revamped its curriculum and the desired skills and competence inbuilt in their pre-service or in-service teacher education programme.

9.1.4 Neurocognitive Function

According to Bressler and Menon (2010), neurocognition is the function of particular areas of neural pathways and cortical networks of the brain during the process of cognition. Neurocognitive functions are the core structure in our everyday survival. Neurocognitive functions include processes like attention, information processing (thinking), comprehension (perceiving), working memory, planning (analysing), concept formation, learning, memory, insight (reflecting) (Hedges et al. 2012) and empathising. Learning is embedded with emotion. The neurocognitive functions and its significance are:

Attention: The brain receives information through a filtering process. It stops the new information which was unattended by brain activation, i.e. the information processing in the brain might miss the important signals. The theories of attention explain issues in learning which is caused by sensory inputs. The five senses are processed in parallel streams and generate consciousness in learning. Based on purpose, attention is classified into selective attention, divided attention, sustained attention and executive attention.

Information Processing (Thinking): Thinking is the process of considering or reasoning about the information received. The information received through attention is processed in different aspects such as concrete, abstract, convergent, divergent, creative, analytical, sequential and holistic. Since the new information should match with the existing concepts in the brain, the matching of new information usually be demonstrated with either a bottom-up system or top-down system or combination of both.

Comprehension (Perceiving): Perception is recognition and interpretation of sensory information and responds to them. During the process of deducing, the individuals construct meaning using their senses. Perception helps to comprehend the senses into meaningful information, i.e. sensing the different single letter and grouping into meaningful words. The executive function of the brain coordinates with the senses and forms the new pattern known as perceptual units (perception).

Working Memory: The perceived or received information is processed by the mental action to integrate it into long-term usage (memory). The working memory holds the information temporarily until further process. The process of mental action carries relevant verdicts. The individual who forgets the information immediately after getting it and cannot reproduce it is due to the information not completely transferred into long-term memory. Thus, researchers say that the brain can process 5 + 2 maximum stimuli (information) at once. The brain takes several types of activities to encode new information. If the information is totally different from the existing stimuli, then it would stand alone as a new unit; otherwise it will assimilate with the old stimuli. Hence, learning a new information must be presented in such a way that it could be matched with the memory structure.

Planning (Analysing): This is a mental process that determines what information should be passed from working memory to long-term memory and from long-term memory to working memory. It decides how to search the long-term memory database and access further memory search related to the retrieved information and evaluate potentially inconsistent data.

Concept Formation (Learning): This is the process of new information accommodated with existing information in memory. Tulving (1972) stated two distinct types of memory: declarative and procedural. Declarative memory is subdivided into episodic and semantic memories. Episodic memory is based on personal experience and specific events, whereas semantic memory deals with general, abstract information. But procedural memory is knowledge of 'how-to' (Huitt & Lutz 2018). It is defined in terms of learned skills and the ability to recall instruction. Apart from that, imagery as the memory structure captures information like a photograph. It can be useful for visual presentation of information.

Memory: The brain has approximately more than 10 billion neurons and each has axons and dendrites. The electrical impulse flows through these axons, and they are transported signals across the synaptic gap between neurons. The neuron connection forms a specific pattern which holds the memories. The synapses (connections) got strengthened when two neurons are activated.

Insight (Reflecting): The act of reflections on one's own experiences and actions is a healthy practice. It keeps the individual aware of his strengths and weaknesses and motivates towards taking steps for further development. Schon (1991) distinguished reflection into 'reflection-on-action' and 'reflection-in-action'.

Empathising: Empathy is an emotional reaction with values to others. Empathising is a quality enveloping mind-reading, reflects understanding and responds intentionally.

Thus, our actions are due to the operation of neurocognitive components. Hence, neurocognitive functions form the structure for all our functioning. Based on the above function, classroom instructional strategy needs to be developed for effective learning.

9.1.5 Neurocognitive Strategy Application

It is a plan of action developing the learners' cognitive function, by which they intend to nurture the skills during the teaching-learning process. It includes asking and raising questions, the interaction of responses on questions, engagement in learning activities, engagement in dialogues, tuning upon listening, scaffolding and brainstorming, generating discussion, facilitating arguments, reflective exercises with appropriate feedback and evaluation. These techniques help in grasping the information from the environment, sharpening the focus to make meaning of the information received via different modes, to solve problems, to plan future actions and to evaluate own thought processes (Hedges et al. 2012).

There are different Neuro-Cognitive Strategy Applications (NCSA) used to activate neurocognitive functions such as Attention, Perception, Thinking, Memory, Reflection, Analysing and Empathising, in which a few notable neurocognitive application strategies are concept mapping approach, flipped classroom approach and constructivism approach. Incorporating a blended learning approach enveloping constructivism philosophy, flipped classroom strategy and neurocognitive strategy application for developing skills among the learners is a new idea. Hence, the classroom teaching practices need to be designed incorporating the above truths and sketch out ways to assess the objectives achieved. Keeping twenty-first-century skills in the framework, a pedagogical strategy application model is given below.

9.1.5.1 Pedagogical Strategies for Developing Creativity

Developing higher-order thinking skills is essentially considered for creating inventive ideas and nurturing creativity among learners. The different techniques to be practised in the classroom situation for enhancing creativity are:

- **Questioning:** Asking open-ended and inspiring questions raises the learner's thinking in a deeper level. The deeper level of thinking allows the learner to solve problems in differentiated ways. To develop creativity, the questioning techniques may be in the form of think-aloud practices, question for discussion, unfilled or partially filled questions from concept sheets and open-ended questions for journal writing.
- **Self-expression:** Every learner thinks in his/her own preferential ways. Providing an opportunity for self-expression by discussion and group activities allows learners to express their views freely. While expressing their own views, learners can verbalise their own thoughts. This kind of practice fulfils the concept of inner speech argued by Lev Vygotsky (1978).
- **Exchanges of ideas:** Discussions allow comparison of ideas, encourage sharing and provide opportunities to interact with others that nurture creativity in learners.

- **Provides feedback and stimulation:** Feedback mechanism is one of the techniques for developing creative thinking skill. Providing immediate feedback, prompts, supports and encouragement will motivate the learner to think differently and accept other's different viewpoints.

9.1.5.2 Pedagogical Strategies for Developing Critical Thinking

Developing an ability to 'raising the question, interpretation, examine, application, evaluation' is essential in the twenty-first-century living. It is the challenge for a teacher to develop critical thinking skill among the learners in a classroom situation in each time. However, different techniques could be practised in developing critical thinking skill. Some suggested techniques are:

- **Brainstorming:** This technique allows the mind to produce ideas without any delay in accessing the values of those ideas at the same time. Before a discussion of any topic, the learners need to be allowed to generate their ideas freely. It could be possible by posing the problem and narrating the situation. It is a strategy to make a group of learners motivated to generate many ideas.
- **Discussion:** It is the action or process of talking about something to reach a decision. Discussion on critical incidents will generate new knowledge and further leads to development of critical thinking skills.
- **Asking open-ended questions:** It provides room for analysing data, identifying alternative possibilities and comparing interventions. The open-ended questions provide a way for brainstorming, discussion and reflective thinking. Moreover, it helps to raise the 'reflection-in-action' and the 'reflection-on-action' process (Anand and Chellamani 2017).
- **Concept mapping:** It is based on assimilation of concepts and relationships among concepts (Novak 2004). It has visual illustrations of thought processes. It is a strategy used for organising concepts, knowledge and processes hierarchically. It prepares learners for a variety of experiences encompassing ability to assess, synthesise complex data and build relationships among data.
- **Reflective writing:** This exercise allows the learners to reflect on their learning experiences, actions and reactions. Consequently, learners connect new meaning to past experiences. It can also be used as a strategy for developing critical thinking (Davut Goker 2016).
- **Reflective exercises with appropriate feedback:** Before getting into the lesson, at an introductory stage, a multiple-choice question may be asked with all the distractors talking about the facts of the same topic. It develops critical thinking skills (Anand and Chellamani 2017).

9.1.5.3 Pedagogical Strategies for Developing Problem-Solving Skill

The researchers attempt to adopt different strategies to develop problem-solving skills. Posing question or problem directly to the learner, creating a situation for allowing them to identify the given problem and its right solution, providing an opportunity to apply different solutions for the same problem and so on are some of the strategies.

In teaching, as pedagogical strategies, there are only two broad ways a teacher can adapt and use for developing problem-solving skill.

- One is to create a proper situation through an application of meta-cognitive behaviour. While teaching, the teacher may pose thought-provoking questions. Asking a question makes the learner search a solution for it. Similarly, allow the learners to project or present their ideas through discussion. It allows the learners freedom to select the right solution by themselves. Sometimes, the teacher may assign teamwork that creates a situation to give a solution to the problem.
- And the other is the application of external stimuli. Here, the learner can use an external tool, i.e. providing assignments such as journal writing, concept mapping and other opportunities for the reflective process. However, in both ways, certain phases are commonly followed. They are defining the problem, collecting information about the source of the problem, developing alternative solutions for the problem, choosing the most suitable solution and applying the solution (Tomas 1999).

9.1.5.4 Pedagogical Strategies for Developing Decision-Making Skill

Decision-making skill can be observed only in a complex situation. The aim of general education is developing logical thinking skill among the learners. Many researchers attempted to develop models for decision-making skill in teaching. From their studies, there are some common ideas to be used for developing decision-making skills in classroom teaching.

- **Providing information and gathering information (input):** Using the flipped classroom method, learners are given content-related materials in advance, both hard copy and soft copy (online), including searchable reference, i.e. canvassing a wide range of alternative courses of action. It will help the learner to perceive the situation.
- **Analysis of the situation given (transformation):** Raising questions for the learner to opt alternative option. Providing various references over the content and posing diluted questions relevant to the content helps the learner to understand the situation. Teamwork, collaboration and discussions are some of the techniques which allow the learners to give their opinion, i.e. choosing suitable alternative possibilities.
- **Decision (output):** Inviting the learners to present their ideas either in a team or individually. Here, all the points in the presented ideas need to be considered.

The consequences of ideas/solution of different alternatives are assessed based on the objectives. Sometime, the feedback may be given to the improper alternatives which help the learners to correct their analogical thinking by themselves, i.e. re-examining the positive and negative consequences.

9.1.5.5 Pedagogical Strategies for Developing Communication Skill

Communication is the most important tool in teaching and learning process. The research (Iksan et al. 2012) says that positive communication gives opportunities to students for better learning. Communication is more effective when the learner understands and practises the skill. Further, it is more meaningful if the physical, spiritual and social factors are considered during the communication process. Classroom communication practices focus verbal, written and social communication skills.

- **Verbal Communication Skills:** It means the information is transmitted through the spoken words**.** Providing opportunities for group discussion, asking brainstorming questions, allowing arguments over the content, calling for the learners to present their ideas, demanding the learner to read the texts from the book and providing helpful feedback are some pedagogical strategies for developing verbal communicative skills. Questioning, discussion, interaction and presentation are the tools for developing listening skills.
- **Written Communication Skills:** It means the information is transmitted through written forms. Compared to verbal communication practices, written communication takes a little more time. But this practice allows the learners to think creatively. It is the way to express individual ideas without any hesitation. In the classroom teaching-learning process, the learners can write their ideas about the content before, while or at the end of the class that helps to develop the written communication skill; asking the learners to write (think-aloud) about the teaching unit before and after teaching will help the learners to give their ideas about what they are going to learn or what they have learned (Anand and Chellamani 2017). Learners may be given partially filled concept sheets to fill as a classroom writing practice, and at the end of teaching they will be given a short write-up about the content taught on that day as a journal and provided awareness and training on portfolio documentation (Walker 2006), such as programme writing, report writing, letter writing and e-mail etiquette.
- **Social Communication Skills:** The language is learned not only from the textbook but also in and out of the school. Social communication focuses on learners' negotiation, language used, culture and politeness. In a classroom set-up, allowing discussion, student-student interaction or face-to-face interactions and assigning teamwork are tools for developing social communication skills. Apart from the classroom interaction, the teacher may use digital techniques such as online comments or interaction by posting study materials or task on blogs/online forums. The twenty-first-century communication skills also recommend

the use of digital devices and online tools for communication purposes (Clariana and Wallace 2007).

9.1.5.6 Pedagogical Strategies for Developing Collaborative Skill

The learners are expected to achieve a common goal with others in a specific way in a collaborative manner. Unity, mutual understanding and cooperation with others are essential to work together and reach the goal easily.

- **Assigning groups/teamwork:** Learning and its process differ from each learner. No teacher can sit with all the learners and improve their learning. It is impossible to teach one-to-one manner. However, they can create opportunities to teach one-to-one model by assigning teamwork. There are various techniques to adopt for forming a group in the classroom. Forming a group with three to five heterogeneous members is effective to facilitate. After forming the group, the teacher assigns the work in such a way that the learners exchange their ideas individually, e.g. learners are asked to discuss on a problem in a group and present it individually.
- **Sharing of authorities:** Distributing authorities to the members of the group as the top-to-bottom hierarchy increases the success of the members in their achievements, e.g. giving problem/issues/activities to the team head, allowing them to discuss within a group and presenting it in the classroom. Here, each learner's participation should be monitored and encouraged to ensure their participation.

9.1.5.7 Pedagogical Strategies for Developing Information Literacy Skill

Unlike traditional classroom practices, the present pedagogical practices implement the new methodology in teaching and learning. It includes an inverted classroom or flipped classroom which improves refining and gathering new information process in learners, i.e. searching enough information in various mode, gathering and keeping the information in an organised manner, evaluating validity and truthfulness in the gained information and using that knowledge for the cognitive process are the key components in modern pedagogical practices.

- **A summary form of note**: In the teaching-learning process, learners need to recognise the information (identification of information). For that purpose, the information may be presented in a summary format in both oral and written. The summary format (concept map) may help the learner to organise the content in sequence, used it for discussion and extend study as a reference point.
- **Emphasising the reference list:** Psychologists say that accommodation and assimilation are two cognitive processes which connect previous knowledge and present knowledge in terms of learning. Therefore, the learner may be given a chance to be aware of the content they are going to learn in advance. This is

possible by giving the exact main source reference to the tutorial topic through a concept map for learning. The main reference on the tutorial topics should be given before the classroom discussion in advance. Other reference lists should be given at the end of the tutorial class teaching. The reference may be from the self-created website, blogs, sharing the slides in social media or Google books, library books, academic journals and so on.

- **Providing the opportunity for extended study:** Providing portfolio assignment at the end of every tutorial class directs the learner to extend the study where the learner refers (search) the topic more and evaluates it for the write-up as document (usage).

9.1.5.8 Pedagogical Strategies for Developing Citizenship, Personal and Social Responsibility Skills

In a school and society, the socio-culture and languages closely intervened the value system. The social responsibly or social skills can be nurtured through collaboration and cooperation of the learners. The belongingness, participation, listening to others, recognising differences, making rules together, managing conflicts and building communities are the components of the social skills (Dusi et al. 2012). In a classroom teaching-learning process, the pedagogical strategies are used for developing social responsibility in assigning teamwork for collaboration.

- **Assigning teamwork:** 'Working in teams' makes learners aware of one's culture and value system. It develops a sense of belongingness. The teamwork makes the member of the team feel protected and recognise the identity of each other in multicultural contexts.
- **Discussion and presentation:** Allowing group discussion makes learners listen to others' point, generate new thoughts and perception, pay attention, etc. It sometimes creates a healthy dialogue among the learners which leads to managing conflicts among themselves in a democratically respectful way.
- **Promoting participation:** Encouraging the learner to participate in various learning activities builds communicative relations in the being-together-with-others. Sharing authorities, respecting others and making rules together are some behaviour uprising while the learner is participating in the tasks.

9.2 Neurocognition-Based Approaches in Teaching

Incorporating a blended learning approach enveloping constructivism philosophy and neurocognition, the latest teaching models are concept mapping approach and flipped classroom approach.

9.2.1 Constructivism

Constructivism and its approaches are the primary solutions to issues regarding individual differences. Constructivism is a learning theory that deals about learning by building or linking the experience to new knowledge at the metacognitive level, and it is not a theory of teaching (Flavell 1979). The methods consider learner's experience such as thinking, creating an idea, sharing or communicating the idea, correcting naive concept, finalising ideas to information and finally concept formation. In this approach, the principle of concept construction operates where the learners make meaning through personal experiences interpreting thought process.

Olusegun (2015) believes that learning occurs while learners actively engaged in a process of knowledge construction. Here, learners automatically derive their mental model of the real world from their perceptions of that world. In every new experience, learners will continually update their mental models reflecting the gained information and, as the result, construct their interpretation of reality. 'There is no single instruction of constructivism that can be readily applied in classrooms' (Alsharif 2014). Hence, constructivists' classrooms are enriched with activities to discover, discuss, appreciate and verbalise new knowledge and ask questions.

9.2.1.1 Philosophy of Constructivism

The origins of constructivism may be traced out in the eighteenth-century philosopher, Giambattista Vico. The constructivist view claims that knowledge and reality do not have an objective or absolute value (Glasersfeld 1995). The reality is made up of the network of things and relationships that we rely on in our living (Von Glasersfeld 1995). Various types of constructivism emerged such as radical, social, individual, evolutionary, postmodern constructivism, information-processing constructivism, ethnocentric constructivism and cybernetic systems (Heylighen 1993).

In the constructivists' view, learning is the process in which learners link new ideas with their already constructed knowledge. It could be through interactions with the physical as well as the social environment. They emphasise that 'knowledge is not transmitted directly from one knower to another but is actively built up by the learner' (Driver et al. 1994). Constructivists opine that knowledge is to be 'reconstructed' and re-contextualised before it could be used in everyday life situations (Heylighen 1993).

The cognitive development theory of Piaget states that peer interaction is a source of experience and it induces cognitive conflict in kids. In the developmental process, individuals tend to diminish this conflict and re-establish the equilibrium at a higher level. Vygotsky (1978) says that cognitive development begins with interaction. It happens in the social process with people of higher mental abilities and later transformed into knowledge construction.

9.2.1.2 Characteristics of Constructivism

Piagetian ideas significantly denote the way in which the individual learns through interaction with the environment. The learning environment fosters students' readiness and curiosity to learn. Four fundamental characteristics of constructivist learning environments were given by Tam (2000) to be considered for applying instructional strategies:

- Knowledge is distributed between teachers and students – To use multiple modes of representation (reflection, metacognition).
- Teachers and students will share authority – To embed learning in realistic contexts.
- The major role of the teacher is guiding or facilitating – To provide multiple experiences with the knowledge construction process.
- Learning groups may be in heterogeneous students – To occur learning in social experience as collaboration.

9.2.1.3 Strategies for Integrating Teaching and Learning

The traditional view of knowledge is based on the belief in the existence of a real world. But the constructivist believes that knowledge is constructed in the learner mind. This perception led to a modification in teaching strategies for the everyday classroom. Teachers should encourage learners to apply their own thought processes to construct knowledge; moreover, teachers do not need to feed knowledge to learners. In a constructivist model, the key to learning is the learner to find numerous ways to link new knowledge or meaning to prior cognitive experiences (Bloch et al. 1994). The constructivist approaches are based on the above principles embedded with neurocognition for the holistic development of the learners.

9.2.2 Concept Mapping Approach

Concept mapping was developed by Novak in 1984, and it is an offshoot of the Ausubelian approach. Joseph D. Novak (2010) states that assimilation of knowledge is acquired through experiences. It involves comparison, reflection, abstraction, ordering and clarification to form a conceptual hierarchy (Edmondson and Smith, 1998). Concept maps are the two-dimensional graphic tools that allow learners to present, relate and communicate conceptual knowledge and build on existing cognitive structures (Novak and Gowin 1984). The concepts are linked by words or propositions. It has a hierarchical structure, and it demonstrates the relationship between each concept (Ford et al. 1996).

Canas et al. (2003) demonstrated three effective uses of concept maps in the educational context. They are:

1. To support learning: concept mapping is used as a constructive learning activity either individually or in groups.
2. To assess the learners' learning.
3. To organise and present information: planning, organising key concepts and connecting ideas, given ahead of the new instruction.

Plotnick (1997) suggests that the concept map leads the learners to participate in a brainstorming session. The points in the concept map are used to compare learner's previous knowledge and present knowledge. Also, it is used to generate a new idea. Simper (2014) emphasises that the construction of the concept map should be on drawing schemas in long-term memory, to handle new information and place it within existing cognitive structures.

9.2.2.1 In a Concept Map, Generally, the Components Being Used Are Given Below

(a) **Concept:** It is a thought or mental framework of an event which is usually presented in enclosed circles or boxes. Initially, the concepts are identified and enlisted various key concepts in the topic. Then, they are arranged in two-dimensional hierarchical descending order. It is stated in NCERT (2013) that the general concepts are to be placed at the top followed by the less inclusive concepts. The concepts occurring at the same level of observation are placed at the same horizontal level.

(b) **Linkages:** The relationship between the concepts is linked by using arrows or lines. It is drawn in all direction within concepts.

(c) **Proposition or labels for linkages:** Labels are words or phrases which highlight the relationship between two concepts. Labels for linkages are called a proposition. Sometimes, two or more concepts cross-linked forming a 'web' of relevant and interrelated concepts. These links enhance the cognitive structure of concepts rather than just connecting general concepts to specific concepts. There is no limit on the number of connecting lines (NCERT 2013).

9.2.3 Flipped Classroom Approach

This digital era fetches a huge variety of technologies in every field of studies. Technologies bring incredible turns into a tangible reality in education and innovation. The traditional methods faded, and innovations are accepted and appreciated by the professionals. Every learner is unique, and hence they expect differentiated instruction according to their needs. By considering varied learning needs, teachers should develop differentiated instruction so that all learners in the classroom can learn effectively. Differentiation aims to maximise the potential of every learner and to ensure incremental growth and a sense of achievement. Therefore, there is a need for a broad awareness of the technology used to promote differentiated instruction. The twenty-first-century learning is not limited to classroom instruction, and the developments in technology provide resources and support to the needs of the individual differences. A flipped classroom instructional strategy is a new trend now. It promotes effectiveness in teaching and learning.

9.2.3.1 Concept of Flipped Classroom

Flipped classroom approach is a blended learning strategy that reverses conventional learning set-up by delivering instruction online outside of the classroom. The instructor shares the predetermined teaching resources to the learners through digital resources outside the classroom (Bergmann and Sams 2012). Here, learning is through technology, especially online video media. Technology supports flipped classrooms by letting learners exposed to new concepts outside the classroom usually through reading or lecture videos. It minimises the lecture time and increases the time for in-class activities. Hence, learners can learn cooperatively. The increased class time is used for assimilating the knowledge gained, perhaps through problem-solving, discussion or debates. The increasing accessibility of educational technologies increases the opportunities to share, explore and create content for the learners (Bergmann and Sams 2012). The flipped classroom strategy promotes learners' responsibilities towards collaborative and cooperative assignments and classroom activities. It also promotes the sense of responsibilities for their work and self-regulation in the submission of assignments (Panich 2013; Yilmaz 2017).

9.2.3.2 Scope of Flipped Classroom Instructional Strategies

The digital technology connects the learner from anywhere and anytime. Incorporating the technology, the flipped classroom instructional strategies provide the learner to be aware of the content in advance which will be taught in class. The flipped classroom instructional strategies provide a variety of opportunities to the learners to learn and get an idea about the content. Bergmann and Sams (2012) listed several points on the flipped classroom strategy:

- It gives the outline and pre-knowledge about the learning content to the student in advance. And it sets the learning goals for students.
- It increases the interaction between learners and the teacher. And it can encourage learners to be responsible for their learning environment.
- Learners get learning material in advance in the form of a video or a text and they learn it at their pace. It provides students a personalised education (Li 2016).
- There is a shift from 'the sage on the stage' to 'the mentor around' with the integration of the direct teaching method and constructivist learning principle.

- It has a simple strategy to take care of missed classes. The student's work is individual. Therefore, students can learn where they left off and start learning from there.
- In this method, learners can avail the teaching resources at any time for their total engagement and participation in learning.

9.2.3.3 Phases in Flipped Classroom Instructional Strategy

The flipped classroom pedagogy has two phases: flip before class and flip in class.

1. In **flip before class**, students are expected to learn the lesson and other related information before they enter the class. They may have a fundamental understanding of the concept to be taught. They are to follow the instructions given that initiate doubts, probes for resource finding and then solve the difficulties with teachers and classmates in the classroom. The micro-video is to be offered to the learners through online with study guides. Therefore, the teacher could facilitate the learner to study before entering the class.
2. **Flipping in class** is checking the learners' understanding of the concept which is learnt before class. Here, the learners expand the knowledge through some practical operations, exploration inside the classroom. The learners in the classroom are required to consolidate fundamental knowledge. The classroom is becoming a venue of preparing learners' abilities to think and operate the basic knowledge towards getting mastery.

9.2.3.4 Some of the Advantages of the Flipped Class

- **Greater learner engagement:** Unlike a passive conventional classroom, here, the learners have tuned actively in solving problems, involving in collaboration activities and group discussions. Thus, the flipped classroom increases learners' engagement with learning.
- **Deeper knowledge:** It allows learners to spend more on analysis, evaluation and creation rather than on memorising and understanding.
- **Learning at learners' own pace:** Traditional classrooms fail to match the average and the gifted, whereas the flipped classroom takes more control over the content of explanations and helps the two extremes to manage their own pace. It promotes higher-order thinking and collaborative learning and enhances reflective practice (Farrell 2004).

9.3 An Illustration from an Experimental Research

Here is an experiment conducted among B.Ed. student-teachers on developing survival skills using neurocognition illustrated.

9.3.1 Research Questions

As teacher educators, we wanted to find out answers for the following questions:

1. Do the learners' consciousness over their survival skills contributes constructively in the development of survival skills?
2. Do the learners have awareness on their application of neurocognitive strategies in their learning process?

9.3.2 Research Design

It is pretest-treatment-posttest design to assess the effectiveness of Neuro-Cognitive Strategy Application on developing survival skills among B.Ed. student-teachers. The target population was B.Ed. student-teachers. The duration of the intervention was 6 months. The impact of the neurocognitive strategy intervention on developing survival skills was observed, and the data were collected through various instruments, namely, awareness tools, demographic profile and achievement test before and after the intervention programme. Two tools were constructed and validated before administration, namely:

Tool 1: Assessment of Awareness on Survival Skills of B.Ed. student-teachers. The reliability of the tool was established and has 49 items under the dimensions: Creativity, Critical thinking, Problem-solving, Decision-making and learning, Communication, Collaboration, Information literacy, Citizenship, Personal and Social Responsibility.

Tool 2: Assessment of awareness on Neuro-Cognitive Strategy Application of B.Ed. student-teachers. The tool has 30 items under the dimensions: Metacognitive Behaviour, Reflective Thinking and Higher-Order Cognitive Skills.

The collected data were analysed during paired t-test and gain ratio to find out whether learners' consciousness over their survival skills and awareness on their application of neurocognitive strategies influence their learning process.

9.3.3 Intervention Programme

Neuro-Cognitive Strategy Application Intervention was operationalised in teaching through flipped classroom and constructivism approach.

In the first phase, the flipped approach was observed which is before entry into the class. In the second phase, the selected neurocognitive strategies were entrenched in classroom transaction with Plickers' assessment, concept mapping exercise and presentations/lectures/discussions. This, in turn, enhanced conscious awareness of the students on their understanding of the given content. Their participation was in different formats such as asking and raising questions, engaging in the activities, creating the habit of listening, scaffolding, brainstorming, appreciating the dialogue, generating discussion and facilitating argumentation. Consequently, the student-teachers were tuned to develop survival skills such as Creativity, Critical thinking, Problem-Solving, Decision-Making and Learning, Communication, Collaboration and Social Skills.

9.3.4 Administration of Pretest and Posttest

The student-teachers' awareness on their survival skills and their Neuro-Cognitive Strategy Application in learning was assessed both at entry and exit level. The aim of administering pretest was to assess the status of the student-teachers' survival skills at entry level using the cautiously planned and developed tools. After the implementation of the Neuro-Cognitive Strategy Application in learning, a posttest was administered to find out its effectiveness of the programme.

9.3.5 Analysis and Interpretation

As per the research questions stated above, the learners' consciousness over their survival skills and awareness on their application of neurocognitive strategies in their learning process, the paired sample 't' test between the pretest and the posttest mean score of the experimental group was found significant (Table 9.1).

The 't' value obtained from the pretest and posttest scores of the experimental group in the assessment of awareness on survival skills (ASS) is 5.677, and the assessment of awareness on Neuro-Cognitive Strategy Application (NCSA) is 3.129. They are significant at the 0.05 level. It is inferred that pretest and posttest mean scores of Awareness on Survival Skills (ASS) and Awareness on Neuro-Cognitive Strategy Application (NCSA) of the experimental group is not the same. This shows that there exists a significant positive difference between the pre- and

Table 9.1 Paired sample 't' test between the pretest and the posttest mean score of students ASS and NCSA

		Pretest		Posttest		't'- value
Variable	N	SD	Mean	SD	Mean	
The assessment of Awareness on Survival Skills (ASS)	34	6.34	78.47	3.71	85.39	5.67
The assessment of Awareness on Neuro-Cognitive Strategy Application (NCSA)	34	6.90	86.76	5.93	90.93	3.21[a]

[a]Significant at 0.05 level

Table 9.2 Gain ratio of ASS and NCSA

Variables	Gain ratio	Gain ratio in percentage
Student-teachers' Awareness on Survival Skills (ASS)	0.2575	25.75%
Student-teachers' Awareness on Neuro-Cognitive Strategy Application (NCSA)	0.1099	10.99%

posttest mean scores of student-teachers' Awareness on Survival Skills (ASS) and students' Awareness on Neuro-Cognitive Strategy Application (NCSA).

To find out the effect of the programme implemented on developing survival skills and awareness of ASS and NCSA among student-teachers at the exit level, gain ratio was calculated (Table 9.2).

- The gain score calculated from the pretest and posttest score of the experimental group's Awareness on Survival Skills (ASS) is 0.2575 (25.75%).
- The gain score calculated from the pretest and posttest score of the experimental group's Awareness on Neuro-Cognitive Strategy Application (NCSA) is 0.1099 (10.99%).

From the above result, it is inferred that the intervention programme has made a positive impact on experimental group student-teachers' Awareness on Survival Skills and Awareness on Neuro-Cognition Strategy Application.

The intervention programme on 'Neuro-Cognitive Strategy Application' has made enhancement in the survival skills of B.Ed. student-teachers. The intervention programme implemented has a system involving teacher input and student action resulting in an exhibition of survival skills which are periodically tuned.

9.4 Recommendations

The above discussion reveals that learning is individualistic and hence pedagogy should be learner-centric. As the researchers of today underline neuroscience in teaching and learning, constructivism principles are analysed in terms of pedagogy. It highlights the significance of the curriculum and pedagogy in teacher education. If only it is streamlined, the education of the future leaders would be set right. In the light of the above lines, it is recommended to:

- Provide orientation to teachers in service and prospective teachers about the importance of neurocognitive components in classroom practices.
- Sensitise learners about the importance of survival skills in daily life as well as in learning.
- Sensitise the learners about the importance of neurocognitive elements while teaching.
- Provide cognitive apprenticeship through experts in skills.
- Encourage teachers to design neurocognitive strategies for classroom practices.

- Provide sensory learning experiences to support learners with a difference.
- Give ideas to the teacher and learner how to construct subject knowledge with students' total participation in learning and acquire the necessary survival skills.
- Develop the learner's self-directed participation and reflective practice, and nurture the fundamental skills that are needed for their livelihood.
- Sensitise the teachers' necessary updating in terms of knowledge and technology appliances and utilisation for teaching and learning.
- Teachers need to be made aware of the significance of vacation provided only to teacher professionals indicating the necessary preparations for the next academic year.

9.5 Conclusion

The Future of Education and Skills: Education 2030 (OECD 2018) recommended that 'Learning to form clear and purposeful goals, work with others with different perspectives, find untapped opportunities and identify multiple solutions to big problems will be essential in the coming years'.

The twenty-first-century skills and competencies can be nurtured using specified pedagogical strategies. Every teacher at every level needs to know about the skills discussed above. If it is the responsibility of the teacher to facilitate opportunities for students to acquire the above skills, it will be more apt to say teachers need to possess first. Therefore, skill development needs to be embedded in the curriculum of teacher education (Hatton and Smith 1995). If it is taken stringently, the UNESCO's Sustainable Development Goal: Education 2030 'Every country in the world needs a high-quality, inclusive and equitable school system which will be the basis of bringing up a generation ready to work and live collaboratively and responsibly both locally and globally, physically and digitally in this century' will be achieved (UNESCO 2016).

References

Alsharif, K. (2014). How do teachers interpret the term 'constructivism' as a teaching approach in the Riyadh primary schools context? *Procedia – Social and Behavioral Sciences, 141*, 1009–1018. https://doi.org/10.1016/j.sbspro.2014.05.170.

Anand, K., & Chellamani, K. (2017). Reflective practices in digital scenario. *Journal of Innovation in Education and Psychology, 06*(10), 29–33.

Anand, K., & Chellamani, K. (2019). Survival skills: Pedagogy for 21st century learners. *Journal of Community Guidance & Research, 36*(01), 141–160.

Bergmann, J., & Sams, A. (2012). Before you flip, consider this. *Phi Delta Kappan.* https://doi.org/10.1177/003172171209400206.

Bloch, M., Lave, J., & Wenger, E. (1994). Situated learning: Legitimate peripheral participation. *Man*. https://doi.org/10.2307/2804509.

Bressler, S. L., & Menon, V. (2010). Large-scale brain networks in cognition: Emerging methods and principles. *Trends in Cognitive Sciences, 14*(6), 277–290. https://doi.org/10.1016/j.tics.2010.04.004.

Brown, C., Willett, J., Goldfine, R., & Goldfine, B. (2018). Sport management internships: Recommendations for improving upon experiential learning. *Journal of Hospitality, Leisure, Sport & Tourism Education*. https://doi.org/10.1016/j.jhlste.2018.02.001.

Canas, A. J., Coffey, J. W., Hoffman, R. R. R., Novak, J. D. J. D., Cañas, A. J., Carnot, M. J., et al. (2003). A summary of literature pertaining to the use of concept mapping techniques and technologies for education and performance support. *Education and Training*, 1–108. https://doi.org/10.1016/j.soilbio.2009.02.014.

Clariana, R. B., & Wallace, P. (2007). A computer-based approach for deriving and measuring individual and team knowledge structure from essay questions. *Journal of Educational Computing Research*. https://doi.org/10.2190/EC.37.3.a.

Davut Goker, S. (2016). Use of reflective journals in development of teachers' leadership and teaching skills. *Universal Journal of Educational Research, 4*(12A), 63–70. https://doi.org/10.13189/ujer.2016.041309.

Delors, J., et al. (1996). Learning: The treasure within. Report to UNESCO of the International Commission on Education for the twenty-first century. Highlights. *Journal of Chemical Information and Modeling*. https://doi.org/10.1017/CBO9781107415324.004.

Driver, R., Asoko, H., Leach, J., Scott, P., & Mortimer, E. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*. https://doi.org/10.3102/0013189X023007005.

Dusi, P., Steinbach, M., & Messetti, G. (2012). Citizenship education in multicultural society: Teachers' practices. *Procedia – Social and Behavioral Sciences, 69*(Iceepsy), 1410–1419. https://doi.org/10.1016/j.sbspro.2012.12.080.

Edmondson, K. M., & Smith, D. F. (1998). Concept mapping to facilitate veterinary students' understanding of fluid and electrolyte disorders. *Teaching and Learning in Medicine*. https://doi.org/10.1207/S15328015TLM1001_5.

Estrada, F. F., & Mariam Rahman, A. (2014). Reflective journal writing as an approach to enhancing students' learning experience. *Brunei Darussalam Journal of Technology and Commerce, 8*(1), 22–35.

Farrell, T. (2004). *Reflective practice in action*. Thousand Oaks: Corwin Press.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist*. https://doi.org/10.1037/0003-066X.34.10.906.

Ford, K. M., Canas, A. J., & Coffey, J. W. (1996). U.S. Patent No. 5506937. Washington, DC: U.S. Patent and Trademark Office.

Glasersfeld, E. von. (1995). A constructivist approach to teaching. In L. P. Steffe & J. Gale (Eds.), *Constructivism in education* (pp. 3–15). Hillsdale: Erlbaum.

Griffin, P., McGaw, B., & Care, E. (2012). Assessment and teaching of 21st century skills. In *Assessment and teaching of 21st century skills*. https://doi.org/10.1007/978-94-007-23245.

Hatton, N., & Smith, D. (1995). Reflection in teacher education: Towards definition and implementation. *Teaching and Teacher Education, 11*(1), 33–49. https://doi.org/10.1016/0742-051X(94)00012-U.

Hedges, H. et al. (2012). Vygotsky's phases of everyday concept development and children's "working theories". *Journal of Learning, Culture and Social Interaction, 1(2), 143–152.* https://doi.org/10.1016/j.lcsi.2012.06.001.

Heylighen, F. (1993). Selection criteria for the evolution of knowledge. In *Proceedings of the 13th international congress on cybernetics* (Association Internat. de Cybernétique, Namur), pp. 524–528

Huitt, W., & Lutz, S. (2018). *Becoming a Brilliant Star: Twelve core ideas supporting holistic education.*

Iksan, Z. H., Zakaria, E., Meerah, T. S. M., Osman, K., Lian, D. K. C., Mahmud, S. N. D., & Krish, P. (2012). Communication skills among university students. *Procedia-Social and Behavioral Sciences, 59*(October), 71–76. https://doi.org/10.1016/j.sbspro.2012.09.247.

Leadbeater, E., & Chittka, L. (2008). Social transmission of nectar-robbing behaviour in bumblebees. *Proceedings of the Royal Society B: Biological Sciences*. https://doi.org/10.1098/rspb.2008.0270.

Li, J. (2016). *Teaching Reform Strategies for the College Public English Course Driven by Source Problems under the Cognitive Neuroscience View, 16, 1670–1677*. https://doi.org/10.12738/estp.2018.5.066.

Mcloughlin, C., & Lee, M. J. W. (2008). The three p's of pedagogy for the networked society: Personalization, participation, and productivity. *International Journal of Teaching and Learning in Higher Education, 20*(1), 10–27.

NCERT. (2013). *Pedagogy of science*. New Delhi: NCERT.

Novak, J. (2004). *The theory underlying concept maps and how to construct and use them: IHM concept map software*. Florida Institute for Human and Machine.

Novak, J. D. (2010). Learning, creating, and using knowledge: Concept maps as facilitative tools in schools and corporations. *Journal of E-Learning and Knowledge Society*. https://doi.org/10.5860/choice.36-1103.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. New York: Cambridge University Press.

OECD. (2018). The Future of Education and Skills: Education 2030. *OECD Education Working Papers, 23*. https://doi.org/10.1111/j.1440-1827.2012.02814.x.

Olusegun, S. (2015). Constructivism learning theory: A paradigm for teaching and learning. *IOSR Journal of Research & Method in Education Ver. I*. https://doi.org/10.9790/7388-05616670.

Panich, P. (2013). *Flipped classroom*. Bangkok: S R Printing Mass Product.

Plotnick, E. (1997). Concept mapping: A graphical system for understanding the relationship between concepts. *ERIC Digest*, 1–7.

Redecker, C., & Punie, Y. (2013). The future of learning 2025: Developing a vision for change. *Future Learning, 1*, 3–17.

Saavedra, A. R., & Opfer, V. D. (2012). *Teaching and learning 21st century skills: Lessons from the learning sciences*. New York: Asia Society.

Schon, D. A. (1991). The *Reflective Turn: Case Studies In and On Educational Practice. New York: Teachers Press, Columbia University.*

Simper, N. (2014). *Concept maps for creative development*. Kingston: Queen's University.

Tam, M. (2000). Constructivism, instructional design, and technology: Implications for transforming distance learning. *Educational Technology & Society, 3*(2), 50–60.

Tomas, S. (1999). Creative problem-solving: An approach to generating ideas. *Hospital Material Management Quarterly Health & Medical Compete, 20*(4), 33–45.

Tulving, E. (1972). Chapter 10: Episodic and semantic memory. In *Organisation of memory*. New York: Academic.

UNESCO. (2016). Unpacking sustainable development goal 4: Education 2030. *United Nations Educational, Scientific and Cultural Organization*, *33*. Retrieved from http://unesdoc.unesco.org/images/0024/002463/246300E.pdf

Vygotsky, L. S. (1978). *Mind and society: The development of higher psychological processes*. Harvard University Press (Original manuscripts [ca. 1930–1934]).

Walker, S. E. (2006). Journal writing as a teaching technique to promote reflection. *Journal of Athletic Training, 41*(2), 216–221.

Yilmaz, R. (2017). Exploring the role of e–learning readiness on student satisfaction and motivation in flipped classroom. *Computers in Human Behavior, 70*, 251–260.

Chapter 10
Neurocognitive Aspects of Mathematical Achievement in Children

Paul Raj and Prakash Padakannaya

10.1 Introduction

Mathematics plays a fundamental role on one's life (Dowker 2019) as it is evident that multiplicity of basic arithmetic operations such as additions, subtractions, multiplications, and divisions is widely used in day-to-day life, especially while purchasing and selling things and calculating interests, discounts, and salaries. Mathematical ability therefore becomes an integral part of everyone's life as it contributes to all-inclusive personality development, covering the development and maintenance of those vital cognitive functions such as one's ability to think, reason out, solve problems, make novel decisions, be creative, and exhibit superior communication skills (Hodaňová and Nocar 2016). Therefore, it is only right to say that in our contemporary world and in success, proficiency in mathematics plays a central role.

It's an incontestable fact that mathematics proficiency commands indisputable importance in academics. For the very same reason, it is also seen that some children, even before they reach mid-elementary school, lose interest in learning mathematics. The most obvious reasons cited for this disinterest are poor or insufficient instruction in school and a child's specific cognitive deficiencies (Das 2014). Superficially, a child's successful display of mathematical skills during preschool years is one of the unmatched predictors of academic success (Desoete 2015a, b; Duncan et al. 2007). Again, high school success in mathematics predicts success in

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college, nature, and growth of early-career earnings, due to the availability of multiple well-paying jobs; the forte of these relations has augmented lately (Siegler et al. 2012).

Consequently, children's early mathematical knowledge has experienced a great deal of research consideration recently from both investigators and policymakers (Watts et al. 2014; Wu et al. 2015). There is a growing consensus among the researchers that infants are endowed with the basic capacities to understand numerosities (Dehaene et al. 2003; Carey 2004; de Hevia et al. 2014; Franzon et al. 2019), but there is a disagreement among them about the meticulous nature of this ability and how it facilitates arithmetic learning in later years (Szűcs et al. 2014). A sense of numbers is present in humans right from birth across all cultural backgrounds regardless of their educational training. Infants' ability to discriminate between quantities is believed to be inborn. Empirical studies on mathematical abilities have documented that 14-month-old infants are capable of distinguishing among arrays of numerosity containing up to three objects, and 1-month-old infants demonstrate the ability to differentiate between objects (Evans and Gold 2019; Schoeller and Sivakumar 2019; Siegal 2013; Tosto et al. 2014). Infants show inherent features manifesting skills to distinguish between small numbers and take part in numerical computation (Clements et al. 2019; Zygouris et al. 2017).

Granted that whatever children fail to accomplish or master a given task in school, it can affect the feelings of sadness and frustration rather than accomplishment (Lerner 2000). This observation is true in the case of children with insufficient mathematical skills for achievement when they encounter intense negative experiences at school and repeatedly perform poorly in academics. Some children exhibit significant difficulties in math and numerical skills at a young age, resulting in the diagnosis of specific learning disorders including mathematical disorder (Beygi et al. 2010; Medina 2020; Sudha and Shalini 2014). Specific learning disorder in mathematics is a kind of neurodevelopmental disorder that entails a definite deficit in the acquisition and use of mathematical skills such as the sense of numbers, memorization of arithmetic facts, accurate or fluent calculation, and accurate math reasoning (American Psychiatric Association 2013). These deficits impair their normal day-to-day functioning including math skills such as number sense, calculations, math reasoning, and memorization of math facts (Soares et al. 2018) and finally their mathematical achievement during schooling and life success as adults. In some cases, the school environment could be filled with unfavorable conditions that impede their healthy development of mathematical skills (Kaufmann and von Aster 2012). These children might develop mathematical anxiety and become more vulnerable and experience emotional, behavioral, and cognitive challenges (Aro et al. 2019; Helton et al. 2018; Tzuriel and Shomron 2018), leading to feelings of inferior competency in academics when compared to their peers (Ofiesh and Mather 2013).

The very presence of difficulties in mathematics can be alarming and stressful for any child, partly due to the unequal competitiveness found in the present educational system. Most of them experience intense feelings of low self-esteem coupled with strong feelings of incompetence and might believe that their present harmful condition would not change for the better. Such feelings of helplessness and hopelessness may act as a significant impediment for self-belief and future success. This negative cycle set in motion can create feelings of despair and fear of failure. Children with such feelings display maladjustments in school and intense emotional symptoms including depression and finally behavioral problems to be labeled as problematic children (Kempe et al. 2011; Martínez and Semrud-Clikeman 2004). Due to these academic and life challenges, many such children can demonstrate poor coping strategies and inner resources to withstand stressful situations.

During the work years, poor mathematical skills may account for reduced job opportunities, abridgement of high-paying jobs, an augmentation of low-paying job opportunities, amplified wage cuts, repeated failure to take advantage of job enhancement training programs, and diminished job promotions. These findings are limited to the Great Britain and the United States, and further investigation is needed before their generalization to other cultural backgrounds including India (Geary 2011; Morgan et al. 2016; Parsons and Bynner 1997; Soares et al. 2018).

10.2 Early Mathematical Skills and Later Math Achievement

Research by developmentalists in the past four decades or so has transformed our understanding of the development of primary mathematical skills. Traditional learning theories maintained that knowledge of mathematical skills commenced in elementary school days with formal teaching in mathematics (Haire 1941; Hilgard and Bower 1966; Bereiter and Engelman 1966; Teale 1995). These theorists believed that younger children did not possess adequate mathematical skills and, as a result, could not use the abstract numerical notations systematically for mathematical achievement. Later, Piaget (1952), through his theory of cognitive development, proposed the idea that mathematical knowledge developed prior to the mathematical teaching at school level. In contemporary times, there is a prodigious consideration for children's early mathematical knowledge (Watts et al. 2014) as they seem to predict future academic achievement, even more than early reading skills (Wu et al. 2015). Most of the studies done in the field over the decades have concluded that young children enjoyed informal mathematical skills that are widespread and transpire at earlier ages than Piaget and his followers predicted (Beins 2012; Bryant 1995; Ginsburg et al. 1998; Nguyen et al. 2016; Siegler and Braithwaite 2017).

Recent research shows that various facets of informal mathematical competencies such as geometric knowledge, spatial reasoning, and math problem-solving advance before a child's formal entry to school, and they lay a solid basis for the procurement of formal mathematical knowledge in school. Particularly, there seems to be a strong association between gains in mathematical knowledge during kindergarten and mathematical achievement during primary and higher primary levels (Li-Grining et al. 2010; Mix et al. 2016). Conversely, children who show a dearth of mathematical skills during the preschool years are at disadvantage when they enter formal schooling, and it continues during the initial years of schooling (Aunio et al. 2005; Serianni 2014). Therefore, it can be certain that preschool mathematical skills such as counting, addition, subtraction, measurement, and geometry are significant predictors of later mathematical achievement.

Though there are different pre-math skills (math skills learned by preschoolers and kindergarteners) such as the sense of numbers or counting, sequencing, numerical representation, spatial sense, measurement, estimation, patterns, problem-solving, and correct pronunciation of numbers, necessary for later mathematical success, there seems to be no clarity on which of these skills develop before Grade 1. There are significant distinctions in early mathematical skills. For example, skills such as quantity discrimination (such as approximating numerical magnitudes) and counting ability (such as simple computation) might develop independently (Feigenson et al. 2004; Okamoto and Case 1996). Mathematical skills such as number sense or number identification (Friso-van Den Bos et al. 2018; Kroesbergen and Van Luit 2003), counting strategies such as finger counting (Grünke et al. 2019; Stein et al. 1997), subitizing or the ability to recognize a group of items without counting (Kroesbergen et al. 2009; Reid 2016), number patterns or sequence of numbers repeating according to a rule (Ferguson 2017; Mulligan and Mitchelmore 2009), and addition or the total sum of two or more numbers (Cheng et al. 2017; Correra et al. 1999) mastered in early years are likely to contribute mathematics proficiency in later years (Cheng et al. 2017; Wu et al. 2015). It is clear that children as young as 2 or 3 years old can distinguish between quantities (e.g., more, less), subtract using small numbers, count small groups of objects, and encompass simple patterns with minimal or no adult aid (Ginsburg et al. 2006). Successful display of aptitudes such as differentiating between the same and different visual stimuli, deducing facts and details from stories, and coding visual stimuli in early years predicted later math achievement in many studies. Preschool numeracy abilities (such as basic and advanced counting) provide the impression to be the sturdiest prognosticators of mathematics achievement in Grade 5. Among them, advanced counting abilities were more predictive than basic counting abilities (Nguyen et al. 2016).

Emphasis on acquiring numerical skills in preschool years resulting in the prediction of later math achievement is documented in studies. This shows that teaching young children with strong mathematical skills such as ordinality, cardinality, and identification and also identifying the momentous role of cognitive and neural mechanisms (Merkley and Ansari 2016) are important. Between the symbolic numerical comparison and the non-symbolic magnitude comparison, the former was found to be an unswerving predictor of mathematics (De Smedt et al. 2013). In this context, both the symbolic comparison and numerical identification were the strongest predictors of arithmetic skills at the start of the formal schooling (Gobel et al. 2014; Lyons et al. 2014).

The integrated theory of numerical development by Siegler et al. (2011) proposes a systematic development of numerical knowledge from infancy to adulthood. It posits that numerical development involves scientifically broadening the knowledge of the class of numbers which contains magnitudes that can be accurately epitomized. This theory also proposes that, among children, learning fractions demand a restructuring of numerical knowledge. This restructuring involves the understanding that whole numbers have peerless successors, can be counted and represented through a single symbol, but cannot be decreased with addition or multiplication, and cannot be increased with division (Morris 2019; Young 2017). Other theorists proposed that the numerical development takes place through four major steps: (a) increasing magnitudes of non-symbolic number representation, (b) forming connections between both symbolic and non-symbolic number representations, (c) carrying forth this knowledge to whole numbers, and (d) applying this understanding to rational number representations (Siegler and Lortie-Forgues 2014). Therefore, the initial knowledge of whole-number development seems to aid and impede with the learning of rational number concepts later. Correlational and casual data highlight the need for an exact depiction of numerical magnitudes. Preschoolers' counting skills success and number knowledge along with the ANS acuity predicted their mathematical achievement 2 years later (Libertus et al. 2011; Mazzocco et al. 2011).

It is also noteworthy that there is a clear skill variability among children in their early stages of mathematical learning, which are found right from preschool and kindergarten years (Clements and Sarama 2020; Levine et al. 2010; Starkey et al. 2004) and are more or less stable till Grade 5. Those children who are good in mathematical skills in early years generally remain so, and on the other hand, those who struggle lag behind later too (Desoete 2015a, b; Duncan et al. 2007; Wu et al. 2015). Even though there exists a significant relationship between initial and later academic knowledge in diverse subjects of these children, the differences in their early and later mathematics knowledge are even more constant than the differences in their reading and other capabilities (Siegler et al. 2012). Therefore, it is palpable to note that there is a significant link between preschool mathematics knowledge and later math learning and academic success. Not many studies have done enough work on whether pre- and early-grade mathematical knowledge predicted achievement beyond elementary school as mathematical tasks become considerably more complex.

Adequate display of number sense, for example, knowledge that while counting operations, each number in the sequence has more weightage than the number that comes just before it and has less weightage than the number that comes soon after, is one of the core indicators that can help in predicting later mathematical disability among children (Jordan et al. 2009; Mazzocco et al. 2011; Siegler and Jenkins 2014). Newborn babies show numerical competency right from birth. For this reason, counting competency is emphasized more during preschool years as it can enable them to master this skill in later years. The meaning attached to counting ability is the foundation on which all other number concepts are based. With this mastery, children inculcate the skill to know that numerals indicate quantities, and they have magnitudes (Clements and Sarama 2020; Nguyen et al. 2016). Preschoolers use counting strategies to determine larger quantities and apprehend small quantity values via verbal subitization automatically. They can perform simple arithmetic tasks and compare magnitudes of numerals. The advanced number sense is mastered through formal instruction, and it helps them to generalize across numerals (Baroody 1987; Case and Griffin 1990; Ginsburg and Russell 1981; Jordan et al. 2012; Le Corre and Carey 2007).

Mastering these numerical abilities was predisposed by the socioeconomic background of the family of the child. It seems mothers from higher socioeconomic backgrounds provide children knowledge and emphasize the advanced numerical skills compared to those from the lower socioeconomic background. This might be a reason for children from lower socioeconomic backgrounds lagging behind with advanced number sense skills when compared to their counterparts (Del Río et al. 2017; Levine et al. 2010). Increasing research evidence concludes a strong relationship between early mathematical knowledge and later mathematical achievement, and it calls for a comprehensive mathematics curriculum targeted at preschool-aged children (Nguyen et al. 2016).

10.3 The Role of Cognition in Mathematical Achievement

A child's math performance is influenced by many factors (Huda 2018), such as the educational factors (Güre et al. 2020; Ryve and Hemmi 2019), social aspects (Zakiah and Fajriadi 2020), language proficiency (Prediger et al. 2018), motivation level (Prast et al. 2018), and personal attitudes (Recber et al. 2018). But empirical research has proved that during the early developmental stages, children develop mastery over their thoughts and behaviors because of development in executive functions (EF) that lead to a goal-directed behavior in them, especially during novel or demanding situations (Carriedo et al. 2016; Duh et al. 2016).

Executive function (EFs) skills, essential for the cognitive control of human behavior, are a group of higher-order cognitive processes that aid young learners to respond effectively to the societal expectations and participate in a thoughtful, goal-directed thinking and behaviors (Carlson et al. 2016). Those superior mental processes like thinking, analyzing, reasoning, comprehending, problem-solving, decision-making, creativity, application, and evaluation are directly associated with goal-directed behavior. They facilitate accomplishing success in the cognitive, psychosocial, emotional, behavioral, and academic effectiveness of children (Selvam et al. 2018). Besides, essential self-management cognitive skills such as effective time management, systematic organization of thoughts, paying attention, efficient planning, novel task selection, task initiation, task maintenance, behavior regulation and control, creative problem-solving, and managing and regulating one's emotions are essential self-management cognitive skills that are critical for the achievement of academic and personal goals. Students who require explicit executive function skills such as time management, systematic organization of thoughts, cognitive planning, paying attention, task planning, initiation, continuity, and successful termination of novel action, problem-solving, critical thinking, and successfully managing and regulating emotional expressions have a bigger advantage to succeed in academics. One might use additional executive functioning skills when there is an absence of any external guidance or the situation is new, demanding, and innovative (Cragg and Gilmore 2014).

The developmental researchers were interested in studying working memory and its multicomponent systems, response inhibition and attention shifting, the three distinct, yet interrelated, executive function skills as they believed to be responsible for one's attention, planning, prioritizing, organizing, initiating, and focusing on tasks, sustaining manifold views, emotional regulation, and self-monitoring. With these skills at its disposal, the brain can filter incoming distractions, control impulse behaviors, prioritize ongoing tasks, set attainable goals and accomplish them, and experience satisfaction in this accomplishment. As these skills are highly interconnected, any successful operation of these skills means a smooth coordination among them. For children, these skills are crucial for learning and development. They are not born with these skills, but they are equipped to master them with a supportive environment.

Inhibition, on the other hand, is the capacity to delay or control automatic responses to sources of interference and suppress distracting thoughts when doing those tasks that require self-regulation and goal-directed behavior (Bull and Scerif 2001; St Clair-Thompson and Gathercole 2006; Kroesbergen et al. 2009; Montoya et al. 2019). This skill enhances one's ability to achieve set goals by blocking inappropriate automatic responses. Contemporary researchers believe that poor inhibitory control results in a range of neuropsychiatric disorders (Richardson 2008), in addition to academic failures. A number of correlational studies have explored the relationship between performance in tasks related to performance inhibitory control and mathematical tests. Smaller amount of studies concluded that future mathematical achievement was predicted by inhibition control in early years (Blair and Razza 2007; Clark et al. 2010; Swanson 2011). Some other findings concluded that children who performed poorly in inhibition control tasks also were identified with mathematical learning disabilities (Szucs et al. 2013; Wang et al. 2012; Winegar 2013). In contrast, many studies have either found a weak link or no link between inhibition and math achievement among children (Bull and Scerif 2001; Miller et al. 2013; Monette et al. 2011; Van der Ven et al. 2012; Waber et al. 2006). Thus, there seems to be mixed evidence regarding the relationship between these two variables.

Finally, cognitive shifting or cognitive flexibility is the ability to freely shift attention back and forth among various tasks and adapt in the presence of novel information so that children can set priorities and resist impulsive actions (Cartwright et al. 2019; Yeniad et al. 2013). It is considered as a key component of executive function skills as it regulates one's thoughts and actions. It develops rapidly during preschool years and continues well into adolescence and adulthood periods, supporting significantly to think divergently, engage in multiple tasks, develop novel behaviors, and adapt to continuously changing environment. Cognitive flexibility has a number of life outcomes for children, important being it predicted achievement in reading and mathematical skills among children between the ages of 4 and 13 years (Yeniad et al. 2013). Among different methods used to improve flexibility, metacognitive training seems to be the best method (Buttelmann and Karbach 2017; Miyake et al. 2000; Jurado and Rosselli 2007).

These executive function skills are differentially related to various functional components of mathematics. For example, while response inhibition was found largely connected with most mathematics components, working memory was associated with advanced mathematical skills such as in the comparison of numbers and quantities. Cognitive flexibility seems to be aiding significantly conceptual and abstract mathematical skills (Cragg and Gilmore 2014; Purpura et al. 2013). Among the executive function skills discussed here, inhibition which is also linked to mathematical performance has gained mixed evidence from the researchers (St Clair-Thompson and Gathercole 2006; Bull et al. 2020). While some studies concluded that poor inhibition resulted in lower mathematical ability (Bull and Scerif 2001; Holmes et al. 2010), Lee and colleagues (2012) concluded that working memory alone and not the combination of inhibition and flexibility components predicted mathematical performance.

Initially, the EF skills were studied from the perspective of the adults (Miyake et al. 2000), and it was further extended to include the role of these three skills in the cognitive functioning of children in their middle ages (Brocki and Bohlin 2004; Huizinga et al. 2006; Lee et al. 2013; Rose et al. 2011). Later research studied the efficacy of these skills during the preschool years (Hofer et al. 2013; Wiebe et al. 2008; Willoughby et al. 2011), which aided some researchers to make inferences that the executive functioning which commences as a unitary system turns out to be differentiated significantly throughout the childhood period (Garon et al. 2008; Lee et al. 2013). Even though these executive function skills demonstrate an amazing developmental gain throughout elementary school years (Schneider et al. 2003; Bock 2015), these are believed to be the last cognitive abilities that develop till the end of the adolescence period (Luna et al. 2004; Huizinga et al. 2006; Conklin et al. 2007).

Among the three executive function skills mentioned above, working memory, the basic mental skills, is the ability to monitor, hold, and use information in the mind during a short period of time (Raghubar et al. 2010). The brain does this important function when needed in short-term memory, and it may then be further processed to transfer to long-term memory for future use. For children and adults, working memory helps in learning, retaining, managing, and executing new information in novel situations, and it is an important cognitive concept (Baddeley 1992) and entails various interrelating brain processes (Heister et al. 2013). Therefore, the efficiency of working memory has been repeatedly used by researchers in the field to predict mathematical achievement at a later stage. It is the temporary storage for processing and manipulating information and is believed to play a critical role in mathematical learning (Baddeley and Logie 1999). This important cognitive mechanism is believed to perform a dominant role in the achievement of mathematical success with its three subsystems (the central executive, the visuospatial sketchpad, and the phonological loop) and the other executive functions skills (inhibition, shifting and updating) (Baddeley 2007; Clark et al. 2010; Passolunghi et al. 2008; St Clair-Thompson and Gathercole 2006; Weiland and Yoshikawa 2013).

The central executive of the working memory coordinates and regulates information from the two subsystems, in addition to initiating, holding, shifting, and inhibiting attention and manipulating and updating the information, thus smoothly carrying a goal-directed behavior (Miyake et al. 2000). An added advantage is that it can hold several items of transitory information within the mind. Unsurprising, it has been recognized as an important predictor of school performance including mathematical achievement (Nyroos et al. 2015). Research evidence supports a strong positive relationship between working memory and mathematical success (St Clair-Thompson and Gathercole 2006; Passolunghi and Cornoldi 2008; Ramirez et al. 2012; Bull and Lee 2014). The working memory skills positively influenced math problem-solving during the elementary school period. For example, children with superior working memory capabilities stand to demonstrate additional cognitive abilities for storing and maintaining information while performing challenging computations and mathematical problem-solving (Andersson 2008; Hord et al. 2020; Swanson and Beebe-Frankenberger 2004). Therefore, studies have concluded that superior working memory that resulted in uninterrupted monitoring and manipulation of incoming information aided in mathematical achievement and poor working memory resulted in poor mathematical performance (Alloway 2009; Bull and Scerif 2001; Blankenship et al. 2015; Cragg et al. 2017b; Gilmore and Cragg 2018).

Among the components of working memory, the visuospatial sketchpad plays an increasingly important role in learning and improving mathematical ability. Defects in any one or more of the components of working memory can impair an individual's ability to control impulses, shift between tasks, and solve problems that are essential in solving mathematical tasks. Impairments in these areas are found to correlate with a specific learning disorder in mathematics as these individuals fail to maintain focus when solving arithmetic problems. Children with learning disorders show particularly vulnerability in the visuospatial sketchpad (Mammarella et al. 2015; Menon 2016; Sharma 2016). Therefore, during the foundational phases of numerical knowledge acquisition, working memory plays an influential role (Cragg et al. 2017a, b; Lemaire 1996).

Many children who experience significant difficulties in learning and thinking exhibit serious problems with working memory functions, that is, they may have less space in their working memory for the organization and integration of new skills. Children who suffer from a specific learning disorder in mathematics show significant deficits in updating working memory (Gathercole et al. 2016; Mammarella et al. 2015). They are inattentive and distracted and fail to complete everyday tasks that require focused attention (Gathercole and Alloway 2008). About 15% of children seem to suffer from poor working memory problems (Holmes et al. 2010). Such children might benefit from training in working memory skills, such as holding on to routines, reduced multitasking, use of checklists when multiple steps are involved, and breaking bigger chunks of information into small meaningful wholes.

The role of executive function skills in successful mathematical learning and performance is persistently documented by the studies in the field (Clements and Sarama 2019). These executive function skills, such as working memory, attention, inhibition, and shifting control, regulate information processing, storage, maintenance, and retrieval of tasks to solve mathematical problems such as encoding numerical symbols, keeping track of intermediate results of calculations, etc.

(Gashaj et al. 2019; Fias 2016; Viterbori et al. 2015). Studies have found that deficits in executive functions negatively impact these children with learning problems. They perform abysmally compared to their peers without learning problems on tasks requiring the use of executive function skills (Bull and Scerif 2001; Gathercole et al. 2004; Kroesbergen et al. 2009).

Children with mathematical learning disorder exhibit explicit inhibitory deficits (Lee and Lee 2019). These children may suppress inappropriate strategies like suppression addition performance when multiplication is asked. Inhibition skills have become reliable predictors of later mathematics scores across lifespan and number sense (Cragg et al. 2017a; Friso-Van Den Bos et al. 2013; Kolkman et al. 2013; Kroesbergen et al. 2009; Panaoura and Philippou 2007). Some studies document the relationship between shifting and mathematical performance. As seen in many mathematical tasks and tests, children need to shift between different tasks, strategies, operations, and quantity range to come to the correct answer (Andersson 2008; Cragg and Gilmore 2014; Friso-Van Den Bos et al. 2013; Peng et al. 2016). Among the three executive functions, updating, which is therefore important among the three, is found to be strongly related to mathematical performance. Updating is involved in the storage and retrieval of tasks while solving a problem and also in remembering important information during the entire problem-solving process. A child with poor updating skills might forget the part of the mathematical problem-solving task and end up committing more procedural errors (De Smedt et al. 2009; Gashaj et al. 2019; Van der Ven et al. 2012).

10.4 Brain Mechanisms in Math Abilities and Disabilities

The human brain processes mathematical information in the form of verbal codes, procedural codes, and magnitude codes in which the brain uniquely encodes the numerals as a series of words in an order instead of mere digits (Dotan and Friedmann 2018). This is regulated by those brain regions, namely, left perisylvian areas in temporal lobes that modulate most linguistic skills and regulate the numerosities. The brain follows a fixed symbol model instead of a mere word style to represent number values (Dotan and Friedmann 2018). This is observed on the left as well as right occipital-temporal regions. There is a progressive acquisition of math skills among children. Initially, they rely more on procedure-based counting that results in the greater activation of the dorsal basal ganglia which controls working memory tasks (Dehaene et al. 2003; Hulme and Snowling 2013). A gradual shift toward more complex math skill processing follows during second or third grades involving retrieval from long-term memory. Most of the complex mathematical tasks are aided by the hippocampus, the medial temporal lobe, and the prefrontal cortex. When compared to adult learners, children seem to use the hippocampus and parahippocampal gyrus predominantly to indicate that young learners involve in memorization and novelty tasks (De Smedt et al. 2011; Dowker 2019; Eichenbaum 2010; Fletcher et al. 2018; Menon 2010). This area of activation shifts to the left posterior parietal cortex (PPC) as children mature and finally activations in multiple areas of the prefrontal cortex (PFC) (Kuhl et al. 2020; Menon 2010).

The brain also encrypts analog quantities to make value judgments between two or more numerals and maintain estimation skills along the inferior parietal regions of cerebral hemispheres (Klein et al. 2016; Schmithorst and Brown 2004; Von Aster 2000; Von Aster and Shalev 2007; Zhou et al. 2006). Deficits in these regions can impede mathematical abilities. Based on the information processing discussed here, when a child lacks these skills, he/she will experience a learning disorder in mathematics that can have three subtypes, as discussed. Firstly, children experiencing verbal dyscalculia face difficulty with number identification, counting, and retrieving stored mathematical information. This particular problem is due to deficits in verbal representations of numerals. Injury to the left hemispheric perisylvian areas makes a child incompetent to identify and name numerals. Secondly, in procedural dyscalculia, children display problems with processing and encoding arithmetic information, and this is localized to the right and left inferior occipital-temporal regions. Thirdly, in semantic dyscalculia, an inability to read size representations among numerical values is observed. The semantic knowledge about numeric qualities that aid a child in estimation skills and quantity judgments are processed by bilateral inferior parietal areas of the brain (Dehaene et al. 2003; Miller et al. 2019; Van Harskamp and Cipolotti 2001; Von Aster 2000).

Specific learning disorder in mathematics (SLD-M) involves dysfunctions in specific brain localities responsible for mathematical skills. The right hemisphere of the brain controls the understanding properties of quantities, spatial value, and the use of arithmetic knowledge to solve problems. In contrast, the left hemisphere regulates comprehension of the abstract meaning of numbers, number sequence, and mathematical operations. Over the years, research in the field has demonstrated that the intraparietal sulcus (IPS) of the posterior parietal cortex (PPC) processes the numerical magnitudes (Dowker 2019; Price et al. 2007). For those children with a mathematical learning disorder, the intraparietal sulcus (IPS) is either deficient or disconnected (Ansari 2008; Pandey and Agarwal 2014) and results in reduced activation (Soares et al. 2018). Seminal studies have reported structural aberrancies such as reduced gray matter density in left and right sides of the IPS and a reduced activation and connectivity between parietal and occipitotemporal regions among children with specific learning disorders in mathematics (Fletcher et al. 2018; Isaacs et al. 2001; Rotzer et al. 2008). A brain imaging study has proved that impairments in mathematical cognition are associated with a lack of brain activity in parietal and frontal regions (Babu and Sasikumar 2019). However, according to the recent neurocognitive models of specific learning disorders in mathematics, different brain areas such as prefrontal, lateral, medial temporal, ventral temporal-occipital, and posterior parietal are contributing to specific learning disorder in mathematics (Fias et al. 2013; Kucian and von Aster 2015; Soares et al. 2018).

According to the core-deficit hypothesis, deficits in number concepts such as numerosity, magnitude, and quantity are associated with the intraparietal sulcus (IPS). On the other hand, the general domain deficit hypothesis states that there are deficits in verbal working memory which is vital for the acquisition of mathematical procedures, long-term memory which is needed for storage and retrieval of mathematical facts, and visuospatial processing. Furthermore, the procedural deficit hypothesis states that the procedural memory of storage and recall of mathematical facts in parietal, frontal, cerebellar, and basal ganglia is defective (Evans and Ullman 2016; Geary 2004; Moeller et al. 2012; Soares et al. 2018).

10.5 Future Prospects

Mathematical proficiency is an integral component of success in contemporary society and in every child's academics and life. It scripts good job prospects, self-confidence, job satisfaction, and quality of life for the individual (Gross et al. 2009; Parsons and Bynner 2005). When mastered these skills, children can excel in their academics and life, and it results in society and individuals concerned experiencing lifelong benefits (Center on the Developing Child at Harvard University 2012, 2015).

There is sufficient research evidence to conclude that executive functions play an imperative role in mathematical achievement as these control and guide information processing, leading to mathematical achievement (Cragg et al. 2017a). But it appears that there is a strong need for additional research to verify the extent to which the three executive function skills (working memory, inhibition, and shifting) are related to the components of mathematical knowledge and finally to mathematics performance and achievement. It is important to determine which of the cognitive skills play significant roles and which are not.

According to some researchers, the links between inhibition and mathematical abilities were palpable in the past studies (Lee et al. 2012) due to measurement issue in research, mainly due to the exclusion of working memory measures (Monette et al. 2011) and the omission of reading and IQ factors (Bull and Lee 2014). Nonetheless, it is important to verify if inhibition facilitates mathematical performance during the early years and if it helps children to suppress ineffective strategies and misconceptions during mathematical tasks. Young children must suppress, for example, specificities about bigger numbers that indicate larger quantities while attempting to work on fractions; they must be able to make out that the larger the denominators, the smaller the quantities. Inhibition may also be necessary while ignoring unwanted information and suppressing the inner urge to work from left to right, instead of following the order of mathematical operations (Cantin et al. 2016). Therefore, this study would look into the specific role played by inhibition in math achievement.

In India, largely, importance is given to performance in academics and mathematics. Success is greeted, while failure is disliked. In this context, for a student with difficulty in mathematical knowledge, mathematics becomes a scary thing. Therefore, it's important to identify the skills that predict later mathematical achievement for two reasons. Firstly, identifying these skills can help the educators to identify those children likely to struggle with mathematics so that appropriate remedial measures can be planned at the right time. Secondly, if those skills that predict mathematical achievement are identified, then the educators have a strong theoretical backup to the role of these skills in predicting mathematical achievement and can design the right interventions to facilitate these skills.

Such measures can lead to a better theoretical understanding and improved mathematical education. Further, researchers can identify various contributors to mathematical achievement among school children by controlling variables like type of family, IQ, and other types of mathematical knowledge. The concept of executive functions can be successfully employed to detect children at risk for mathematical disabilities at the earlier stage itself. Again, while these studies highlight the point that executive function skills are predictors of later mathematical skills in preschool children, which of these executive function skills are better predictors compared to the other skills discussed above entails further exploration.

Using a comprehensive tool such as the Brain-Based Intelligence Test (BBIT), a brain-based comprehensive approach to the understanding of cognition, for the assessment of executive function skills and new information integration can support in establishing a framework for intelligence which can have significant implications for mathematical education and brain plasticity. In this comprehensive tool, intelligence is understood as a selective cluster of diverse cognitive processes that are localized in broad divisions of the human brain. The author of this tool believes that neuronal changes appear to occur because of learning throughout life (Das et al. 2020). This assessment uses cognitive processes to replace IQ. This does not mean that intelligence is a random collection of such processes; instead, the study wants to indicate how the mind works while solving problems relating to three major domains – perceptual, memory (mnestic), and conceptual, following Luria's PASS (Planning, Attention-Arousal, Simultaneous, and Successive) theory of intelligence. The cognitive functions in this theory are one example of a brain-based approach to intelligence. Each of the four PASS components, especially simultaneous and successive processes, has direct implications for education.

Therefore, if there is a conclusion on strong relationships among executive functions skills, and mathematical skills, if the first two components predict the outcome of the latter in academics, and if these influential agents can be effectively targeted by educators early on, then possibly the educational structure can foil at-risk children in mathematics from falling further behind. The study will focus on finding out which of the executive function skills lead to the prediction of later math achievement more compared to the rest. Assessment of children's relative strengths based on early mathematical skills and weaknesses can provide vital information to work out an educational plan that is appropriate for them (Siraj-Blatchford and Nah 2014).

10.6 Conclusion

Mathematical skill is a vital necessity in contemporary life. Math precocity among boys and girls during the preschool years significantly predicted success in critical occupational roles late in life. Most of the kindergarten mathematics curricula are associated with number sense – whole-number knowledge, number relationships, and their operations. The knowledge of numbers and position of numbers are the powerful predictors of adult mathematical achievement. Successful display of mathematical skills during preschool years has positive consequences. It can result in easy learning during primary and secondary school years, positive college attendance and performance, increased earning potential, judicious financial administration, and overall life enhancement.

Baddeley's working memory model, the concept of executive function skills, various neural correlates, and the new information integration skills can provide a comprehensive picture of mathematical abilities in schoolchildren (Baddeley 1986; Bull and Scerif 2001) and their contribution to life success. All the components of working memory and executive function skills are related to mathematical performance but to varying degrees. Among these, the role of information integration skills is not explored adequately, concerning their contribution to mathematical achievement. Some of the inconsistent research findings in this regard are explicated in the context of different challenges associated with tasks and constructs specific to these components (Raghubar et al. 2010). Among all the contributing factors, the role of neurocognitive aspects seems to be integral for math achievement among school children, even though the role of home and school environment cannot be ignored. Therefore, while undertaking research, we need to give added weightage to the role of executive function skills and information integration skills in math achievement. This can help in better policy-making and overall success of students in their academic and life achievement.

References

Alloway, B. J. (2009). Soil factors associated with zinc deficiency in crops and humans. *Environmental Geochemistry and Health, 31*(5), 537–548.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). https://doi.org/10.1176/appi.books.9780890425596

Andersson, U. (2008). Working memory as a predictor of written arithmetical skills in children: The importance of central executive functions. *British Journal of Educational Psychology, 78*(2), 181–203.

Ansari, D. (2008). Effects of development and enculturation on number representation in the brain. *Nature Reviews Neuroscience, 9*(4), 278–291.

Aro, T., Eklund, K., Eloranta, A. K., Närhi, V., Korhonen, E., & Ahonen, T. (2019). Associations between childhood learning disabilities and adult-age mental health problems, lack of education, and unemployment. *Journal of Learning Disabilities, 52*(1), 71–83.

Aunio, P., Hautamäki, J., & Van Luit, J. E. H. (2005). Mathematical thinking intervention programmes for preschool children with normal and low number sense. *European Journal of Special Needs Education, 20*, 131–146.

Babu, A. G., & Sasikumar, N. (2019). Need for neurocognitive approach in teaching mathematics for children with dyscalculia. *International Journal of Basic and Applied Research, 9*(4), 194–200.

Baddeley, A. D. (1986). *Working memory*. New York: Oxford University Press.

Baddeley, A. (1992). Working memory. *Science, 255(5044), 556–559.* https://doi.org/10.1126/science.1736359.

Baddeley, A. (2007). *Working memory, thought and action*. New York: Oxford University Press.

Baddeley, A. D., & Logie, R. H. (1999). Working memory: The multiple-component model. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 28–61). New York: Cambridge University Press.

Baroody, A. J. (1987). The development of counting strategies for single-digit addition. *Journal for Research in Mathematics Education, 18*, 141–157.

Beins, B. C. (2012). *Jean Piaget: Theorist of the child's mind*.

Bereiter, C., & Engelman, S. (1966). *Teaching disadvantaged children in the preschool*. Englewood Cliffs: Prentice-Hall.

Beygi, A., Padakannaya, P., & Gowramma, I. P. (2010). A remedial intervention for addition and subtraction in children with dyscalculia. *Journal of the Indian Academy of Applied Psychology, 36*(1), 09–17.

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78*(2), 647–663.

Blankenship, T. L., O'Neill, M., Ross, A., & Bell, M. A. (2015). Working memory and recollection contribute to academic achievement. *Learning and Individual Differences, 43*, 164–169.

Bock, A. M. (2015). *The cognitive components of patterning: The relation between executive function and patterning* (Doctoral dissertation, George Mason University).

Brocki, K. C., & Bohlin, G. (2004). Executive functions in children aged 6 to 13: A dimensional and developmental study. *Developmental Neuropsychology, 26*(2), 571–593.

Bryant, P. (1995). Children and arithmetic. *Journal of Child Psychology and Psychiatry, 36*, 3–32.

Bull, R., & Lee, K. (2014). Executive functioning and mathematics achievement. *Child Development Perspectives, 8*(1), 36–41.

Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. *Developmental Neuropsychology, 19*(3), 273–293.

Bull, R., Lee, K., & Muñez, D. (2020). Numerical magnitude understanding in kindergartners: A specific and sensitive predictor of later mathematical difficulties? *Journal of Educational Psychology*.

Buttelmann, F., & Karbach, J. (2017). Development and plasticity of cognitive flexibility in early and middle childhood. *Frontiers in Psychology, 8*, 1040.

Cantin, R. H., Gnaedinger, E. K., Gallaway, K. C., Hesson-McInnis, M. S., & Hund, A. M. (2016). Executive functioning predicts reading, mathematics, and theory of mind during the elementary years. *Journal of Experimental Child Psychology, 146*, 66–78.

Carey, S. (2004). Bootstrapping and the origin of concepts. *Daedalus, 133*, 59–68.

Carlson, S. M., Faja, S., & Beck, D. M. (2016). Incorporating early development into the measurement of executive function: The need for a continuum of measures across development. In J. A. Griffin, P. McCardle, & L. S. Freund (Eds.), *Executive function in preschool-age children: Integrating measurement, neurodevelopment, and translational research* (pp. 45–64). American Psychological Association. https://doi.org/10.1037/14797-003.

Carriedo, N., Corral, A., Montoro, P. R., Herrero, L., & Rucián, M. (2016). Development of the updating executive function: From 7-year-olds to young adults. *Developmental Psychology, 52*(4), 666.

Cartwright, K. B., Marshall, T. R., Huemer, C. M., & Payne, J. B. (2019). Executive function in the classroom: Cognitive flexibility supports reading fluency for typical readers and teacher-identified low-achieving readers. *Research in Developmental Disabilities, 88*, 42–52.

Case, R., & Griffin, S. (1990). Child cognitive development: The role of central conceptual structures in the development of scientific and social thought. In *Advances in psychology* (Vol. 64, pp. 193–230). North-Holland.

Center on the Developing Child at Harvard University. (2012). *Executive function* (InBrief). Retrieved from www.developingchild.harvard.edu

Center on the Developing Child at Harvard University. (2015). *Executive function & self-regulation.* Retrieved from www.developingchild.harvard.edu

Cheng, W., Lei, P. W., & DiPerna, J. C. (2017). An examination of construct validity for the EARLI numeracy skill measures. *The Journal of Experimental Education, 85*(1), 54–72.
Clark, C. A., Pritchard, V. E., & Woodward, L. J. (2010). Preschool executive functioning abilities predict early mathematics achievement. *Developmental Psychology, 46*(5), 1176.
Clements, D. H., & Sarama, J. (2019). Executive function and early mathematical learning difficulties. In *International handbook of mathematical learning difficulties* (pp. 755–771). Cham: Springer.
Clements, D. H., & Sarama, J. (2020). *Learning and teaching early math: The learning trajectories approach. Routledge.*
Clements, D. H., Sarama, J., & MacDonald, B. L. (2019). Subitizing: The neglected quantifier. In *Constructing number* (pp. 13–45). Cham: Springer.
Conklin, H. M., Luciana, M., Hooper, C. J., & Yarger, R. S. (2007). Working memory performance in typically developing children and adolescents: Behavioral evidence of protracted frontal lobe development. *Developmental Neuropsychology, 31*(1), 103–128.
Correra, J., Nunes, T., & Bryant, P. (1999). Young children's understanding of division: The relationship between division terms in a noncomputational task. *Journal of Educational Psychology, 90*, 321–329.
Cragg, L., & Gilmore, C. (2014). Skills underlying mathematics: The role of executive function in the development of mathematics proficiency. *Trends in Neuroscience and Education, 3*(2), 63–68.
Cragg, L., Keeble, S., Richardson, S., Roome, H. E., & Gilmore, C. (2017a). Direct and indirect influences of executive functions on mathematics achievement. *Cognition, 162*, 12–26. https://doi.org/10.1016/j.cognition.2017.01.014.
Cragg, L., Richardson, S., Hubber, P. J., Keeble, S., & Gilmore, C. (2017b). When is working memory important for arithmetic? The impact of strategy and age. *PLoS One, 12*(12), e0188693. https://doi.org/10.1371/journal.pone.0188693.
Das, J. P., (2014). *Modules for math: A manual for cognitive training*. Alberta: J. P. Das Centre on Developmental and Learning Disabilities.
Das, J. P., Bhushan, B., Dash, U. N., Goyal, R., Nair, P., Nair, R., Padakannaya, P., & Samantaray, S. (2020). *Brain-Based Intelligence Test. Bhubaneshwar: The Learning Clinic.*
de Hevia, M. D., Izard, V., Coubart, A., Spelke, E. S., & Streri, A. (2014). Representations of space, time, and number in neonates. *Proceedings of the National Academy of Sciences of the United States of America, 111*(13), 4809–4813.
De Smedt, B., Swillen, A., Verschaffel, L., & Ghesquiere, P. (2009). Mathematical learning disabilities in children with 22q11. 2 deletion syndrome: A review. *Developmental Disabilities Research Reviews, 15*(1), 4–10.
De Smedt, B., Holloway, I. D., & Ansari, D. (2011). Effects of problem size and arithmetic operation on brain activation during calculation in children with varying levels of arithmetical fluency. *NeuroImage, 57*(3), 771–781.
De Smedt, B., Noel, M.-P., Gilmore, C., & Ansari, D. (2013). How do symbolic and non-symbolic numerical magnitude processing skills relate to individual differences in children's mathematical skills? A review of evidence from brain and behavior. *Trends Neuroscience Education, 2*, 48–55. https://doi.org/10.1016/j.tine.2013.06.001.
Dehaene, S., Piazza, M., Pinel, P., & Cohen, L. (2003). Three parietal circuits for number processing. *Cognitive Neuropsychology, 20*(3–6), 487–506.
Del Río, M. F., Susperreguy, M. I., Strasser, K., & Salinas, V. (2017). Distinct influences of mothers and fathers on kindergartners' numeracy performance: The role of math anxiety, home numeracy practices, and numeracy expectations. *Early Education and Development, 28*(8), 939–955.
Desoete, A. (2015a). Predictive indicators for mathematical learning disabilities/dyscalculia in kindergarten children. In *The Routledge international handbook of dyscalculia and mathematical learning difficulties* (pp. 90–100).

Desoete, A. (2015b). Cognitive predictors of mathematical abilities and disabilities. In R. C. Kadosh & A. Dowker (Eds.), *Oxford library of psychology. The Oxford handbook of numerical cognition* (pp. 915–932). Oxford: Oxford University Press.

Dotan, D., & Friedmann, N. (2018). A cognitive model for multidigit number reading: Inferences from individuals with selective impairments. *Cortex, 101*, 249–281.

Dowker, A. (2019). *Individual differences in arithmetic: Implications for psychology, neuroscience and education*. Abingdon: Routledge.

Duh, S., Paik, J. H., Miller, P. H., Gluck, S. C., Li, H., & Himelfarb, I. (2016). Theory of mind and executive function in Chinese preschool children. *Developmental Psychology, 52*(4), 582.

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., et al. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428–1446. https://doi.org/10.1037/0012-1649.43.6.1428.

Eichenbaum, H. (2010). Hippocampus. *The Corsini Encyclopedia of Psychology*, 1–2.

Evans, L. A., & Gold, L. A. (2019). Pre mathematics skills in infants: Numerosity as a game. *Contemporary Issues in Early Childhood*, 1463949119840755.

Evans, T. M., & Ullman, M. T. (2016). An extension of the procedural deficit hypothesis from developmental language disorders to mathematical disability. *Frontiers in Psychology, 7*, 1318.

Feigenson, L., Dahaene, S., & Spelke, E. (2004). Core systems of number. *Trends in Cognitive Sciences, 8*, 307–314.

Ferguson, S. (2017). Make me a pattern. *Prime Number, 32*(2), 17.

Fias, W. (2016). Neurocognitive components of mathematical skills and dyscalculia. In *Development of mathematical cognition* (pp. 195–217). Academic Press.

Fias, W., Menon, V., & Szucs, D. (2013). Multiple components of developmental dyscalculia. *Trends in Neuroscience and Education, 2*(2), 43–47.

Fletcher, J. M., Lyon, G. R., Fuchs, L. S., & Barnes, M. A. (2018). *Learning disabilities: From identification to intervention*. Guilford Publications.

Franzon, F., Zanini, C., & Rugani, R. (2019). Do non-verbal number systems shape grammar? Numerical cognition and number morphology compared. *Mind & Language, 34*(1), 37–58.

Friso-Van Den Bos, I., Van der Ven, S. H., Kroesbergen, E. H., & Van Luit, J. E. (2013). Working memory and mathematics in primary school children: A meta-analysis. *Educational Research Review, 10*, 29–44.

Friso-van Den Bos, I., Kroesbergen, E. H., & Van Luit, J. E. (2018). Counting and number line trainings in kindergarten: Effects on arithmetic performance and number sense. *Frontiers in Psychology, 9*, 975.

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134*(1), 31.

Gashaj, V., Oberer, N., Mast, F. W., & Roebers, C. M. (2019). Individual differences in basic numerical skills: The role of executive functions and motor skills. *Journal of Experimental Child Psychology, 182*, 187–195.

Gathercole, S. E., & Alloway, T. P. (2008). *Working memory and learning: A practical guide for teachers*. Sage.

Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from national curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology, 18*, 1–16.

Gathercole, S. E., Woolgar, F., Kievit, R. A., Astle, D., Manly, T., & Holmes, J. (2016). How common are WM deficits in children with difficulties in reading and mathematics? *Journal of Applied Research in Memory and Cognition, 5*(4), 384–394.

Geary, D. C. (2004). Mathematics and learning disabilities. *Journal of Learning Disabilities, 37*(1), 4–15.

Geary, D. C. (2011). Consequences, characteristics, and causes of mathematical learning disabilities and persistent low achievement in mathematics. *Journal of developmental and behavioral pediatrics: JDBP, 32*(3), 250.

Gilmore, C., & Cragg, L. (2018). The role of executive function skills in the development of children's mathematical competencies. In *Heterogeneity of function in numerical cognition* (pp. 263–286). Academic Press.

Ginsburg, H. P., & Russell, R. L. (1981). Social class and racial influences on early mathematical thinking. *Monographs of the Society for Research in Child Development*, 1–69.

Ginsburg, H. P., Klein, A., & Starkey, P. (1998). The development of children's mathematical thinking: Connecting research with practice. In W. Damon, I. E. Sigel, & K. A. Renninger (Eds.), *Handbook of child psychology: Child psychology in practice* (Vol. 4, 5th ed., pp. 401–476). New York: Wiley.

Ginsburg, H., Cannon, J., Eisenband, J., & Pappas, S. (2006). Mathematical thinking and learning. In K. McCartney & D. Phillips (Eds.), *Blackwell handbook of early childhood development* (pp. 208–229). Malden: Blackwell.

Gobel, S. M., Watson, S. E., Lervag, A., & Hulme, C. (2014). Children's arithmetic development: It is number knowledge, not the approximate number sense, that counts. *Psychological Science, 25*, 789–798.

Gross, J., Hudson, C., & Price, D. (2009). The long term costs of numeracy difficulties. Every child a chance trust and KPMG.

Grünke, M., Karnes, J., & Hisgen, S. (2019). The effects of a multicomponent motivational intervention on math performance of elementary school students with learning disabilities. *Insights into Learning Disabilities, 16*(1), 23–35.

Güre, Ö. B., Kayri, M., & Erdoğan, F. (2020). Analysis of factors effecting PISA 2015 mathematics literacy via educational data mining. *Egitim ve Bilim, 45*(202).

Haire, M. (1941). Review of conditioning and learning [Review of the book *Conditioning and learning,* by E. R. Hilgard & D. G. Marquis]. *The Journal of Abnormal and Social Psychology, 36*(1), 124–126. https://doi.org/10.1037/h0052738.

Heister, D., Diwakar, M., Nichols, S., Robb, A., Angeles, A. M., Tal, O., ... & Huang, M. (2013). Resting-state neuronal oscillatory correlates of working memory performance. *PloS one, 8(6), e66820.*

Helton, J. J., Gochez-Kerr, T., & Gruber, E. (2018). Sexual abuse of children with learning disabilities. *Child Maltreatment, 23*(2), 157–165.

Hilgard, E. R., & Bower, G. H. (1966). *Theories of learning* (3rd ed.). Appleton-Century-Crofts.

Hodaňová, J., & Nocar, D. (2016). Mathematics importance in our life. In *Conference: 10th annual International Technology, Education and Development Conference (INTED2016), At Valencia, Volume: INTED2016 proceedings* (pp. 3086–30863092).

Hofer, K. G., Farran, D. C., & Cummings, T. P. (2013). Preschool children's math-related behaviors mediate curriculum effects on math achievement gains. *Early Childhood Research Quarterly, 28*(3), 487–495.

Holmes, J., Gathercole, S. E., & Dunning, D. L. (2010). Poor working memory: Impact and interventions. In *Advances in child development and behavior* (Vol. 39, pp. 1–43). JAI.

Hord, C., Ladrigan, E., & Saldanha, R. L. (2020). A student with a learning disability and multistep equations with fractions. *Learning Disabilities: A Contemporary Journal, 18*(1), 111–121.

Huda, M. (2018). Investigating factors influencing mathematics teaching performance: An empirical study. *International Journal of Instruction, 11*(3), 391–402.

Huizinga, M., Dolan, C. V., & Van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia, 44*(11), 2017–2036.

Hulme, C., & Snowling, M. J. (2013). *Developmental disorders of language learning and cognition*. Wiley.

Isaacs, E. B., Edmonds, C. J., Lucas, A., & Gadian, D. G. (2001). Calculation difficulties in children of very low birthweight: A neural correlate. *Brain, 124*(9), 1701–1707.

Jordan, N. C., Kaplan, D., Ramineni, C., & Locuniak, M. N. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology, 45*(3), 850.

Jordan, N. C., Glutting, J., Dyson, N., Hassinger-Das, B., & Irwin, C. (2012). Building kindergartners' number sense: A randomized controlled study. *Journal of Educational Psychology, 104*(3), 647–660. https://doi.org/10.1037/a0029018.

Jurado, M. B., & Rosselli, M. (2007). The elusive nature of executive functions: A review of our current understanding. *Neuropsychology Review, 17*(3), 213–233.

Kaufmann, L., & von Aster, M. (2012). The diagnosis and management of dyscalculia. *Deutsches Arzteblatt International, 109*(45), 767–778. https://doi.org/10.3238/arztebl.2012.0767.

Kempe, C., Gustafson, S., & Samuelsson, S. (2011). A longitudinal study of early reading difficulties and subsequent problem behaviors. *Scandinavian Journal of Psychology, 52*(3), 242–250.

Klein, E., Suchan, J., Moeller, K., Karnath, H. O., Knops, A., Wood, G., et al. (2016). Considering structural connectivity in the triple code model of numerical cognition: Differential connectivity for magnitude processing and arithmetic facts. *Brain Structure and Function, 221*(2), 979–995.

Kolkman, M. E., Hoijtink, H. J. A., Kroesbergen, E. H., & Leseman, P. P. M. (2013). The role of executive functions in numerical magnitude skills. *Learning and Individual Differences, 24*, 145–151. https://doi.org/10.1016/j.lindif.2013.01.004.

Kroesbergen, E., & Van Luit, J. (2003). Mathematics interventions for children with special educational needs. *Remedial and Special Education, 24*, 97–114.

Kroesbergen, E. H., Van Luit, J. E. H., Van Lieshout, E. C. D. M., Van Loosbroek, E., & Van De Rijt, B. A. M. (2009). Individual differences in early numeracy: The role of executive functions and subitizing. *Journal of Psychoeducational Assessment, 27*(3), 226–236. https://doi.org/10.1177/0734282908330586.

Kucian, K., & von Aster, M. (2015). Developmental dyscalculia. *European Journal of Pediatrics, 174*(1), 1–13.

Kuhl, U., Friederici, A. D., Emmrich, F., Brauer, J., Wilcke, A., Neef, N., et al. (2020). Early cortical surface plasticity relates to basic mathematical learning. *NeuroImage, 204*, 116235.

Le Corre, M., & Carey, S. (2007). One, two, three, four, nothing more: An investigation of the conceptual sources of the verbal counting principles. *Cognition, 105*(2), 395–438.

Lee, K., & Lee, H. W. (2019). Inhibition and mathematical performance: Poorly correlated, poorly measured, or poorly matched? *Child Development Perspectives, 13*(1), 28–33.

Lee, K., Bull, R., & Ho, R. M. (2013). Developmental changes in executive functioning. *Child Development, 84*(6), 1933–1953.

Lee, K., Ng, S. F., Pe, M. L., Ang, S. Y., Hasshim, M. N. A. M., & Bull, R. (2012). The cognitive underpinnings of emerging mathematical skills: Executive functioning, patterns, numeracy, and arithmetic. *British Journal of Educational Psychology, 82(1), 82–99.* https://doi.org/10.1111/j.2044-8279.2010.02016.x.

Lemaire, P. (1996). The role of working memory resources in simple cognitive arithmetic. *European Journal of Cognitive Psychology, 8*(1), 73–104.

Lerner, J. W. (2000). *Learning disabilities: Theories, diagnosis, and teaching strategies*. Boston: Houghton Mifflin.

Levine, S. C., Suriyakham, L. W., Rowe, M. L., Huttenlocher, J., & Gunderson, E. A. (2010). What counts in the development of young children's number knowledge? *Developmental Psychology, 46*(5), 1309.

Libertus, M. E., Feigenson, L., & Halberda, J. (2011). Preschool acuity of the approximate number system correlates with school math ability. *Developmental Science, 14*(6), 1292–1300.

Li-Grining, C. P., Votruba-Drzal, E., Maldonado-Carreño, C., & Haas, K. (2010). Children's early approaches to learning and academic trajectories through fifth grade. *Developmental Psychology, 46*(5), 1062.

Luna, B., Garver, K. E., Urban, T. A., Lazar, N. A., & Sweeney, J. A. (2004). Maturation of cognitive processes from late childhood to adulthood. *Child Development, 75*(5), 1357–1372.

Lyons, I. M., Price, G. R., Vaessen, A., Blomert, L., & Ansari, D. (2014). Numerical predictors of arithmetic success in grades 1–6. *Developmental Science, 17*(5), 714–726. https://doi.org/10.1111/desc.12152.

Mammarella, I. C., Hill, F., Devine, A., Caviola, S., & Szűcs. (2015). Math anxiety and developmental dyscalculia: A study on working memory processes. *Journal of Clinical and Experimental Neuropsychology, 37*(8), 878–887.

Martínez, R. S., & Semrud-Clikeman, M. (2004). Emotional adjustment and school functioning of young adolescents with multiple versus single learning disabilities. *Journal of Learning Disabilities, 37*(5), 411–420.

Mazzocco, M. M., Feigenson, L., & Halberda, J. (2011). Preschoolers' precision of the approximate number system predicts later school mathematics performance. *PLoS One, 6*(9), e23749.

Medina, J. (2020, January 17). Specific learning disorder. PsychCentral. https://psychcentral.com/disorders/specific-learning-disorder/

Menon, V. (2010). Developmental cognitive neuroscience of arithmetic: Implications for learning and education. *ZDM Mathematics Education, 42*, 515–525. https://doi.org/10.1007/s11858-010-0242-0.

Menon, V. (2016). Working memory in children's math learning and its disruption in dyscalculia. *Current Opinion in Behavioral Sciences, 10*, 125–132.

Merkley, R., & Ansari, D. (2016). Why numerical symbols count in the development of mathematical skills: Evidence from brain and behaviour. *Current Opinion in Behavioral Sciences, 10*, 14–20. https://doi.org/10.1016/j.cobeha.2016.04.006.

Miller, M. R., Müller, U., Giesbrecht, G. F., Carpendale, J. I., & Kerns, K. A. (2013). The contribution of executive function and social understanding to preschoolers' letter and math skills. *Cognitive Development, 28*(4), 331–349.

Miller, D. C., Maricle, D. E., Kaufman, A. S., & Kaufman, N. L. (2019). *Essentials of school neuropsychological assessment*. Wiley.

Mix, K. S., Levine, S. C., Cheng, Y. L., Young, C., Hambrick, D. Z., Ping, R., & Konstantopoulos, S. (2016). Separate but correlated: The latent structure of space and mathematics across development. *Journal of Experimental Psychology: General, 145*(9), 1206.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*(1), 49–100.

Moeller, K., Fischer, U., Cress, U., & Nuerk, H. C. (2012). Diagnostics and intervention in developmental dyscalculia: Current issues and novel perspectives. In *Reading, writing, mathematics and the developing brain: Listening to many voices* (pp. 233–275). Dordrecht: Springer.

Monette, S., Bigras, M., & Guay, M. C. (2011). The role of the executive functions in school achievement at the end of Grade 1. *Journal of Experimental Child Psychology, 109*(2), 158–173.

Montoya, M. F., Susperreguy, M. I., Dinarte, L., Morrison, F. J., San Martin, E., Rojas-Barahona, C. A., & Förster, C. E. (2019). Executive function in Chilean preschool children: Do short-term memory, working memory, and response inhibition contribute differentially to early academic skills? *Early Childhood Research Quarterly, 46*, 187–200.

Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2016). Who is at risk for persistent mathematics difficulties in the United States? *Journal of Learning Disabilities, 49*(3), 305–319.

Morris, J. (2019). *Effects of an explicit instruction and video modeling intervention with augmented reality on the rational number mathematics outcomes of students with disabilities*.

Mulligan, J., & Mitchelmore, M. (2009). Awareness of pattern and structure in early mathematical development. *Mathematics Education Research Journal, 21*, 33–49.

Nguyen, T., Watts, T. W., Duncan, G. J., Clements, D. H., Sarama, J. S., Wolfe, C., & Spitler, M. E. (2016). Which preschool mathematics competencies are most predictive of fifth grade achievement? *Early Childhood Research Quarterly, 36*, 550–560. https://doi.org/10.1016/j.ecresq.2016.02.003.

Nyroos, M., Jonsson, B., Korhonen, J., & Eklöf, H. (2015). Children's mathematical achievement and how it relates to working memory, test anxiety and self-regulation: A person-centred approach. *Education Inquiry, 6*(1), 26026.

Ofiesh, N., & Mather, N. (2013). Resilience and the child with learning disabilities. In *Handbook of resilience in children* (pp. 329–348). Boston: Springer.

Okamoto, Y., & Case, R. (1996). Exploring the microstructure of children's central conceptual structures in the domain of number. In R. Case & Y. Okamoto (Eds.), *The role of central conceptual structures in the development of children's thought*. Monographs of the Society for Research in Child Development, 60 (5–6, Serial No. 246, pp. 27–58).

Panaoura, A., & Philippou, G. (2007). The developmental change of young pupils' metacognitive ability in mathematics in relation to their cognitive abilities. *Cognitive Development, 22*, 149–164. https://doi.org/10.1016/j.cogdev.2006.08.004.

Pandey, S., & Agarwal, S. (2014). Dyscalculia: A specific learning disability among children. *International Journal of Advanced Scientific and Technical Research, 4*(2), 912–916.

Parsons, S., & Bynner, J. (1997). Numeracy and employment. *Education+ Training*.

Parsons, S., & Bynner, J. (2005). *Does numeracy matter more?*.

Passolunghi, M. C., & Cornoldi, C. (2008). Working memory failures in children with arithmetical difficulties. *Child Neuropsychology, 14(5), 387–400.*

Passolunghi, M.-C., Mammarella, I. C., & Altoè, G. (2008). Cognitive abilities as precursors of the early acquisition of mathematical skills during first through second grades. *Developmental Neuropsychology, 33*, 229–250. https://doi.org/10.1080/87565640801982320.

Peng, P., Namkung, J., Barnes, M., & Sun, C. (2016). A meta-analysis of mathematics and working memory: Moderating effects of working memory domain, type of mathematics skill, and sample characteristics. *Journal of Educational Psychology, 108*(4), 455.

Piaget, J. (1952). *The child's conception of number*. London: Routledge & Kegan Paul Ltd.

Prast, E. J., Van de Weijer-Bergsma, E., Miočević, M., Kroesbergen, E. H., & Van Luit, J. E. (2018). Relations between mathematics achievement and motivation in students of diverse achievement levels. *Contemporary Educational Psychology, 55*, 84–96.

Prediger, S., Wilhelm, N., Büchter, A., Gürsoy, E., & Benholz, C. (2018). Language proficiency and mathematics achievement. *Journal für Mathematik-Didaktik, 39*(1), 1–26.

Price, G. R., Holloway, I., Räsänen, P., Vesterinen, M., & Ansari, D. (2007). Impaired parietal magnitude processing in developmental dyscalculia. *Current Biology, 17*(24), R1042–R1043.

Purpura, D. J., Baroody, A. J., & Lonigan, C. J. (2013). The transition from informal to formal mathematical knowledge: Mediation by numeral knowledge. *Journal of Educational Psychology, 105*, 453–464.

Raghubar, K. P., Barnes, M. A., & Hecht, S. A. (2010). Working memory and mathematics: A review of developmental, individual difference, and cognitive approaches. *Learning and Individual Differences, 20*, 110–122. https://doi.org/10.1016/j.lindif.2009.10.005.

Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2012). Spatial anxiety relates to spatial abilities as a function of working memory in children. *Quarterly Journal of Experimental Psychology, 65*(3), 474–487.

Recber, S., Isiksal, M., & Koç, Y. (2018). Investigating self-efficacy, anxiety, attitudes and mathematics achievement regarding gender and school type. *Anales de Psicología/Annals of Psychology, 34*(1), 41–51.

Reid, K. (2016). *Preschoolers and numeracy development*. Accessed from https://www.teachermagazine.com.au/articles/preschoolers-and-numeracy-development

Richardson, T. (2008). Inhibitory control in psychiatric disorders-a review of neuropsychological and neuroimaging research. *The Undergraduate Research Journal for the Human Sciences, 7*.

Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2011). Modeling a cascade of effects: The role of speed and executive functioning in preterm/full-term differences in academic achievement. *Developmental Science, 14*(5), 1161–1175.

Rotzer, S., Kucian, K., Martin, E., von Aster, M., Klaver, P., & Loenneker, T. (2008). Optimized voxel-based morphometry in children with developmental dyscalculia. *NeuroImage, 39*(1), 417–422.

Ryve, A., & Hemmi, K. (2019). Educational policy to improve mathematics instruction at scale: Conceptualizing contextual factors. *Educational Studies in Mathematics, 102*(3), 379–394.

Schmithorst, V. J., & Brown, R. D. (2004). Empirical validation of the triple-code model of numerical processing for complex math operations using functional MRI and group Independent Component Analysis of the mental addition and subtraction of fractions. *NeuroImage, 22*(3), 1414–1420.

Schneider, W., Bjorklund, D. F., & Valsiner, J. (2003). Memory and knowledge development. In *Handbook of developmental psychology*, (pp. 370–403).

Schoeller, F., & Sivakumar, K. (2019, January 14). *Emotions underlying early numerical cognition in humans*. https://doi.org/10.31234/osf.io/wjp6q

Selvam, S., Thomas, T., Priya, S., Thennarasu, K., Raman, V., Khanna, D., Mehra, R., Kurpad, A. V., & Srinivasan, K. (2018). Development of norms for executive functions in typically-developing Indian Urban preschool children and its association with nutritional status. *Child Neuropsychology, 24*(2), 226–246. https://doi.org/10.1080/09297049.2016.1254761.

Serianni, B. (2014). *Supporting middle school students with emotional or behavioral disorders in blended learning: A fraction intervention using virtual manipulatives*. Orlando: University of Central Florida.

Sharma, M. (2016, September 19). *Working memory: Role in mathematical learning (Part One)*. Mathlanguage.wordpress.com. https://mathlanguage.wordpress.com/2016/09/19/working-memory-role-in-mathematics-learning/

Siegal, M. (2013). *Knowing children: Experiments in conversation and cognition*. Psychology Press.

Siegler, R. S., & Braithwaite, D. W. (2017). Numerical development. *Annual Review of Psychology, 68*, 187–213.

Siegler, R., & Jenkins, E. A. (2014). *How children discover new strategies*. Psychology Press.

Siegler, R. S., & Lortie-Forgues, H. (2014). An integrative theory of numerical development. *Child Development Perspectives, 8*(3), 144–150.

Siegler, R. S., Thompson, C. A., & Schneider, M. (2011). An integrated theory of whole number and fractions development. *Cognitive Development, 62*, 273–296.

Siegler, R. S., Duncan, G. J., Davis-Kean, P. E., Duckworth, K., Claessens, A., Engel, M., Susperreguy, M. I., & Meichu, C. (2012). Early predictors of high school mathematics achievement. *Psychological Science, 23*(7), 691–697.

Siraj-Blatchford, I., & Nah, K. O. (2014). A comparison of the pedagogical practices of mathematics education for young children in England and South Korea. *International Journal of Science and Mathematics Education, 12*(1), 145–165.

Soares, N., Evans, T., & Patel, D. R. (2018). Specific learning disability in mathematics: A comprehensive review. *Translational Pediatrics, 7*(1), 48–62. https://doi.org/10.21037/tp.2017.08.03.

St Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *The Quarterly Journal of Experimental Psychology, 59*, 745–759. http://dx.doi.org/10.1080/17470210500162854.

Starkey, P., Klein, A., & Wakeley, A. (2004). Enhancing young children's mathematical knowledge through a pre-kindergarten mathematics intervention. *Early Childhood Research Quarterly, 19*(1), 99–120. https://doi.org/10.1016/j.ecresq.2004.01.002.

Stein, M., Silbert, J., & Carnine, D. (1997). *Designing effective mathematics instruction: A direct instruction approach* (3rd ed.). Upper Saddle River: Merrill Prentice Hall.

Sudha, P., & Shalini, A. (2014). Dyscalculia: A specific learning disability among children. *International Journal of Advanced Scientific and Technical Research, 4*(2), 912–918.

Swanson, H. L. (2011). Working memory, attention, and mathematical problem solving: A longitudinal study of elementary school children. *Journal of Educational Psychology, 103*(4), 821.

Swanson, H. L., & Beebe-Frankenberger, M. (2004). The relationship between working memory and mathematical problem solving in children at risk and not at risk for serious math difficulties. *Journal of Educational Psychology, 96*, 471–491.

Szucs, D., Devine, A., Soltesz, F., Nobes, A., & Gabriel, F. (2013). Developmental dyscalculia is related to visuo-spatial memory and inhibition impairment. *Cortex, 49*(10), 2674–2688.

Szűcs, D., Devine, A., Soltesz, F., Nobes, A., & Gabriel, F. (2014). Cognitive components of a mathematical processing network in 9-yearold children. *Developmental Science, 17*, 506–524. https://doi.org/10.1111/desc.12144.

Teale, W. H. (1995). Young children and reading: Trends across the twentieth century. *Journal of Education, 177*(3), 95–127.

Tosto, M. G., Petrill, S. A., Halberda, J., Trzaskowski, M., Tikhomirova, T. N., Bogdanova, O. Y., & Kovas, Y. (2014). Why do we differ in number sense? Evidence from a genetically sensitive investigation. *Intelligence, 43*(100), 35–46. https://doi.org/10.1016/j.intell.2013.12.007.

Tzuriel, D., & Shomron, V. (2018). The effects of mother-child mediated learning strategies on psychological resilience and cognitive modifiability of boys with learning disability. *British Journal of Educational Psychology, 88*(2), 236–260.

Van der Ven, S. H., Kroesbergen, E. H., Boom, J., & Leseman, P. P. (2012). The development of executive functions and early mathematics: A dynamic relationship. *British Journal of Educational Psychology, 82*(1), 100–119.

Van Harskamp, N. J., & Cipolotti, L. (2001). Selective impairments for addition, subtraction and multiplication. Implications for the organisation of arithmetical facts. *Cortex, 37*(3), 363–388.

Viterbori, P., Usai, M. C., Traverso, L., & De Franchis, V. (2015). How preschool executive functioning predicts several aspects of math achievement in Grades 1 and 3: A longitudinal study. *Journal of Experimental Child Psychology, 140*, 38–55.

Von Aster, M. G. (2000). Developmental cognitive neuropsychology of number processing and calculation: Varieties of developmental dyscalculia. *European Child & Adolescent Psychiatry, 9*(2), S41–S57.

Von Aster, M. G., & Shalev, R. S. (2007). Number development and developmental dyscalculia. *Developmental Medicine & Child Neurology, 49*(11), 868–873.

Waber, D. P., Gerber, E. B., Turcios, V. Y., Wagner, E. R., & Forbes, P. W. (2006). Executive functions and performance on high-stakes testing in children from urban schools. *Developmental Neuropsychology, 29*(3), 459–477.

Wang, L. C., Tasi, H. J., & Yang, H. M. (2012). Cognitive inhibition in students with and without dyslexia and dyscalculia. *Research in Developmental Disabilities, 33*(5), 1453–1461.

Watts, T. W., Duncan, G. J., Siegler, R. S., & Davis-Kean, P. E. (2014). What's past is prologue: Relations between early mathematics knowledge and high school achievement. *Educational Researcher, 43*(7), 352–360. https://doi.org/10.3102/0013189X14553660.

Weiland, C., & Yoshikawa, H. (2013). Impacts of a prekindergarten program on children's mathematics, language, literacy, executive function, and emotional skills. *Child Development, 84*(6), 2112–2130.

Wiebe, S. A., Espy, K. A., & Charak, D. (2008). Using confirmatory factor analysis to understand executive control in preschool children: I. Latent structure. *Developmental Psychology, 44*(2), 575.

Willoughby, M. T., Wirth, R. J., & Blair, C. B. (2011). Contributions of modern measurement theory to measuring executive function in early childhood: An empirical demonstration. *Journal of Experimental Child Psychology, 108*(3), 414–435.

Winegar, K. L. (2013). *Inhibition performance in children with math disabilities* (Doctoral dissertation, UC Riverside).

Wu, Q., Lei, P., DiPerna, J. C., Morgan, P. L., & Reid, E. E. (2015). Identifying differences in early mathematical skills among children in Head Start. *International Journal of Science and Mathematics Education, 13*, 1403–1423. https://doi.org/10.1007/s10763-014-9552-y.

Yeniad, N., Malda, M., Mesman, J., Van IJzendoorn, M. H., & Pieper, S. (2013). Shifting ability predicts math and reading performance in children: A meta-analytical study. *Learning and Individual Differences, 23*, 1–9.

Young, L. K. (2017). *Numerical magnitude knowledge: Are all numbers perceived alike?* Temple University.

Zakiah, N. E., & Fajriadi, D. (2020, August). Self regulated learning for social cognitive perspective in mathematics lessons. *Journal of Physics: Conference Series, 1613*(1): 012049. IOP Publishing.

Zhou, X., Chen, C., Zhang, H., Xue, G., Dong, Q., Jin, Z., et al. (2006). Neural substrates for forward and backward recitation of numbers and the alphabet: A close examination of the role of intraparietal sulcus and perisylvian areas. *Brain Research, 1099*(1), 109–120.

Zygouris, N. C., Stamoulis, G. I., Vlachos, F., Vavougios, D., Dadaliaris, A. N., Nerantzaki, E., …, & Striftou, A. (2017, April). Screening for disorders of mathematics via a web application. In *2017 IEEE Global Engineering Education Conference (EDUCON),* (pp. 502–507). IEEE.

Chapter 11
Memory and Learning: Basic Concepts

Delon D'Souza and Amrutha Avati

11.1 Introduction

Our higher cognitive functions define us as the most evolved species on the planet. Our ability to think and reason, to communicate through language, and to learn and form memories makes our everyday experiences meaningful and insightful. The human brain has remained an enigma for several centuries, and the understanding of how we learn and how we memorise has been the subject of intense study and research. *Learning is the process of acquiring knowledge and modifying our behaviour that happens through experience.* Learning is a relatively permanent change and is one of the most important capacities we have as human beings. Learning influences our thoughts, behaviours, emotions and helps us survive in the world as a species by keeping us away from harm. Memory is the ability to retrieve what has been learnt and retained. In this chapter, we wish to recapitulate the basic mechanisms of memory and learning.

11.2 Memory: Classification and Basic Concepts

Memory can be classified based on temporal aspects as *short-term* and *long-term memory*. Short-term memory is information that we acquire and store for a few seconds to minutes. Long-term memory or remote memory is information that is stored for days, months, or years. There is a distinct type of memory called "working memory", wherein the information that we acquire is held in our consciousness and actively manipulated to perform the next task (Brem et al. 2013). For example,

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memorising a phone number and then dialling it in, or having a discourse with a colleague: you need to hold the information that you are receiving, compare it with the knowledge you have, and give an appropriate reply.

According to the content or its nature, long-term memory can be further classified as *declarative and non-declarative memory (Scoville and Milner* 1957). *Declarative memory or explicit memory is the one that* requires a conscious awareness for its retrieval. It can be further classified as *episodic memory* and *semantic memory*. This distinction was first described by a Canadian psychologist, Endel Tulving. Episodic memory pertains to our personal lived experiences, and it is recollected in the context of the time and place in which we acquire the experience. For example, in the memory of your summer holiday, it brings to mind the visual memory of the holiday home, the sights of your family around you, the echoic memory of laughter and music, and the emotional memory of how you felt relaxed and peaceful. You remember it as an experience that you have lived. It is an autobiographical memory that is personal to you. Semantic memory on the other hand is the knowledge of facts and figures that we acquire in this world, for example, the meaning of words, the capitals of countries, or the names of Prime Ministers. The context in which we acquired this information is immaterial. Both episodic and semantic memories require conscious retrieval of information stored in the brain. Hence, they are called declarative memory or explicit memory.

Non-declarative or implicit memory on the other hand does not require a conscious retrieval. There are four types of non-declarative memory – procedural memory, associative learning, non-associative learning, and priming. Most of the skills that we learn, like driving a car or playing a musical instrument, are stored as implicit memory. Once we have acquired the skill, we can perform the task automatically without having to focus on its individual components. When we have to perform the task, the motor and/or sensory pathways are activated subconsciously. This is called as procedural memory. Priming is a type of implicit memory, wherein due to exposure to a stimulus, the response to a subsequent stimulus is modified. A further description and mechanism of priming is beyond the scope of this chapter. The other types of implicit memory, associative and non-associative learning, will be explained later in this chapter.

We also need to understand the steps in the process of creating a memory. When we learn or experience any event, we acquire information, which is then stored for further use. This stored knowledge is consolidated and retrieved as and when required. *Encode, store, consolidate, and retrieve* are the basic steps involved in memory (Brem et al. 2013). Encoding any information is the first key step which depends on the attention that is given to the event as well as the level of motivation. We also associate the new information with any pre-existing knowledge that we have about the subject. This is called "deep encoding", which helps us to remember the events better. Once the information is encoded, it is stored for long-term use. Consolidation of the memory is an important step, where, at the cellular level, there are multiple new proteins being synthesised and structural changes that happen in the neurons to strengthen this new memory. Retrieval is when we recall the stored

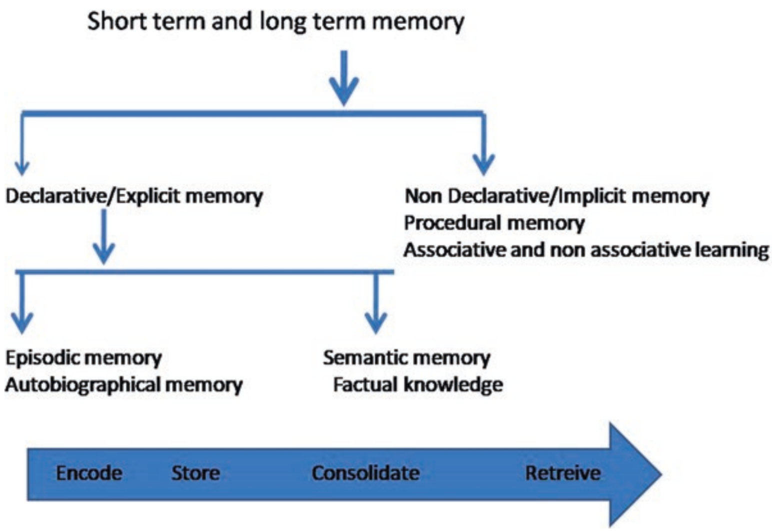

Fig. 11.1 Classification of memory

information from different sites of the brain. It can be initiated by a conscious recall or various sensory cues.

Figure 11.1 is a summary of the memory processes but at best is an oversimplification of this complex cognitive function. Each of these subcomponents can be further studied with regard to various physiological processes involved, which is beyond the scope of this chapter.

11.3 Models of Memory

These basic mechanisms of memory were first described through several models by neuropsychologists (Camina and Güell 2017). One of most influential models of memory that was initially described by Atkinson and Shiffrin was known as *modal model*. According to this model, there are three principal storage systems: sensory, short-term, and long-term storage systems. *Sensory memory* that lasts for less than a second has a limitless capacity but a fast decay. It is the information that we perceive through our senses. Iconic memory is information that we obtain through our sense of vision, and echoic memory is data that we process through our sense of hearing. Haptic memory is memory acquired through the sense of touch. Of these, iconic memory has been well described and studied. This memory is then transferred to a *short-term storage* system that has a limited capacity and can retain information for a few minutes. Among these, the memories that have been rehearsed or given attention to are then transferred to as a *long-term storage system* that again has a limitless capacity.

While this model was the basis of several studies, with years of research, it became increasingly clear that it had several lacunae and could not account for all the different processes involved in memory. Another memory model that became popular was "level of processing" model by Craik and Lockhart. They postulated that rather than separate storage systems, the memories depended on the level of processing. Shallow processing leads to faster decay of memories, while deep processing leads to stronger memories. When we memorise the structure of an object or letters of a word, that amounts to shallow processing, and this information can be easily forgotten. When we attend to the meaning of the word (semantics), it is deep processing that allows us to integrate this new information with what we already know and strengthens the memory. This model too had several strengths and weaknesses. Another popular memory model is Baddeley's model, which accounted for the process of working memory as well. According to this model, when we receive any information, there is a central executive system that oversees or gives the attention to the new information. There are two subsystems under the executive system: one for the visual and spatial information (visuospatial sketch pad) and the other for the language content (phonological loop). These two subsystems are integrated in another system called the episodic buffer which is controlled by the central executive system. This multi-store system allows us to retain and manipulate information.

With the advance in technology and better noninvasive tools to study dynamic brain functions, it was found that rather than specific areas of the brain, it is neural networks distributed across the hemispheres that are responsible for storing memories. These neural networks are constantly modified based on the activity of the neurons in the network. One such network theory is the "parallel distributed processing model". Like a computer system, multiple neural networks work in parallel in our brains, and the activity in the networks can be modified to strengthen or weaken the memory. Our understanding of memory is continuing to evolve. There are several such theories that are now being explored to explain this complex cognitive function.

11.4 Neuroanatomical Basis of Memory

Where is memory formed and stored? This was a question that had kept scientists guessing for a long time. In the early days of research, we got some insight into the working of the brain from the study of patients with brain injuries. Initially, soldiers with gunshot injury to the brain were studied to identify important areas of specific cognitive and motor functions. Path-breaking discovery emerged in the twentieth century, through the study of a patient named Henry Gustav Molaison, better known as H. M. The study of this patient is arguably one of the most important landmarks in neuroscience. He suffered from refractory epilepsy, and by his early 20s, he was severely incapacitated due to it, and had to quit his job. It was the era of experimental psychosurgery, and Dr. William Beecher Scoville, one of the leading neurosurgeons of the time, conducted lobotomies on asylum patients in an attempt to cure them of their psychosis. Henry Molaison underwent an experimental surgery in 1953 in which Dr. Scoville removed both his medial temporal lobes, hippocampi with the parahippocampal regions, and amygdala in an attempt to cure him of epilepsy. After the surgery, his seizures improved; but there was a devastating consequence. Henry Molaison had lost his ability to form new memories! He could not remember any event after his surgery. He often asked if he had eaten his breakfast and had to be reintroduced to people he had met. Henry Molaison was initially evaluated by a psychologist Brenda Milner, and he became the subject of several studies and research papers (Scoville and Milner 1957). It was found that H.M. could not form new explicit or declarative memories; however, his implicit memory was intact. He could be taught new skills which over time he performed without a mistake, though he could not recollect learning the skill. He could recollect childhood and college year experiences with great detail and clarity, which meant that his long-term memory was intact. While he definitely had no new memories after the surgery ("anterograde amnesia"), he could also not recollect events just prior to the surgery ("retrograde amnesia"). Interestingly, he could engage in conversations and converse meaningfully with another person, which meant that his working memory was intact. However, if he was distracted from the conversation with an interfering task, he failed to recollect the conversation or even the person he was talking to. There was no change in his personality, intelligence, and language functions. Through this unintended experiment, it was convincingly proven that there are specific areas of the brain responsible for different kinds of memory.

Through the study of patient H.M. and similar such patients with medial temporal lobe lesions, it was clear that the hippocampus is an important area for forming new explicit or declarative memories. However, since he could recollect his childhood memories, it could be inferred that once memory was formed in the hippocampus, it was stored in a different area for retrieval. As working and implicit memory were spared, it was concluded that the hippocampus had no role in these memories.

Several such neuropsychological tests were carried out on similar subjects with different brain lesions. Now our understanding of the anatomical substrates involved in different physiological processes has greatly improved with noninvasive brain studies. With the advent of modern technology, we have several tools at our disposal to study brain functions. The PET scan with the help of radio-labelled tracers shows blood flow changes in active areas of the brain during any activity. The functional MRI (fMRI) lights up the active brain network while performing any task. The candidate can be given a memory task to see the areas that are activated in real time during an fMRI. Similarly, through the EEG which measures the electrical activity of the brain in different areas, the sequence of activation in different circuits can be identified. These tests are complementary –the MRI gives excellent spatial resolution in terms of areas involved, while EEG provides an excellent temporal resolution as to the sequence in which circuits are activated. In addition, techniques such as transcranial magnetic stimulation and transcranial direct current stimulation are tools which can stimulate or suppress targeted areas of the brain to study their contribution to the cognitive processes. Using these and several more tools, we are now getting newer insights as to how different areas of the brain contribute to memory and learning.

Through the pioneering study on patient HM, the hippocampus was identified as an important region for new declarative memory. When we are experiencing an event through our senses, we are perceiving information. While we are constantly exposed to a barrage of sensory experiences, our brain filters the information and brings into conscious awareness only those which we pay attention to. So to begin with, we need to pay *attention to acquire* information. This attention is the role of the prefrontal cortex which is a part of the frontal lobe. Once we pay attention, the information is processed in various cortical association areas. For example, if we were to encounter a tiger, we *see* a four-legged ferocious brown-striped animal, we *hear* the loud roar, and we feel intense fear. The visual and auditory association areas convey this information to the hippocampus through the perirhinal cortex, entorhinal cortex, and parahippocampal cortex. Information regarding the object ("what") projects through the perirhinal and lateral entorhinal areas, while the topographic information ("where") is transferred via the parahippocampal and medial entorhinal areas. In the hippocampus, the information goes through several neural networks where it is encoded and stored as short-term memory and is projected back to the parahippocampus and cortex via the same pathways for long-term storage and retrieval. The areas for long-term storage are widely distributed in the cerebral cortex. When we recollect an event, the cerebral cortex, particularly the prefrontal cortex, helps us to retrieve this information. It has been found that the right prefrontal cortex has a greater role in retrieval. Remote memory is not under the control of the medial temporal lobe and is widely distributed in several areas of the cerebral cortex. Remote memory is therefore spared in dementias. Interestingly, it has been found that damage to areas that are strongly connected to the medial temporal lobe such as the thalamus, amygdala, and frontal lobe also results in episodic memory loss (Kandel et al. 2013; Squire 2004).

Semantic memory, which is the memory of concepts and abstract knowledge, has a widely distributed anatomical network. The exact networks involved in different aspects of semantic memory are still under investigation. Through several noninvasive functional studies, it has been found that semantic memory is represented in the heteromodal association areas of the inferior parietal lobe, lateral temporal lobe, and prefrontal cortices. The heteromodal association areas receive and integrate sensory and motor information from various motor and sensory modality-specific association areas of the cortex (Kandel et al. 2013; Squire 2004).

Implicit memory or procedural memory requires contributions from several structures such as the cerebellum and the striatum (part of basal ganglia) and the limbic system. We will be describing important aspects of associative learning, which is a type of implicit memory in the subsequent section.

11.5 Types of Learning

Modern study of learning began at the turn of the last century. While studying the physiology of digestion in dogs, Pavlov recognised that the dogs in his experiments were learning when to anticipate food. His further experiments gave the first model of learning in animals. Since then, the theories of learning have expanded, and much like laws of gravity, the laws of learning are always in play.

Learning can be broadly categorised into two groups – associative and non-associative. *Associative learning* (also called *conditioning*) is when learning occurs through association between two or more stimuli. The association sometimes results in a reward or a punishment, which in turn modifies our behaviour through learning. *Non-associative learning* is learning in which the stimuli and behaviour are not linked.

Associative learning is the most basic type of learning seen in all animals, not just humans. Associative learning can be studied as two fundamental subtypes – classical conditioning and operant conditioning.

11.6 Classical Conditioning

Classical conditioning is a fundamental process of learning and is a ubiquitous phenomenon. Conditioning refers to the association of a neutral stimulus with a second stimulus, which naturally evokes a certain behaviour in an animal. Classical conditioning was first studied by the Russian physiologist Ivan Petrovich Pavlov. His life's work was primarily on the physiology of the digestive system for which he won a Nobel Prize in 1904.

During his experiments on dogs, Pavlov noticed that the dogs started salivating when presented with meat powder. The meat powder was the unconditioned stimulus (US), and the salivation to the meat powder was the unconditioned response (UR). This occurred naturally without any associative learning or conditioning. Pavlov then paired a neutral stimulus, ringing of a bell, with the presentation of the meat powder. Over such repeated pairings, he noticed that the dog began to salivate at the sound of the bell even without the presentation of the meat powder. The neutral stimulus had now become a conditioned stimulus (CS) by causing salivation in the dog, the conditioned response (CR).

This landmark experiment was one of the first studies on learning, and it established that classical conditioning is a fundamental process seen even in animals. Pavlov's experiment proved that learning can be studied through the observation of behaviour, and it also laid the foundation for *behaviourism* – which is the study of observable behaviour of animals rather than internal mental processes.

Another important study in classical conditioning was done by the American psychologist John B. Watson, called the Little Albert experiment. Watson's experiment was aimed at inducing emotions in humans to a wide range of cues. In the experiment, an infant was introduced to a small rat (neutral stimulus), and each time the infant tried to play with the rat, a loud noise was created with a hammer (US), and the infant would cry because of the noise (UR). After repeated pairings, the infant started crying at the sight of the rat (CR). This experiment proved that even humans, not just animals, learn through classical conditioning. It also raised the possibility that if behaviour or phobias can be induced, then classical conditioning could potentially be used to alter the behaviour or phobias.

The responses in classical conditioning are "elicited" and are involuntary in nature – the dog is the passive respondent in the experiment. The learning here is not a new behaviour but rather a natural biological response to a new stimulus. Repeated pairings of the CS with US lead to strengthening of the response (acquisition phase). After this, when CS is presented without US, there is a gradual reduction in response – a process called extinction (over time, the dog no longer salivates just at the sound of the bell). When CS is reintroduced at a later time after extinction, the response is seen again – called spontaneous recovery (the dog salivates again just at the sound of the bell).

A real-life example of classical conditioning would be using popular celebrities to endorse brands to create a positive feel towards the brand, which is otherwise a neutral stimulus. Another example would be checking your smartphone in a public place when you hear a familiar ringtone, only to realise it is someone else's phone that is ringing.

When the conditioned response occurs to stimuli other than but similar to the conditioned stimulus, it is called *generalisation*. For example, after you get your own pet dog, you seem to like all dogs in general. The fear of spiders is for all spiders, not just poisonous ones. *Discrimination* is the ability to distinguish between different stimuli and respond accordingly.

11.7 Operant (Instrumental) Conditioning

Operant conditioning is learning through rewards and punishments. The animal "operates" on the environment through its behaviour, and the consequences of that behaviour (positive or negative) strengthen or weaken the said behaviour, respectively. Important experiments in operant conditioning were done by American psychologists Edward Thorndike and B F Skinner. Thorndike and Skinner were both comparative psychologists. Their experiments were designed to study the behaviour of animals and use the results to study the evolution of the human mind with a cross-species comparison.

Edward Thorndike designed a "puzzle box" inside which a cat was locked and the cat had to learn how to escape from the box. After repeated haphazard attempts, the cat learned that pressing a certain lever opened the box. In subsequent trials, the cat opened the box by pressing the lever in fewer attempts. Based on his experiments with these puzzle boxes, Thorndike developed the law of effect (Sadock et al.

2009) – when a behaviour produces a positive outcome, it is more likely to be strengthened, and similarly when the outcome is negative, it is likely to be weakened.

BF Skinner expanded on Thorndike's ideas of operant learning through his own experiments. Skinner placed a rat inside an operant chamber (called a Skinner box) with a lever inside. When the rat pressed the lever, the rat would be rewarded with a food pellet. As per the law of effect, the rat learnt to press the lever to earn food pellet rewards. This experiment allowed the study of motivation and observes how an animal can modify its behaviour to gain rewards. In contrast to classical conditioning, operant conditioning is learning a new behaviour to gain rewards and avoid punishment. The food pellet is the "reinforcer" or "reward" which strengthens the rat's response of pressing the lever. The rat's behaviour here is voluntary, unlike in classical conditioning.

Reinforcement is an outcome that strengthens a behaviour. Reinforcement can be positive (you get a good grade on a project) or negative (taking a painkiller removes your headache, clearing your desk so that you can work better). Negative reinforcement is not a punishment. It is an outcome that removes something negative and strengthens the behaviour. Punishment is an outcome that weakens a behaviour. Punishment can be positive (you pay a fine when you break a traffic rule) or negative (you lose your driver's license when you drink and drive).

Reinforcement can be used to expand the horizon of operant learning. When used continuously, reinforcement leads to rapid learning and, similarly, rapid extinction when the reinforcement stops. A vending machine always gives you snacks, but you stop going to the machine when it runs out of snacks.

Partial or intermittent reinforcement involves fewer rewards and leads to slower learning of a behaviour but also shows greater resistance to extinction and is likely to last longer. The schedule of the reinforcement determines the behaviour outcome. The reinforcement could be on any of the below schedules:

(a) Fixed ratio – here the reward comes after a specific number of responses (e.g. you get a free coffee after purchasing every ten coffees).
(b) Variable ratio – the reward comes after an unpredictable number of responses (e.g. slot machines in a casino).
(c) Fixed interval – the reward comes after a specific amount of time (e.g. monthly salary).
(d) Variable interval – the reward comes after an unpredictable amount of time (e.g. pop-up notifications on a smartphone).

Operant conditioning is used in providing incentives to employees, discounts for customers, and benefits of membership programmes. Complex learning requires a process called *shaping*. Shaping is the process by which complex behaviours are taught – like tricks done by circus animals – through a series of successful approximations or micro-behaviours directed towards a final target behaviour. Skinner, in his later experiments, gradually increased the complexity of tasks for the rats inside the boxes to achieve their food pellet rewards.

11.8 Non-associative Learning

Non-associative learning is the other form of learning where there is no association between different stimuli and does not involve any reward or punishment. Habituation is the decrease in response to a particular stimulus after repeated exposure – the shudder you feel when you hear thunder for the first time reduces when you hear it over and over again. Sensitisation is an increase in response to a stimulus on repeated exposure – the annoyance you feel towards a noisy neighbour increases with time.

11.9 Social Learning

The theories of learning through conditioning were exemplary in explaining a lot of human learning and behaviour, yet there were still some behaviours that were not explained by conditioning, for example, latent learning, which is the unapparent learning that happens without any incentive or punishment. It is the information that is stored subconsciously in us and becomes visible in a situation of need – like when we need directions to our house or when we sing along to a song playing on the radio. Latent learning indicates that animals, including humans, can learn through just observation and experiences. This learning that occurs through observation of behaviour of others is called *observational learning* or *social learning* or *modelling*.

Observational learning was studied in the famous Bobo doll experiment conducted by Albert Bandura at Stanford University. In this experiment, Bandura showed a group of children either a video or a cartoon of an adult violently punching a Bobo doll, kicking it, and hitting it with a hammer. After that, the children were given toys to play with but for a very short period of time, with the intention of creating frustration among them. The children were then left alone with the Bobo doll. Bandura observed that the children imitated the violent behaviour they had seen in the video and hit the Bobo doll themselves. This challenged the theory that all learning happens through reward and punishment and proved that learning can happen though imitation of observed behaviours.

Observational learning has an evolutionary basis in that we learn about dangers in our environment by observing the experiences of others. On the other hand, observational learning leads to imbibing of aggressive behaviour in children who grow up in violent families. Children who are victims of abuse grow up into adults who inflict violence on their partners and children. Children who grow up observing altruistic behaviour imbibe the same in themselves.

11.10 Cellular Basis of Learning

There are approximately 86 billion neurons in our brain, and these neurons constantly communicate with each other through connections called synapses. A synapse is a junction between two neurons – called pre- and postsynaptic neurons – where electrical nerve impulses are transmitted from the presynaptic neuron to the postsynaptic neuron via chemical messengers called neurotransmitters. The neurons form a highly interconnected network with a typical neuron having from 1000 to 10,000 synapses, and certain neurons like the Purkinje cells can have up to 200,000 synapses per neuron! One of the estimates quotes around 150 trillion synapses in our cerebral cortex alone.

Unlike most other cells in our body, neurons cannot replicate. We have the same absolute number of neurons in our body since birth. So what happens when we learn or acquire new memories? How does the brain adapt itself to store the information we are constantly acquiring? The answer lies in the number of synapses and how synapses change when we repeat a certain activity multiple times.

When the synapse between two neurons receives repeated stimulation, a phenomenon called long-term potentiation (LTP) – which results in the strengthening of the synaptic connection – is observed. *LTP is the cellular and molecular basis of memory and learning.* LTP is the result of repeated interaction between two neurons – hence, the more you practice or read, the better you learn.

LTP has been studied most extensively in the hippocampus region of the brain, particularly in the region called Schaffer collaterals. Schaffer collaterals are axonal projections from a region called CA3 (Cornu Ammonis or the horn of the Egyptian God Ammon) to another region called CA1 in the hippocampus. It is a part of important circuits involved in memory and emotion and is named after a Hungarian scientist Károly Schaffer. At the synapses, the neurotransmitter involved, called glutamate, has two receptors on the postsynaptic neuron – NMDA (N-methyl-D-aspartate) and AMPA (α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid). Receptors are the equivalent of gates, which open when an impulse reaches the synapse and permit the movement of sodium and calcium ions into the postsynaptic neuron to continue the propagation of the impulse.

AMPA receptors respond even to smaller impulses, whereas NMDA receptors require greater stimulation, due to a blocking magnesium ion. When glutamate activates the AMPA receptor, sodium ions enter the postsynaptic neuron. When there is repeated stimulation, greater amount of sodium ions enter and dislodge the magnesium ions blocking the NMDA receptors and open the NMDA receptors. Once the NMDA receptors are open, there is an inflow of calcium ions into the postsynaptic neuron (Fig. 11.2).

Calcium is an important intracellular messenger which activates secondary changes inside the postsynaptic neuron when there is repeated stimulation:

(a) Stimulates protein synthesis which leads to additional AMPA receptors being added to the postsynaptic neuron.

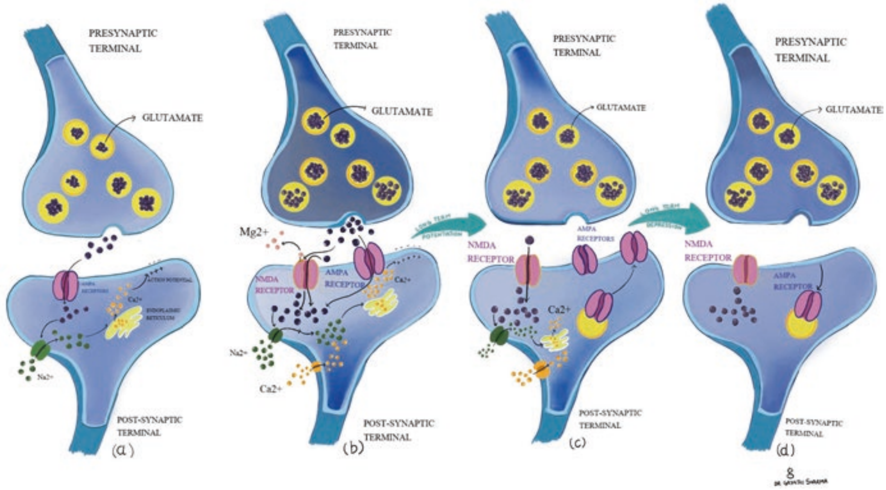

Fig. 11.2 (**a**) Glutamate stimulating the AMPA receptor. (**b**) Repeated stimulation of AMPA receptor leads to removal of the blocking Mg^{2+} ion at the NMDA receptor. (**c**) NMDA receptor stimulation leads to influx of calcium ions into the postsynaptic neuron and secondary changes of long-term potentiation like increased number of AMPA receptors and increased AMPA receptor sensitivity. (**d**) When the stimuli reduce over time, the secondary changes of LTP reduce, a process called long-term depression. Illustration by Dr Gayatri Sharma

(b) AMPA receptors remain open for longer periods of time, resulting in increased sensitivity to glutamate.
(c) Growth factors are released, which increase the number of synapses between the neurons, a phenomenon called *synaptic plasticity*.

Hence, LTP strengthens the connection between existing synapses, increases receptor sensitivity to glutamate, and leads to increase in the number of synapses between neurons.

LTP occurs in two phases – an induction phase which lasts for an hour and a maintenance phase which lasts for days. It is in the maintenance phase where the new proteins are formed and lasting changes occur between neurons. This is the molecular basis why repeated studying and practice are required to learn something new. The more you practice, the more LTP occurs between your neurons.

11.11 Important Clinical Aspects

In everyday life, we are not aware of the millions of neural networks that determine our memories and learning. Understanding the theories of learning has roots in understanding human behaviour and psychological issues. In the 1950s and 1960s, behavioural therapy (now called cognitive behavioural therapy) gained momentum. Behavioural therapy uses the principles of learning to understand and manage psychiatric disorders. For example, aggressive behaviour of a child in school needs to be identified as either respondent or operant behaviour to then correct the antecedent event or the consequence, so that such behaviour reduces in the future. Reward learning principles help us understand addictions. Aversion therapy uses classical conditioning to reduce addiction or deviant behaviour by pairing it with an unpleasant stimulus. Desensitisation techniques use classical conditioning to reduce anxiety and phobias by pairing an anxiety/phobia, inducing stimulus with another that creates the opposite response. Operant conditioning has been used to manage alcohol addiction by using reinforcements (offering money to quit alcoholism, opportunities for employment, social interaction) and punishment (social isolation).

Similarly, in the field of neurology as we deal with diseases that affect memory predominantly, we understand the importance of these cognitive functions for day-to-day functioning. A classic example of a memory disorder is Alzheimer's disease. It is a degenerative disease characterised by the involvement of the medial temporal lobe, the hippocampus in particular wherein episodic memory is stored. Patients gradually lose their ability to remember details of recent events. Initially, it is mistaken for absent-mindedness, but gradually the person realises that he cannot recollect events of the recent past or work commitments. In addition to recent episodic memory loss, the person also finds it difficult to navigate and often gets lost. The memory decline worsens over time, and the patient is not able to recollect names or recognise people. This leads to frustration for the patient with severe anxiety and depression. In the severe form of the disease, they need assistance for activities of daily living, and their day-to-day functioning gets impaired. In another form of dementia called semantic dementia (semantic variant of primary progressive aphasia), there is a gradual loss of factual knowledge. It first manifests as difficulty in language due to loss of meaning of words. There are word-finding pauses in their conversations. They start to substitute words in their sentences and may not be able to understand the meaning of phonetically difficult words, while their autobiographical memory remains intact. They also forget the meaning of objects and may not know how to use these objects. These patients have atrophy of the left anterior temporal lobes on neuroimaging. In diseases that affect the basal ganglia such as Parkinson's disease and Huntington's chorea, the procedural memory or implicit memory may be affected early, while they may retain declarative memories for a longer time (Matthews 2015).

Learning is a continuum from birth to death. Every day we learn from our environment; we adapt. We consolidate our learning. Learning gives us a survival advantage. It gives us the ability to evolve and adapt to our ever-changing environments; we learn to increase positive reinforcements and reduce punishments. And all types of learning are occurring simultaneously all the time. As we learn every day, we make memories and we cherish the experiences. But little do we realise that this process is an elaborate chemical and electrical reaction happening in a sophisticated network of millions of neurons. This chapter is by no means exhaustive and is only a sneak peek into the fascinating field of cognitive science. We hope that it has evoked an interest for further reading on the subject.

References

Brem, A. K., Ran, K., & Pascual-Leone, A. (2013). Learning and memory. *Handbook of Clinical Neurology, 116*, 693–737.

Camina, E., & Güell, F. (2017). The neuroanatomical, neurophysiological and psychological basis of memory: Current models and their origins. *Frontiers in Pharmacology, 8*, 438. Published 2017 Jun 30.

Kandel, E. R., Schwartz, J. H., & Jessell, T. M. (2013). *Principles of neural science* (5th ed.). New York: McGraw-Hill, Health Professions Division.

Matthews, B. R. (2015). Memory dysfunction. *Continuum (Minneapolis Minnesota)., 21*(3 Behavioral Neurology and Neuropsychiatry), 613–626.

Sadock, B. J., Sadock, V. A., Ruiz, P., & Kaplan, H. I. (2009). *Kaplan & Sadock's comprehensive textbook of psychiatry* (9th ed.). Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins.

Scoville, W. B., & Milner, B. (1957). Loss of recent memory after bilateral hippocampal lesions. *Journal of Neurology, Neurosurgery, and Psychiatry, 20*(1), 11–21. https://doi.org/10.1136/jnnp.20.1.11.

Squire, L. R. (2004). Memory systems of the brain: A brief history and current perspective. *Neurobiology of Learning and Memory, 82*(3), 171–177.

Part II
Brain-Based Learning and Cognition

Chapter 12
Essential Oil-Related Brain Disorders: An Unexplored Under-recognized Conundrum

Thomas Mathew

12.1 Introduction

Essential oils (EOs) are organic compounds obtained from plants or its parts and have been used for medicinal purposes from ancient times. They consist of benzenoids, phenylpropanoids, monoterpenoids, and sesquiterpenoids. According to history, the use of EOs for the treatment of various ailments started almost 2000 years back, in countries like ancient Egypt, India, Persia, Mesopotamia, and China. Because of their fragrance, they have been used for many religious ceremonies in these countries (Lizarraga-Valderrama 2020). They were also used as food additives, insecticides, and pesticides. They are present in various over-the-counter balms and oils, toothpastes, perfumes, etc. and are being used by most people on a day-to-day basis. Though EOs are in use from time immemorial, their side effects are less recognized and hardly reported. Many EOs have brain stimulatory properties, which might have implications in neuropsychiatric disorders, characterized by hyperexcitable neuronal networks such as epilepsy, headaches, and anxiety disorders.

The human brain has approximately 86 to 100 billion (10^{11}) neurons. One neuron has on an average 7000 synapses or connections, thus amounting to a total of 10^{15} synapses. There are only two types of synapses in the brain, either excitatory or inhibitory. These excitatory and inhibitory synapses keep the electrical activity of the brain in perfect balance. An increase in excitation beyond the usual limits results in neurological disorders like seizure/epilepsy, migraine, anxiety disorders, and chronic pain syndromes. Hyperexcitable neuronal networks in a particular region of brain are the main pathophysiological mechanism of these brain disorders. For

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example, excess electrical activity in the cortical pyramidal neurons results in seizure/epilepsy, while hyperexcitable neurons in the pain pathways of the brain, brainstem, and spinal cord result in migraines and other chronic musculoskeletal pain syndromes like fibromyalgia. Hyperexcitable neurons in the corticolimbic circuits may underlie anxiety and mood disorders. Physicians rarely take the history of exposure to EOs in their patients with various hyperexcitable disorders. Because they have a label "natural," many people presume them to be safe and rarely report their use to their treating doctors. If they do report, physicians rarely consider it as important, because of the lack of awareness and knowledge about the side effects of these commonly used essential oils. The effects of brain stimulatory EOs on neuropsychiatric disorders need to be evaluated objectively for potential benefits and risks. The health hazards of these preparations are rarely studied in humans and need to be explored in an unbiased scientific way. In this review, we will focus on the current and evolving knowledge about the relationship of brain stimulatory EOs and neuropsychiatric disorders.

12.2 Essential Oils (EOs)

Essential oils (EOs) are oils derived from plant or its parts by various concentrating techniques. The word "essential" is a misnomer and does not mean it is "essential" to humans but indicates that it is the essence or concentrate of a plant or one of its parts. Do not mistake them as essential like essential amino acids or fatty acids. Many studies have shown that EOs from plants can stimulate the nervous system. EOs of 11 plants are reported to be powerful convulsants (Table 12.1). Extracts from these plants contain highly reactive monoterpene ketones, like camphor, cineole, fenchone, pinocamphone, pulegone, sabinylacetate, and thujone, which have convulsant properties (Burkhard et al. 1999). We will elaborate on the effects of the

Table 12.1 Brain stimulatory essential oils

1.	Eucalyptus	*Eucalyptus globulus*
2.	Fennel	*Foeniculum vulgare*
3.	Hyssop	*Hyssopus officinalis*
4.	Pennyroyal	*Mentha pulegium* or *Hedeoma pulegioides*
5.	Rosemary	*Rosmarinus officinalis*
6.	Sage	*Salvia officinalis*
7.	Savin	*Juniperus sabina*
8.	Tansy	*Tanacetum vulgare*
9.	Thuja	*Thuja occidentalis*
10.	Turpentine	*Pinus* species
11.	Wormwood	*Artemisia absinthium*

commonly used brain stimulatory EOs on various neuropsychiatric disorders like epilepsy, migraine, and anxiety disorders.

12.3 Essential Oils and Seizures

Seizure is a sudden, uncontrolled electrical discharge originating from the brain resulting in abrupt changes in movement, behavior, and feelings with or without alteration in levels of consciousness. If you have two or more **seizures** or a tendency to have recurrent seizures, then it is called epilepsy. The main pathophysiological mechanism of seizure/epilepsy is an abnormal, hypersynchronously firing network of neurons. Brain stimulatory essential oils can increase these abnormal currents in the brain and result in seizure. These **essential oil-related seizure** (**EORS**) can be due to any of the previously mentioned brain stimulatory essential oils listed in Table 12.1, but are most commonly due to the essential oils of camphor and eucalyptus.

12.4 Camphor

12.4.1 Chemical Structure

Camphor is a pleasant smelling terpenoid with chemical structure $C_{10}H_{16}O$ (1,7,7-trimethylbicyclo[2.2.1]-2-heptanone). It is present in two enantiomeric forms, (1S)-(−)- and (1R)-(+)-camphor, and (+)-isomer is more widely distributed. The term "camphor" is used interchangeably to denote the tree from which it originates the essential oil of camphor and the monoterpene compound (Tisserand and Young 2014).

12.4.2 Origin of Camphor

Camphor was originally produced by the distillation of barks from the tree *Cinnamomum camphora* but is currently synthesized chemically from α-pinene derived from turpentine oil. The crude extract from the tree has a camphor content of about 50% (Tisserand and Young 2014). The other sources of camphor are *Dryobalanops aromatica* (Borneo camphor tree), *Ocotea usambarensis* (East African camphorwood tree), and *Ocimum kilimandscharicum* (camphor basil). Camphor basil is the major source of camphor in Asia. Many aromatic plants contain camphor as a major component, and these plants are shown in Table 12.2.

Table 12.2 The various plants containing camphor

Sweet wormwood	*Artemisia annua*
Greek sage	*Salvia fruticosa*
	Achillea sintenisii
Rosemary	*Rosmarinus officinalis*
	Salvia macrochlamys
	Salvia recognita
	Osmitopsis asteriscoides
Greek sage	*Salvia fruticosa*
Lavender cotton	*Santolina insularis*
California sagebrush	*Artemisia californica*
Sage	*Salvia officinalis*
Camphor basil	*Ocimum kilimandscharicum*
Chinese cinnamon	*Cinnamomum cassia*
Chinese star anise	*Illicium verum*
Camphor laurel	*Cinnamomum camphora*
Fresh hawthorn	*Crataegus* berries
Basil oil	*Ocimum basilicum*
Absinthe wormwood	*Artemisia absinthium*
Hyssop	*Hyssopus officinalis*
Thuja	*Thuja occidentalis*
Cedar	*Juniperus* and *Cupressus* spp.
Toothbrush tree, miswak	*Salvadora persica*

12.5 History

During the outbreaks of pandemics like plague (Black Death), small pox, and cholera, camphor was used as an antiviral and anti-bacterial agent. In the eighteenth century, seizures were considered a good treatment for psychosis. Hence, camphor was used to induce seizures to treat psychiatric disorders like mania and schizophrenia. Leopold von Auenbrugger (19 November 1722–17 May 1809), an Austrian physician, described the use of camphor for manic psychosis in the book *Experimentumnascens de remediospecifico sub signospecifico in mania virorum* (Lesky 1959). **Paracelsus** (1494–24 September 1541), a Swiss physician, also treated psychotic patients with camphor-induced seizures(Dubovsky 1995). **Dr. Robert Whytt** (1714–1766), a Scottish physician, in his book *Observations on the Nature, Cause, and Cure of Those Disorders Which Are Commonly Called Nervous, Hypochondriac or Hysteric*, narrated similar treatment for psychiatric disorders (Whytt 1767). In 1785, Dr. William Oliver, a British physician, reported the cases of two patients treated with camphor-induced seizures, in *The London Medical Gazette.* Camphor was replaced by another pro-convulsant brain stimulatory chemical agent pentylenetetrazole (Metrazol) by the 1930s, for the induction of seizures in psychiatric patients. Later, pentylenetetrazole (Metrazol) was replaced by another method of induction of seizure, the electroconvulsive therapy, which is still in use in the field of psychiatry (Pearce 2008).

12.5.1 Uses of Camphor

Camphor is a versatile molecule, with multiple uses like cold remedy, antiseptic, aphrodisiac, analgesic, antitussive, antimicrobial, antiviral, and anticancer agent. It is present in many Ayurvedic preparations and over-the-counter products including toothpastes. Camphor is also used to reduce milk production in lactating women. It is used as an insecticide and moth repellant. It is used as a culinary spice and food flavorant and is also found in many perfumes and cosmetics. It is a component of incense and is a commonly used household substance for religious ceremonies. It is also used for embalming the dead bodies. The commercial importance of camphor is revealed by the fact that the annual market value of camphor is about 80–100 millions of US$ (Chen et al. 2013).

12.5.2 Pharmacokinetics

Camphor is metabolized by oxidation in the human liver by microsomal cytochrome (P450) enzymes especially CYP2A6 to various metabolites like campherol, which is then conjugated with glucuronic acid, before final excretion by kidneys, in urine (Gyoubu and Miyazawa 2007). Fetuses lack the enzymes necessary to hydroxylate and conjugate camphor, and hence camphor induces abortion (Riggs et al. 1965).

12.5.3 Pharmacodynamics

Though precise mechanisms of effects of camphor are not known, it has been postulated that camphor acts intraneuronally at the oxidation cycle. The postmortem findings of severe neuronal hypoxia suggest the action of camphor may be at the step above the flavoprotein cytochrome-b of the cytochrome oxidase system (Rivera and Barrueto 2014). Camphor can also suppress neuromuscular transmission by the inhibition of the nicotinic acetylcholine receptors (nAChRs) (Park et al. 2001). The exact mechanism of seizure induction by camphor was not known till recently. Vatanparast and Andalib-Lari (2017) evaluated the mechanism of camphor-related epileptogenicity(Vatanparast and Andalib-Lari 2017). They did their studies in the subesophageal ganglia of the land snail *Caucasotachea atrolabiata* and recorded the spontaneous activities of these neurons using single-electrode current clamp (Vatanparast and Andalib-Lari 2017). These neurons were exposed to various concentrations of camphor and ion channel blockers. They demonstrated that at low concentration (0.25 mM), camphor decreased the duration of afterhyperpolarization, disrupting the baseline rhythmic neuronal activity. At higher concentration [camphor (0.5 mM)], there were further disruption in the precision of spontaneous baseline nerve action potentials and increase in the neuronal firing frequency along with a reduction of action potential falling slope and afterhyperpolarization. At even higher concentration of camphor, neurons demonstrated paroxysmal depolarization shift (PDS) and burst firing. This camphor-induced epileptiform activity was attributed to the blockade of K^+ channels and upregulation of inward currents of Ca^{2+}. The Na^+ currents and ion channel phosphorylation with protein kinases A and C were not involved in the induction of camphor-induced paroxysmal depolarization shift. This work provided novel evidence that direct blockade of K^+ channels may underlie the pro-convulsive effect of camphor(Vatanparast and Andalib-Lari 2017).

12.5.4 Toxicity

Camphor is a very toxic substance and can affect many internal organs like the brain, gastrointestinal tract, respiratory system, heart, liver, and kidneys. Camphor crosses the placental barrier and affects the development of the embryo. In a dose-dependent way, camphor can decrease motility and viability of human sperms. The amount of camphor which can be lethal to an adult is about 3.5 gm (50–500 mg per Kg body weight), while it is 0.5 gm to 1 gm in children. In children, a dose above 30 mg/Kg is considered toxic (Patra et al. 2015). Oral intake of small amounts of camphor can result in sudden onset of nausea, vomiting, irritability, and convulsions which can be lethal in young children. Because of its highly lipid-soluble nature, camphor readily crosses the blood-brain barrier and hence is highly neurotoxic. Neurological manifestations like confusion, irritability, and seizures can occur after ingestion of small amounts of camphor(Patra et al. 2015). Postmortem studies of the brain of children who succumbed to camphor poisoning showed necrosis of the pyramidal neurons in the hippocampus(Smith and Margolis 1954). Many people presume only oral intake to be dangerous, but camphor is readily absorbed by other routes of administration like inhalation and dermal application. Studies have shown that in cutaneous application the speed of absorption is fast but the amount absorbed is relatively low when compared to other modes of application (Zuccarini 2009).

Camphor toxicity can occur in a few minutes as it is readily absorbed from the gastrointestinal tract and skin. Common modes of poisoning are ingestion, nasal application, dermal application, and inhalation of vapor. Camphor can also irritate the mucous membranes, eyes, and skin. The gastrointestinal symptoms are usually seen in 15–20 min after oral intake, while the neurological symptoms are observed in 30–60 min. The cause of mortality is usually respiratory arrest. The common gastrointestinal side effects are nausea, vomiting, abdominal pain, and diarrhea. The neurological manifestations of camphor toxicity include headaches, dizziness, nausea, vomiting, myoclonus, fasciculations, ataxia, seizures, altered sensorium, and coma. Camphor also is a cardiac toxin and can impair the ventricular systolic function. It can cause cardiac rhythm disturbances like tachycardia, cardiac conduction blocks, prolonged QTc and QRS intervals, and ST segment changes (Rahnama-Moghadam et al. 2015).

The renal toxicity of camphor has been studied in rabbits (*Oryctolagus cuniculus*). The administration of camphor orally for ten consecutive days produced glomerulonephritis and tubular necrosis (Enaibe et al. 2008). Ocular toxicity in the form of central serous chorioretinopathy (CSCR) was documented in a 50-year-old Chinese lady after application of Chinese herbal medicinal patches containing camphor for prolonged periods(Kahook et al. 2007). Infants lack enzymes needed for hepatic metabolism making them susceptible to camphor toxicity especially hepatotoxicity. This led to the recommendation that camphor-containing products (Vicks VapoRub, Ben-Gay, Afrin saline mist) should not be used in children below 2 years(Strader and Seeff 2012).

There are many reports of camphor-induced toxicity in literature. Reported cases most probably form only a tip of the iceberg as many cases are probably not documented, not reported, and unpublished due to various reasons. There are case reports of death in children aged 16 months and 19 months after exposure to one teaspoon of camphorated oil which contain approximately 1 mL of camphor(Hausner and Poppenga 2013). A small dose of camphor application to the nose resulted in the immediate collapse of an infant (Arena 1979). Neurological complications like convulsions and coma after the dermal application with camphor are documented. Exposure to camphor resulted in ataxia and convulsions in a 15-month-old child who crawled through camphor spirits, containing 10% camphor. He slowly recovered over 2 weeks' time. After 1 year while inhaling from camphorated vaporizer containing 4.81% camphor, the child developed another seizure (Camphor 2016). Along with neurotoxicity, hepatotoxicity also is reported in children after chronic exposure to camphor(Hausner and Poppenga 2013). An 18-month-old and a 3-year-old had generalized seizures, half an hour, after inserting a camphor cube into the mouth(Patra et al. 2015; Sahana and Rajiv 2012). In the latter case, the camphor cube, which was used for religious purposes, was mistaken for a sugar cube. A 15-month-old accidentally ingested 70 ml of a common household ointment having 4.73% camphor, 2.6% menthol, and 1.2% eucalyptus oil and developed seizure after 2 h(Gouin and Patel 1996). There are many other reports of camphor-related seizures in children(Michiels and Mazor 2010; Agarwal and Malhotra 2008). Camphor was kept at home for spiritual purposes, for treatment of cold, and for control of pests. In the report of three cases by Khine et al.(2009), two children swallowed camphor, while one got toxicity after repetitive rubbing of camphor on the skin. All three of them had leukocytosis, while hyperglycemia was seen in two. One patient developed transient respiratory depression and required ventilator support.

The camphor-induced seizure in adults is more iatrogenic than accidental. The large body surface area may reduce the impact of camphor toxicity in adults. The traditional practice of "Cao Gio" (coining) in Southeast Asian countries like Cambodia, where abrasions are made in the skin by a coin after applications of oils or balms, containing camphor has resulted in toxicity(Rampini et al. 2002). Agarwal and Malhotra described the case of a 22-year-old man who developed seizures and altered sensorium after intake of 4.5 gms of camphor with banana(Agarwal and Malhotra 2008).

Based on the reports of camphor toxicity, the New York City Department of Health warned the public to keep camphor-containing products out of reach of children(Khine et al. 2009). The US FDA (United States Food and Drug Administration) evaluated the efficacy and toxicity of camphor-containing products and recommended a limit of 11% in consumer products in 1983 and banned products labeled as camphorated oil, camphor oil, camphor liniment, and camphorated liniment completely. The data from the American Association of Poison Control Centers Toxic Exposure Surveillance System (TESS) in 2001 showed 8505 exposures to camphor-containing products(Manoguerra et al. 2006). In most countries, especially in developing countries, products containing camphor as high as 20% are easily available in the markets. In countries like India, the concentration of camphor is not mentioned in many of the over-the-counter products.

12.5.5 Treatment

The treatment of camphor poisoning is largely symptomatic and supportive. Standard treatments like activated charcoal or gastric lavage are not helpful as camphor is rapidly absorbed from the gastrointestinal tract. As there is chance of seizure and respiratory depression after camphor poisoning, gastric lavage and induced emesis may be dangerous because of the risk of aspiration. Hence, the American Association of Poison Control Centers does not recommend these treatments. The protection of the airway and management of seizure are important in these patients. The commonly employed anti-seizure medications are benzodiazepines such as lorazepam and diazepam(Patra et al. 2015).

12.6 Eucalyptus Oil (EuO)

12.6.1 Chemical Structure

Eucalyptus oil (1,3,3-trimethyl-2-oxabicyclo[2.2.2.]-octane) is a lipid-soluble essential oil, which is rapidly absorbed orally, and can be inhaled as a liquid or aerosol. It is obtained from the leaves of *Eucalyptus*, a genus of the plant family Myrtaceae by steam distillation. The oil is a pale yellow or clear liquid with characteristic smell and taste. EuO is composed of complex mixtures of volatile organic compounds, mainly monoterpenes. The main constituent of pharmaceutical-grade EuO is 1,8-cineole. 1,8-Cineole is also called "eucalyptol" and must constitute at least 70% of the contents. Depending on the storage conditions of the raw materials and the techniques used to obtain the oil, the composition of the extracted EuO can change over time. Though the highest cineole content of 80–95% is seen in *Eucalyptus kochii* and *Eucalyptus polybractea*, the global production is dominated by *Eucalyptus globulus*.

12.6.2 History

Eucalyptus was used for centuries by the Australian natives, the Aborigines, for its antiseptic nature and healing powers. Eucalyptus was used by surgeons as an antiseptic in the 1700–1800s. It suddenly became high in demand during World War I and was used to control a meningitis outbreak and the influenza of 1919, which had killed as many as a hundred million people. The number could have been much higher without the use of eucalyptus oil. In India, eucalyptus was first planted around 1790 by Tipu Sultan, the ruler of Mysore, in his palace garden on Nandi hills near Bangalore from seeds he had received.

12.6.3 Uses of Eucalyptus Oil

EuO has been used for various indications ranging from pharmaceutical to industrial. Many people use it as an over-the-counter remedy for treating common disorders like cold, sinusitis, bronchial asthma, gum bleeding, and skin ulcers. It is also used in perfumes, mosquito repellants, and insecticides. It has anti-inflammatory, anti-bacterial, antiviral, and antifungal properties.

12.6.4 Pharmacokinetics

EuO is rapidly absorbed when ingested, when applied over the skin, or when inhaled, and the absorption may be enhanced by the intake of fat and milk.

12.6.5 Pharmacodynamics

It is metabolized in the liver by primarily oxidative metabolism to hydroxycineole that might involve the induction of the cytochrome P450 enzyme system and is subsequently excreted in urine.

12.6.6 Toxicity

EuO is rapidly absorbed when consumed orally, and symptoms appear after 10–15 min. The symptoms include burning sensation in the mouth and throat, nausea, vomiting, and abdominal pain(Patel and Wiggins 1980; Flaman et al. 2001). The neurological manifestations consist of giddiness, ataxia, confusion, seizures, altered sensorium, and coma(Karunakara and Jyotirmanju 2012). In children, the onset of seizures after accidental ingestion of EuO ranged from 10 min to 2 h, but can be delayed up to 4 to 9 h (Flaman et al. 2001; Kumar et al. 2015; Day et al. 1997; Ruha et al. 2003). The lethal dose of EuO in adults is about 30 ml but can even occur with 4–5 ml also. In children, minor poisoning results in vomiting, abdominal pain, and ataxia. Intake of more than 5 ml of EuO results in significant depression of consciousness in children(Tibballs 1995). The application on the skin also can cause serious side effects. A 4-year-old girl developed seizure after topical application of a head lice preparation containing essential oil(Waldman 2011). In people with epilepsy, topical application of essential oils is found to provoke seizures(Bozorg and Benbadis 2009). Inhalation of EuO was reported to produce seizures in a cohort of both adults and children, who never had seizures in the past(Mathew et al. 2017). Seizures happened 2–10 min after inhalation. Inhalation appears to affect the brain faster than ingestion as inhaled volatile oils reach the brain directly and excite the cortical neurons. The exact mechanisms of eucalyptus oil-induced seizures are not known. Experiments with rat models suggest that the epileptogenic action may be secondary to increased cellular hyperexcitability secondary to loss of tissue sodium and potassium gradient in the neurons(Steinmetz et al. 1987).

Status epilepticus (SE) by definition is a seizure with 5 min or more of continuous clinical and/or electrographic seizure activity or recurrent seizure activity without recovery of consciousness between seizures. SE is a medical emergency and needs immediate medical treatment to prevent morbidity and mortality. There are reports of status epilepticus after exposure to eucalyptus oil. Kumar et al. described two cases of status epilepticus in children after ingestion of eucalyptus oil. A hale and healthy, 6-year-old boy developed eight episodes of tonic-clonic convulsions within 10 min of accidental oral intake of 10 ml of eucalyptus oil. The second was a 3-year-old boy with four episodes of tonic-clonic convulsions within 10 min of accidental intake of 5 ml of EuO[34]. Thng and Tan reported SE in a 20-year-old lady shortly after the ingestion of 150 ml of EuO[42]. Recently we had reported three patients with SE after exposure to EOs of eucalyptus and camphor (Mathew et al. 2020). The first two cases ingested EuO orally, while the third had cutaneous exposure. The first young man consumed EuO accidentally and died of status epilepticus and multiorgan dysfunction. His story was unfortunate as his father had transferred EuO from a leaky bottle to the cough syrup bottle. The boy consumed EuO from the cough syrup bottle for his upper respiratory tract symptoms, without knowing it is EuO. He developed multiple episodes of seizure after 10 min of ingestion. The second patient had been using few drops of EuO for abdominal pain infrequently for many years. This time he took two to three teaspoon full of EuO and had many episodes of generalized tonic-clonic seizures. The third case we had reported had complex partial status epilepticus (focal-impaired awareness status epilepticus) after dermal application of various balms containing EOs of eucalyptus and camphor.

EOs such as eucalyptus, camphor, and rosemary contain aromatic monoterpene 1,8-cineole(Kumar et al. 2015; Thng and Tan 2012). 1,8-Cineole has a mechanism of action similar to pentylenetetrazole, a known pro-convulsant used in various animal models of epilepsy(Culic et al. 2009). 1,8-Cineole was observed to produce seizures at a dosage of 0.5 mL/kg, in animal models(Kumar et al. 2015; Thng and Tan 2012). The effects of eucalyptol (1,8-cineole) was evaluated in the neurons of the land snail *Caucasotachea atrolabiata* by Zeraatpisheh and Vatanparast (2015). Eucalyptol (3 mM) when applied to these neurons caused membrane depolarization and increased the firing frequency in a time-dependent fashion. At higher concentrations, the firing pattern changed to burst firing associated with paroxysmal depolarization shift (PDS). These effects of eucalyptol on the neurons were found to be reversible. A synergistic action was observed when low doses of eucalyptol and potassium channel blockers, tetraethylammonium and 4-aminopyridine, were administered together, to produce burst firing. These effects were independent of sodium currents and ion channel phosphorylation by protein kinases A and C. These observations pointed that the epileptogenic action of EuO was most probably due to the blockade of the calcium-activated potassium channels involved in repolarization and afterhyperpolarization(Zeraatpisheh and Vatanparast 2015).

According to our observations, topical application appears to be the major unrecognized trigger of seizure. We had presented papers on essential oil-related seizures (EORS) due to applications of various balms and oils containing camphor and eucalyptus in adults, in the Asian and Oceanian Epilepsy Congress, Bali, Indonesia, and in the 72nd Annual **Meeting** of the **American Epilepsy** Society (AES) at **New Orleans**, USA, in 2018(Mathew et al. 2018a, b). We had patients with new-onset seizures (EOIS – essential oil-induced seizures) after the application of these essential oils and also known persons with epilepsy with essential oil-triggered breakthrough seizures (EOPS – essential oil-provoked seizures).

EuO and other essential oil-induced seizures in adults may be reported rarely in the literature because of lack of awareness among patients and caregivers, ignorance among healthcare providers, and publication bias. Isolated case reports are not usually accepted by journal editors as there is nothing novel in it, resulting in a negative publication bias. It is high time for the public and physicians to keep their eyes and ears open to identify these cases, document them, and put all the efforts to report and publish. Another important public health hazard is that there is no advice available on the labels of these over-the-counter products regarding the safe or toxic dosages or potential side effects of EOs contained in them. Every physician should enquire regarding the exposure to these oils in their patients with the first episode of seizure and in those with breakthrough seizures. In all patients with seizure/epilepsy, physicians should strongly advise them to avoid these pro-convulsant essential oils. Patients with seizure and epilepsy should reveal to their physicians if they are using these products. It may be prudent to avoid these products in all its forms in patients with seizures and epilepsy due to the potential for seizure induction and provocation. The knowledge that these so-called "natural and safe" substances can indeed be toxic and can cause seizures should be disseminated among the public and physicians so that these untoward events can be prevented. The relationship between exposure to EuO and seizures definitely needs to be further evaluated in large epidemiologic studies in various populations.

12.7 Essential Oils and Headache Disorders

Migraine and epilepsy are disorders secondary to hyperexcitable neuronal networks. Migraine and epilepsy have many features in common. Both are paroxysmal brain disorders and have preictal, ictal, and postictal phases. Sleep deprivation can trigger both migraine and seizure. Migraine headaches cause photophobia, while certain types of epilepsy have photosensitivity. They both can have a menstrual worsening effect as evidenced by catamenial epilepsy and menstrual migraine. Migraine and epilepsy can be treated by the same type of medications like valproate and topiramate. Status epilepticus and status migrainosus respond to intravenous valproate. Neuromodulation with vagal nerve stimulation is effective for both. Transcranial magnetic pulse can abort a headache attack of migraine and also a seizure. For the above reasons, it is possible that the brain stimulatory essential oils can worsen migraine attacks similar to epilepsy. This is a totally unexplored field of medicine.

We reported our first case of essential oil-related medication overuse headache (EORMOH) in a migraineur recently(Mathew and John 2020). This 14-year-old boy came to me for his refractory chronic migraine. He had episodic infrequent migraines in the beginning which became a daily affair for the past 1 year. He was on multiple medications when he visited me but with no effect on his headache. He had been extensively evaluated with an MRI scan of the brain and lumbar puncture. We were perplexed with this case and were at a loss as to how to treat him. On detailed enquiry, we found that he was applying a balm called Amrutanjan containing 10% camphor and 14.5% eucalyptus daily on his forehead for his headache. He thought it worked initially for his headache, but now there was no difference whether he applied it or not. With the knowledge that both eucalyptus and camphor can have brain stimulatory potential, we advised him to stop the application completely. To our surprise and his relief, the headache subsided within 2 weeks of cessation of topical application. He followed up with us regularly and was headache-free at 1 year follow-up. This case was an eye-opener for us, and nowadays we enquire about essential oil exposure in all our cases of chronic headaches and advise them to stop their application. Recently, we had a patient with medically refractory cluster headache whose headache got relieved after stopping a toothpaste containing essential oils of camphor (unpublished data). We are also seeing patients with acute headaches precipitated by essential oils which gets relieved after stopping these, within 72 h (unpublished data), fulfilling the International Classification of Headache Disorders (ICHD 3) criteria for substance use headaches. These cases highlight the importance of enquiring about the exposure to essential oils in patients with various headache disorders. We did a brief survey on essential oil usage in 150 apparently normal people, and the findings were surprising. 86% of people were using one or the other essential oils as remedy for cold, headache, and backaches (unpublished data).

When patients suffering from primary headache disorders like migraine take painkillers for more than 10 days in a month, their migraine slowly changes into a chronic daily headache, called medication overuse headache (MOH). MOH is an important comorbidity in patients with chronic migraine with a worldwide prevalence of 1–2% (Kristoffersen and Lundqvist 2014). The painkillers like nonsteroidal anti-inflammatory drugs ergots and triptans are the common causes of MOH. EOs as a cause of MOH is not reported in literature. To implicate a medication as a cause for medication overuse headache, the medication prescribed should have beneficial effect on migraine. Though there are no formal scientific literature on the effects of EOs of camphor and eucalyptus, there are studies showing that EOs of lavender and cedar improve postoperative pain in patients(Hasanzadeh et al. 2016; Olapour et al. 2013). These EOs probably relieve headaches by an anti-inflammatory action or by counterirritant effect (gate theory of pain). 1,8-Cineole's anti-inflammatory action may be the result of its ability to reduce the levels of pro-inflammatory cytokines like prostaglandin E2, leukotriene B4, interleukin-1β, and tumor necrosis factor-α as evidenced by studies in animals and persons with bronchial asthma(Santos and Rao 2000; Santos et al. 2004; Juergens et al. 2003; Juergens et al. 1998; Juergens et al. 2004; Bastos et al. 2011). The analgesic effects may also result from various effects on the descending pain-modulating systems and pathways involving serotonin, noradrenaline, dopamine, and endocannabinoids(Martins et al. 2015). The exact mechanism of EORMOH is not clear, but alterations in serotonergic, dopaminergic, and endocannabinoid systems may be involved in its pathogenesis(Meng et al. 2011). Most of the antimigraine medications act through the blockade of sodium and calcium channels, preventing depolarization of neurons, while essential oils like eucalyptus and camphor have an exact opposite mechanism of action by blocking the potassium channels, which finally results in the excitation of neurons. This causes a functional antagonism of the antimigraine drugs, leading to pharmacoresistance and pseudo-refractoriness of migraine. The field of brain stimulatory essential oils and headache disorders is totally unexplored. Until further studies are conducted, it will be prudent for the physicians to advice their patients to avoid essential oil exposure. Patients with headaches especially migraine should be careful with the over-the-counter medications they use, especially those containing brain stimulatory essential oils.

12.8 Essential Oils and Anxiety Disorders

According to WHO, in 2017, the worldwide prevalences of depression and anxiety disorders were 4.4% and 3.6%, respectively(Lizarraga-Valderrama 2020). The effects of essential oils on these disorders are not well known. Some essential oils like linalool, limonene, and pinene may reduce anxiety, but the effect of brain stimulatory essential oils like camphor and eucalyptus on anxiety is not well studied. The latest entry into the market of essential oil products are the toothpastes which contain camphor or/and eucalyptus or various plants containing them. The effect of chronic usage of these products on the hyperexcitable neuropsychiatric disorders like anxiety is not known. There is a possibility that low-dose exposure over time may cause toxicity in these patients, especially those who are genetically predisposed. Pentylenetetrazol (PTZ), a GABA(A) receptor antagonist, is a prototypical anxiety-inducing drug and has been extensively utilized in animal models of anxiety(Bastos et al. 2011). The same PTZ was used in animal models of epilepsy. In the history of psychiatric treatment, camphor was replaced by PTZ, for treating psychiatric disorders, before electroconvulsive therapy came into existence. We have observed dramatic improvement in anxiety after stopping the usage of these toothpastes in a few of our patients (unpublished data). The relationship between essential oils of camphor and eucalyptus and anxiety disorders needs to be explored in future studies. Till then it will be prudent to avoid brain stimulatory substances in patients with anxiety disorders especially brain stimulatory essential oils.

12.9 Essential Oils, Abuse, and Addiction

When we interviewed our patients with various neuropsychiatric disorders, we found that many of them have been applying various over-the-counter balms and ointments for many years without any definite medical reasons. They were abusing these substances and probably have psychological and physical dependence. In the survey we did in 150 apparently healthy individuals, 52% were using these essential oil products for more than 6 years, and 7–10% were addicted according to DSM 5 criteria (unpublished data). The implications of these findings are that most people use these products in an unsupervised way and the effects of these EOs on their physique and psyche are not known. Because of their brain stimulatory properties, there is potential for their misuse as cognitive enhancers by many, especially students. Usage of brain stimulatory essential oils as cognitive enhancers should be avoided because of their various neuropsychiatric side effects. Future studies should explore and evaluate the incidence, prevalence, and gravity of these essential oil abuses and addictions in the population at large.

12.10 Conclusion

Essential oils with brain stimulatory properties might worsen hyperexcitable neuropsychiatric disorders like seizure, epilepsy, migraine, and anxiety disorders. They may induce these disorders in previously normal individuals especially those who are genetically predisposed. They may also worsen or aggravate these disorders in those already suffering from these disorders. The relationship between the proconvulsant essential oils and seizure/epilepsy has some evidence, but those related to migraine and anxiety are just evolving and have to be explored by the scientific community. Physicians treating hyperexcitable neuropsychiatric disorders should be aware of the extensive list of brain stimulatory essential oils and enquire about their usage in their patients(Bahr et al. 2019). They should keep their eyes and ears open to find the impact of these essential oils on their patients. They should follow up these patients after the stoppage of their essential oil use and document the improvement from the baseline status. They should report and publish their observations with due diligence, so that a complete picture of the impact of usage of brain stimulatory essential oils is clear. Till then it may be advisable for patients with hyperexcitable neuropsychiatric disorders to avoid these brain stimulatory EOs, especially those of eucalyptus and camphor.

12.11 Significance of This Chapter with Respect to Learning

The journey of essential oil-related brain disorders started in 2014, after we saw a case of seizure after steam inhalation with eucalyptus oil. There were no reports of similar nature in the literature at that time. From that case till now, we were able to identify many cases of seizures and other hyperexcitable brain disorders caused by the exposure to the brain stimulatory essential oils of eucalyptus and camphor. This has changed the life of many patients and families suffering from seizures, migraines, cluster headaches, and anxiety disorders. This journey highlights the importance of simple observations, careful and detailed analysis, literature search, building up evidence especially when there is no obvious evidence, and persistence, in the field of scientific learning, understanding, and progress.

References

Agarwal, A., & Malhotra, H. S. (2008). Camphor ingestion: An unusual cause of seizure. *The Journal of the Association of Physicians of India, 56*, 123–124.

Arena, J. M. (1979). *Poisoning: Toxicology, symptoms, treatments* (4th ed.). Springfield: CC. Thomas.

Bahr, T. A., Rodriguez, D., Beaumont, C., et al. (2019). The effects of various essential oils on epilepsy and acute seizure: A systematic review. *Evidence-Based Complementary and Alternative Medicine, 2019*, 6216745.

Bastos, V. P., Gomes, A. S., Lima, F. J., et al. (2011). Inhaled 1,8-cineole reduces inflammatory parameters in airways of Ovalbumin-challenged Guinea Pigs. *Basic & Clinical Pharmacology & Toxicology, 108*(1), 34–39.

Bozorg, A. M., & Benbadis, S. R. (2009). Essential oils as a cause of breakthrough seizure after temporal lobectomy. *Seizure, 18*(8), 604–605.

Burkhard, P. R., Burkhardt, K., Haenggeli, C. A., & Landis, T. (1999). Plant-induced seizures: Reappearance of an old problem. *Journal of Neurology, 246*(8), 667–670.

Camphor. (2016). *Meyler's side effects of drugs, 44*. https://doi.org/10.1016/b978-0-444-53717-1.00441-8

Chen, W., Vermaak, I., & Viljoen, A. (2013). Camphor--a fumigant during the Black Death and a coveted fragrant wood in ancient Egypt and Babylon--a review. *Molecules, 18*(5), 5434–5454.

Culic, M., Kekovic, G., Grbic, G., et al. (2009). Wavelet and fractal analysis of rat brain activity in seizures evoked by camphor essential oil and 1,8-cineole. *General Physiology and Biophysics, 28*, 33–40.

Day, L. M., Ozanne-Smith, J., Parsons, B. J., et al. (1997). Eucalyptus oil poisoning among young children: Mechanism of access and the potential for prevention. *Australian and New Zealand Journal of Public Health, 21*, 297–302.

Dubovsky, S. L. (1995). Electroconvulsive therapy. In H. I. Kaplan & B. J. Sadock (Eds.), *Comprehensive textbook of psychiatry, ed 6* (p. 2129). Baltimore: Williams and Wilkins.

Enaibe, B., Eweka, A., & Adjene, J. (2008). Toxicological effects of camphor administration on the histology of the kidney of the rabbit (*Oryctolagus cuniculus*). *The Internet Journal of Toxicology, 5*. https://doi.org/10.5580/29a.

Flaman, Z., Pellechia-Clark, S., Bailey, B., & McGuigan, M. (2001). Unintentional exposure of young children to camphor and eucalyptus oils. *Paediatrics & Child Health, 6*, 80–83.

Gouin, S., & Patel, H. (1996). Unusual cause of seizure. *Pediatric Emergency Care, 12*(4), 298–300.

Gyoubu, K., & Miyazawa, M. (2007). In vitro metabolism of (-)-camphor using human liver microsomes and CYP2A6. *Biological and Pharmaceutical Bulletin, 30*(2), 230–233.

Hasanzadeh, F., Kashouk, N. M., Amini, S., et al. (2016). The effect of cold application and lavender oil inhalation in cardiac surgery patients undergoing chest tube removal. *EXCLI Journal, 15*, 64–74.

Hausner, E. A., & Poppenga, R. H. (2013). Hazards associated with the use of herbal and other natural products. In *Small animal toxicology* (3rd ed.).

Juergens, U. R., Stober, M., & Vetter, H. (1998). Steroid-like inhibition of monocyte arachidonic acid metabolism and IL-1β production by 1,8-cineole. *AtemwegLungenkrank, 24*, 3–11.

Juergens, U. R., Dethlefsen, U., Steinkamp, G., et al. (2003). Anti-inflammatory activity of 1.8-cineol (eucalyptol) in bronchial asthma: A double-blind placebo-controlled trial. *Respiratory Medicine, 97*(3), 250–256.

Juergens, U. R., Engelen, T., Racké, K., et al. (2004). Inhibitory activity of 1, 8-cineol (eucalyptol) on cytokine production in cultured human lymphocytes and monocytes. *Pulmonary Pharmacology & Therapeutics, 17*(5), 281–287.

Kahook, M. Y., Thomas, S. A., & Ciardella, A. P. (2007). Central serous chorioretinopathy associated with chronic dermal camphor application. *The Internet Journal of Ophthalmology and Visual Science, 4*, 2.

Karunakara, B. P., & Jyotirmanju, C. S. (2012). Eucalyptus oil poisoning in children. *Journal of Pediatric Sciences, 4*, e132.

Khine, H., Weiss, D., Graber, N., Hoffman, R. S., Esteban-Cruciani, N., & Avner, J. R. (2009 May). A cluster of children with seizures caused by camphor poisoning. *Pediatrics, 123*(5), 1269–1272.

Kristoffersen, E. S., & Lundqvist, C. (2014). Medication-overuse headache: Epidemiology, diagnosis and treatment. *Therapeutic Advances in Drug Safety, 5*(2), 87–99.

Kumar, K. J., Sonnathi, S., Anitha, C., & Santhoshkumar, M. (2015). Eucalyptus oil poisoning. *Toxicology International, 22*(1), 170–171.

Lesky, E. (1959). Auenbrugger's camphor therapy and the convulsive therapy of psychoses: on the occasion of the 150th anniversary of Auenbrugger's death on 18th May 1959. *WienKlinWochenschr, 71*, 289–293.

Lizarraga-Valderrama, L. R. (2020). Effects of essential oils on central nervous system: Focus on mental health. *Phytotherapy Research*, 1–23. https://doi.org/10.1002/ptr.6854.

Manoguerra, A. S., Erdman, A. R., Wax, P. M., Nelson, L. S., Caravati, E. M., Cobaugh, D. J., Chyka, P. A., Olson, K. R., Booze, L. L., Woolf, A. D., et al. (2006). Camphor Poisoning: An evidence-based practice guideline for out-of-hospital management. *Clinical Toxicology, 44*, 357–370.

Martins, D. F., Emer, A. A., Batisti, A. P., et al. (2015). Inhalation of *Cedrus atlantica* essential oil alleviates pain behavior through activation of descending pain modulation pathways in a mouse model of postoperative pain. *Journal of Ethnopharmacology, 175*, 30–38.

Mathew, T., & John, S. K. (2020, January). An unsuspected and unrecognized cause of medication overuse headache in a chronic migraineur—Essential oil-related medication overuse headache: A case report. *Cephalalgia Reports*. https://doi.org/10.1177/2515816319897054

Mathew, T., Kamath, V., Kumar, S., et al. (2017). Eucalyptus oil inhalation induced seizure: A novel under recognized preventable cause of acute symptomatic seizure. *Epilepsia Open, 2*, 350–354.

Mathew, T., Kamath, V., Jadav, R., et al. (2018a). Essential oil-induced (EOIS) and provoked seizures (EOPS): A multicentric prospective observational study from South India. In *Proceedings of the 12th Asian and Oceanian Epilepsy congress*. Bali: American Epilepsy Society.

Mathew, T., Kamath, V., Jadav, R., et al. (2018b). *Essential Oil-Induced (EOIS) and Provoked Seizures (EOPS): A Multicentric Prospective Observational Study From South India*. 72nd Annual Meeting of the American Epilepsy Society (AES) at New Orleans, United States of America in 2018. Poster 1.435.

Mathew, T., John, S. K., Kamath, V., et al. (2020). Essential oil–related status epilepticus: A small case series study. *JACEP Open*, 1–4.

Meng, I., Dodick, D., Ossipov, M., et al. (2011). Pathophysiology of medication overuse headache: Insights and hypotheses from preclinical studies. *Cephalalgia, 31*, 851–860.

Michiels, E. A., & Mazor, S. S. (2010). Toddler with seizures due to ingesting camphor at an Indian celebration. *Pediatric Emergency Care, 26*(8), 574–575.

Olapour, A., Behaeen, K., Akhondzadeh, R., et al. (2013). The effect of inhalation of aromatherapy blend containing lavender essential oil on cesarean postoperative pain. *Anesthesiology and Pain Medicine, 3*(1), 203–207.

Park, T., Seo, H., Kang, B., & Kim, K. (2001). Noncompetitive inhibition by camphor of nicotinic acetylcholine receptors. *Biochemical Pharmacology, 61*, 787–793.

Patel, S., & Wiggins, J. (1980). Eucalyptus oil poisoning. *Archives of Disease in Childhood, 55*, 405–406.

Patra, C., Sarkar, S., Dasgupta, M. K., & Das, A. (2015). Camphor poisoning: An unusual cause of seizure in children. *Journal of Pediatric Neurosciences, 10*(1), 78–79.

Pearce, J. M. S. (2008). Leopold Auenbrugger: camphor-induced epilepsy – remedy for manic psychosis. *European Neurology, 59*, 105–107.

Rahnama-Moghadam, S., Hillis, L. D., & Lange, R. A. (2015). *Heart and toxins* (pp. 75–132). Elsevier Inc.

Rampini, S. D., Schneemann, M., Rentsch, K., et al. (2002). Camphor intoxication after Cao Gio (coin rubbing). *JAMA, 288*, 45–43.

Riggs, J., Hamilton, R., Homel, S., & McCabe, J. (1965). Camphorated oil intoxication in pregnancy; Report of a case. *Obstetrics & Gynecology, 25*, 255–258.

Rivera, H. L., & Barrueto, F. (2014). *Encyclopedia of toxicology* (3rd ed., pp. 627–629).

Ruha, A. M., Graeme, K. A., & Field, A. (2003). Late seizure following ingestion of Vicks VapoRub. *Academic Emergency Medicine, 10*, 691.

Sahana, K. S., & Rajiv, D. (2012). Camphor poisoning. *Indian Pediatrics, 49*, 841–842.

Santos, F. A., & Rao, V. S. (2000). Anti-inflammatory and anti-nociceptive effects of 1,8-cineole a terpenoid oxide present in many plant essential oils. *Phytotherapy Research, 14*, 240–244.

Santos, F. A., Silva, R. M., Campos, A. R., et al. (2004). 1,8-Cineole (eucalyptol), a monoterpene oxide attenuates the colonic damage in rats on acute TNBS-colitis. *Food and Chemical Toxicology, 42*(4), 579–584.

Smith, A. G., & Margolis, G. (1954). Camphor poisoning; anatomical and pharmacologic study; report of a fatal case; experimental investigation of protective action of barbiturate. *The American Journal of Pathology, 30*(5), 857–869.

Steinmetz, M. D., Vial, M., & Millet, Y. (1987). Actions of essential oils of rosemary and certain of its constituents (eucalyptol and camphor) on the cerebral cortex of the rat in vitro. *Journal de Toxicologie Clinique et Experimentale, 7*, 259–271.

Strader, D. B., & Seeff, L. B. (2012). Hepatotoxicity of herbal preparations. In *Zakim and Boyer's hepatology* (6th ed.). Philadelphia: Saunders-Elsevier.

Thng, S. Y., & Tan, H. H. (2012, May 25–June 1). *Status Epilepticus from large ingestion of eucalyptus oil*. Abstracts of the 2012 International Congress of the European Association of Poisons Centres and Clinical Toxicologists.

Tibballs, J. (1995). Clinical effects and management of eucalyptus oil ingestion in infants and young children. *Medical journal of Australia, 163*, 177–180.

Tisserand, R., & Young, R. (2014). Essential oil profiles. In *Essential oil safety* (2nd ed., pp. 187–482). Churchill Livingstone: St. Louis.

Vatanparast, J., & Andalib-Lari, F. (2017 May). Camphor elicits epileptiform discharges in snail neurons: The role of ion channels modulation. *Neurotoxicology, 60*, 299–307.

Waldman, N. (2011). Seizure caused by dermal application of over-the-counter eucalyptus oil head lice preparation. *Clinical Toxicology (Phila), 49*, 750–751.

Whytt, R. (1767). Observations on the nature, causes and cure of those disorders which are commonly called nervous, hypochondriac, or hysteric to which are prefixed some remarks on the sympathy of the nerves. In T. Becket & P. du Hondt (Eds.), *The works of Thomas Whytt, ed 3*. London: Becket and du Hondt.

Zeraatpisheh, Z., & Vatanparast, J. (2015). Eucalyptol induces hyperexcitability and epileptiform activity in snail neurons by inhibiting potassium channels. *European Journal of Pharmacology, 764*, 70–78.

Zuccarini, P. (2009). Camphor: Risks and benefits of a widely used natural product. *Journal of Applied Sciences and Environmental Management, 13*, 69–74.

Chapter 13
A Review on Pedagogical Methods Supporting Development of Cognitive Abilities in Preschoolers

J. V. Archana and P. S. Sreedevi

13.1 Introduction

Normal development of a child involves a pattern and sequential achievements of various key skills or tasks, such as crawling, walking, and smiling, which are referred to as milestones (CDC n.d.). Globally, child development is monitored by following a series of standardized developmental milestones which are particular to an age range. Dosman et al. (2012) proposed an evidence-based five-sector milestone framework to facilitate an early identification of milestones in children right from birth to 5 years of age. This comprehensive chart includes a series of gross and fine motor, language, cognitive, and socio-emotional developmental milestones. According to this, under normal development, a child must attain a predictable milestone at an upper age limit. This easily facilitates to predict any delayed disorder which can be corrected by necessary interventions like physical, speech, and occupational therapy or any other interventions (Scharf et al. 2016). Worldwide, this framework can be adopted as a reference because in a multicultural society various factors may contribute to the child's development (Bellman et al. 2013). Theorists like Jean Piaget and Erik Erikson have proposed different developmental theories, and according to these, the cognition is a sequential evolution of biologically driven abilities. These attainable and increasingly complex abilities gave rise to the concept of executive functioning which is a combined effort of working memory and expertise (Hurley 2005).

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13.2 Methodology

The methodology adopted in the present chapter included literature search which covered journals, book chapters, and records of conference proceedings. For identifying published articles related to pedagogical methods, namely, Montessori, kindergarten, and play-way methods supporting development of cognition among preschoolers, the search involved several databases like Wiley online, Taylor & Francis, Science Direct, Emerald, and Inderscience. Besides, an attempt was made using Google Scholar to identify other articles that are not accessible in the online search databases. Also, the key attributes, like pedagogical methods, developmental benefits, cognitive development, interventions of cognitive development, and comparative studies, were reviewed.

13.3 Evaluations of Key Elements of Different Pedagogical Methods for Preschool Children

The present segment assesses the studies that have investigated the Montessori, kindergarten, and play-way pedagogical practices that share elements with each other. The evaluation with our increasing understanding of the methods supporting cognitive development as well as learning in preschool children can include in the documentation base for Montessori, kindergarten, and play-way methods of education.

The significance of theoretical understanding as the basis of children's ability to develop thinking and understanding skills using various teaching methods has been stressed (Siegler et al. 2010). The Montessori pedagogical method teaches sensorial activities using practical exercises like folding napkins to lay the conceptual foundation for children (Marshall 2017a, b). In terms of teaching activities like letter and sound relationship, the Montessori pedagogical method is systematic and done in an organized manner (Morris 1990). Besides, the Montessori teaching approach is more synthetic and less logical, where sound and letter codes are used to teach children before using it in the form of spelling (words) followed by decode (reading). However, this synthetic approach has been criticized since the letters and sounds are taught not in a meaningful language context (Wyse and Styles 2007). Since comprehension is recognized as the goal of reading, therefore the interaction between language competencies like terminology, syntax, and word structure, and code-based competencies, at multiple levels, is crucial for cognitive development and learning abilities in children (Torgerson et al. 2006). The explicit teaching of letter and sound relationship in the context of a language (both oral and transcribed) is crucial to the development of syllabus for Montessori. However, no assessments have performed yet regarding the teaching of the letter and sound relationship in the Montessori classroom versus other teaching methods, and so whether the former is relatively effective is not known (Marshall 2017a, b). An increasing count of studies has illustrated that the specific Montessori method of teaching writing involves a variety of elements, like spelling, handwriting, vocabulary, and sentence construction, and improves the quality of writing in children (Berninger et al. 2011; Graham and Santangelo 2014). The Montessori pedagogical method practices these skills independently before being brought together. With respect to teaching activities, certain acclaimed undertakings, like enabling children to identify, label, and match figures and then to attach and detach figures, fit within the Montessori method of teaching (Wolf et al. 2017). Besides, other activities like helping children to label things with numerals map onto Montessori teaching method.

The current accountability of pedagogical practices regarding their impact on student learning has met with a significant debate between advanced procedures and the necessity to impart recommended academically driven criterions (Einrsdottir 2008; Ray and Smith 2010). The dichotomy of pedagogical practices has been opposed with ample proof to indicate that teachers are accomplished to stabilize numerous demands of educational programs based on their instructional aptitude (Goldstein 2007). A developmentally suitable program uses child-directed learning that nurtures aspects of psychological development in children (Parker and Neuharth-Pritchett 2006). On the other hand, an academically driven learning gives priority to the development of academic skills (Russell 2011). It was also observed that teachers who identify the main objective of learning in the procurement of elementary skills generally rely on teacher-centered pedagogical attitude (Stipek and Byler 2004). Alternatively, teachers who perceive advancement of cognitive and social skills as the learning objectives often rely on child-oriented pedagogical attitude. Currently, kindergarten pedagogical methods encounter obstacles in finding a way through the pedagogical practices to balance development of both cognition and academic skills (Gullo and Hughes 2011). In the last few years, kindergarten education has undergone noticeable changes (Pyle et al. 2020). Generally, kindergarten education was theorized to nurture children's developmental learning, engage them in self-directed exploration, and provide an inspiring environment for them (Frobel 1967). Over time, this vision shifted toward increasingly academic learning and rigid developmental practices. The present kindergarten pedagogical practice focuses on acquisition of standards-based academic skills along with traditional developmental skills (Bautista et al. 2016). Development of academic skills (literacy and numerals) focuses on preparing the students with a conceptual basis for the academic learning required in the higher grades (Russell 2011). Simultaneously, it is needed that kindergarten pedagogical practice meets the requirements of traditional developmental learning goals related to children's changes within classroom settings, including supporting their self-regulation, social, and emotional development (Brown and Lee 2012). Thus, while kindergarten method has advanced to generate an emphasis on assessment-oriented teaching, instructional procedures may still be shaped by a progressive approach to learning to teach. The kindergarten method actively engages children in observing their knowledge through self and teacher-based responses, with the aim of developing their conceptual foundation along with their psychological development (Pyle and DeLuca 2013). The kindergarten method teaches sensorial activities to children through songs, games, and stories. The kindergarten method involves the pretense play where children are engaged in imaginary notions to help them learn the outside world in an interesting manner. Despite the scholastic assessment of the kindergarten method to balance between developmental and academic skills, there remains little evidence to substantiate to support academic learning within child-centered developmental oriented pedagogical stance at kindergarten level and how teachers navigate this balance at kindergarten level (Curby et al. 2009; La Paro et al. 2009; Pyle and DeLuca 2013; Sullivan et al. 2015).

The national and international educational policies have called for better educational accountability and improved learning outcomes and academic standards (No Child Left Behind Law of 2001, 2002; Ministry of Education and Research 2010; OECD 2015). An initial attempt in this direction is often highlighted. This resulted in a better focus on direct, teacher-directed approach in preschool education in the national settings (Hesterman 2018). Simultaneously, a concern regarding the "restrained withdrawal of play" from the preschool teaching practices had also grown (Nicolopoulou 2010). Similarly, attention for protecting children's natural and unstructured child-initiated activities has been advanced (Sundsdal and Øksnes 2015). Existing studies further strengthen an image of instructional strategies for preschool children as a twofold choice between academic knowledge, early assessment, and stress on acquisition of skills within school settings, while free, hands-on, and child-oriented play with no formal interruption, alternatively. Given the many-sided theoretical effects that also support learning, attempts at merging the two choices have produced a number of studies with no unanimity either, despite that play is usually identified as a foundation for children's learning (Brooker et al. 2014). The play-way method has been recommended as an instructional method in the educational program in numerous national preschools (Danniels and Pyle 2018). Although the integration between play and a feasible preschool pedagogy is the main focus of play-way method, there is, however, no conceptual consensus. As such, the play-way method continues to attract discussions. Previous studies have stressed that such conceptual ambiguity makes the play-way pedagogical method a possibly difficult concept for the preschool education practitioners to convert into a professional exercise (Rogers 2010). Likewise, the scholastic prospects of the play-way method may continue to be not properly realized (Bennett 1997). Given the consensus about the implication of play during childhood, concepts and key elements of the play-way method prosper (Bergen 2014). Numerous key elements of play-way method are in circulation, which are developed along several interlinked projects and theme-based learning (Popoola 2014). While some emphasize the content of play, like functional, rule-governed, and cognitive plays with direct knowledge (Vorkapić and Katić 2015), others revolve around behavior associated with play, like physical (muscular activities), daily used objects (toys or gifts), or pretense play (symbolic and fantasy with imaginary notions) (Smith 2005). The play-way method teaches sensorial activities to children by engaging them to perform activities like free play, puzzles, and building blocks that lay the foundation of concepts that are being introduced to them. This enables the children to learn and play amicably with other children in the class. The play-way method enables children to interact and communicate maximum in the classroom and helps to learn vocabulary through enjoyable activities like songs and unstructured child-oriented activities. In terms of learning numerals, the play-way method involves a series of activities like constructive plays with creating structures, gardening, and games like magic squares, checkers, and puzzles.

Another important aspect in the context of the educational discussion concerning play-way pedagogy is the beneficial influence of play on fostering children's development. This aspect often leads to distinctions among various regions of development, mainly cognitive, learning, social, and emotional, and how play-way method can support these developments (Nair et al. 2014). Many researchers have documented that play-way methods represent the best pedagogical method for children (Brewer 2007; Bubikova-Moan et al. 2019). In support of this assertion, Brewer (2007) described the play-way method as a hands-on pedagogical activity which contributes to the psychological development in children. The play-way approach is a child-centric informal method of teaching to naturally suit the child's interests and enables them to learn concepts and ideas (Nair et al. 2014; Ihekerenma 2017; Ashari and bintiHushairi 2018). The play-way method emphasizes on the development of creative skills of children through the use of specific or simple everyday objects that can be used to create new objects (Scarfo and Littleford 2008). However, previous studies with cognitive outcomes have given much attention to academic learning through knowledge procurement as well as problem-solving abilities, and very less focus has been laid on creative development of children as a part of cognitive outcome (Orr and Kukner 2015). While the existing studies substantiate the beneficial effects of play-way method, it does not deliver a balanced depiction of the associations between distinct developmental benefits and the play-way pedagogy and how different key elements of play-way pedagogical practice may contribute and nurture cognition in children in an inclusive way (Wallerstedt and Pramling 2012; Lillard et al. 2013; Pyle et al. 2017).

In the above context, Table 13.1 represents the studies evaluating the distinct developmental benefits in children through the use of different pedagogical methods.

Finally, this section emphasized on the constant attention that has been argued to characterize the engagement of children with the instructional resources in the Montessori, kindergarten, and play-way classrooms (Siegler et al. 2010; Lillard 2012). These are important aspects of cognitive development, which also comprise memory that can process information for a short term, inhibition, and planning. The fact that cognitive development is vital for educational achievement is substantiated by numerous research evidence (Diamond and Lee 2011; Cragg and Gilmore 2014; Shaul and Schwartz 2014). Due to this vital role, cognitive development has become the objective for several involvements, complete curriculum, and additions to classroom courses. In view of these, the pedagogical methods hold the greatest potential for ease of access to all and synchronized involvement to bring children on the accurate path from the beginning and affect cognitive development largely (Marshall 2017a, b).

Table 13.1 Pedagogical practices and developmental benefits in preschool children

Author	Method of study	Pedagogical practice	Findings	Suggested research
Cheng (2001)	Survey	Play-way in kindergarten framework	Lack of understanding in the concept of play-way method to apply for kindergarten children	Learning through play in preschool education is recommended
Lillard and Else-Quest (2006)	Survey	Montessori	Enhances thinking and learning in students	Montessori education, when implemented properly, is suggested to nurture social and learning skills that are equivalent to or better than other pedagogical practices
Curby et al. (2009)		Kindergarten	Kindergarten pedagogical practice improved learning abilities in children	Teacher-child interactions and improvement in academic activities through kindergarten method are recommended
La Paro et al. (2009)	Interviews and observations	Kindergarten	Children experience low to medium quality of instructional support in kindergarten	Recommendations to improve cognition and learning in children
Lillard (2012)	Survey	Montessori	Enhances outcome measures like reading, executive function, numerals, language, and problem-solving skills in preschool children	High fidelity application of Montessori education is related to improved results
Cutter-Mackenzie and Edwards (2013)		Play-way	Play-way pedagogical practices like play with no predetermined limitations, modeled play, and child- and teacher-initiated plays improve learning and cognitive development in preschool children	Future research associated with these play-way frameworks is recommended
Pyle and Deluca (2013)	Interviews and observations	Kindergarten	A direct association between curricular stance and kindergarten method of pedagogy	Necessity to understand teachers' pedagogical stances while they engage advanced assessment and teaching practices is recommended

(continued)

Table 13.1 (continued)

Author	Method of study	Pedagogical practice	Findings	Suggested research
Baker (2014)	Focus groups and nominal group technique	Play-way method in kindergarten framework	Different consensus on play-way practice but its importance in children's cognitive development is recognized	Improved understanding of teachers on play practices of preschool children is suggested
Bhatia et al. (2015)		Montessori and kindergarten	Students with Montessori treatment had higher accuracy in terms of cognitive and physical development	A balanced approach concerning cognitive and physical aspects of children's activity is recommended
Aras (2016)	Interview and observation	Play-way	Free play is essential to improve developmental outcomes in preschool children	Involvement of teachers in children's free play
Lillard and Heise (2016)		Montessori	Improved outcomes in reading, executive functions, and numerals	Recommends appropriate implementation of Montessori methods for improving executive functions in preschool children
Randolph et al. (2016)	Secondary data	Montessori	Improves academic and social outcomes in elementary students	Montessori education is suggested to improve learning skills in elementary students
Pyle and Danniels (2017)	Interviews and observations	Play-way	First profile of teachers perceived play and learning as two separate constructs, while the second profile of teachers perceived play as an important method of academic learning	Play-based learning in pedagogical approach is recommended

13.4 Cognitive Development

In 1956, Benjamin Bloom in his Taxonomy of Learning Domains categorized the learning into three domains, the cognitive domain which focused on knowledge, psychomotor domain referring to the skills, and affective domain with the development of attitudes (Hoque 2017). The revised taxonomy categorized the cognitive processes into different levels of *understanding, remembrance, implementation, assessment, creation,* and examination (Adams 2015). The term "cognition" is originated from the Latin word "*cognosco,*" meaning "to theorize" or "to identify," and indicates the ability to process the understanding, reasoning, thinking, problem-solving, and other activities related to the mind (Suresh et al. 2015). The cognitive development is an interactive and complex process, and in children the cognitive ability is usually tested to predict the outcomes in the academics, social surroundings, etc. Different stages of childhood are marked with a series of cognitive development, like formation of sensory and perceptual systems and socio-emotional behavior, and these have lasting effects on children. \\The theories related to cognitive development emphasize the use of symbolic systems like games and toys, to enhance societal interactions. With changing times, these symbols have evolved, and different technologies, digital media have taken the place and mediate cognitive development, such as executive function, scientific thinking, and literate communication in children (Daiute and Lee 2019). The theory of cognition by Piaget is the oldest and comprehensive of all the proposed cognitive developmental theories. The development of cognition was divided into four sequential stages which include the earliest stage of learning characterized by sensory-motor interactions in children followed by the engagement in symbolic play (pre-operational), development of organized and balanced thinking (concrete operational), and ability to formulate and systematically arrive at a solution to a problem (Simatwa 2010). Eventually, the constructive phases of cognition by Piaget were utilized by educators to derive instructional strategies in the education sector to help children (students) with cognitive development (Simatwa 2010; Joubish and Khurram 2011). Among the different stages of Piaget's cognitive development theory, with an increase in child's age from 4 to 7 years, the prevalence of cognitive egocentrism especially the pre-operational stage was observed supporting the correctness of Piaget's principles even in current situation (Marwaha et al. 2017). However, the existence and contribution of other cognitive developmental theories in the development of student's cognitive functioning cannot be overlooked (Nicolopoulou 1999). Vygotsky's sociocultural cognitive theory focused on sociocultural interaction (Helou and Newsome 2018), and information processing theory which is focused on attention, memory, retention, and problem-solving ability (Mohanty 2015) impacts the cognitive development in terms of students' understanding, thinking and performance.

Cognitive competence can be domain-general (Macnamara et al. 2011) like memory (temporary memory, immediate recall, and memory for indefinite period) and attention (capacity to focus), as well as domain-specific, such as evolution of language (Adesope et al. 2010) and executive functions (inhibitory control). The relationship between domain-general and domain-specific cognitive function, such as association of working memory and language comprehension, is still in progress (Fedorenko 2014). In children different cognitive processes like orientation (aptitude to locate self with respect to people, place, and time), judgment, perception, language (physical development), and memory evolve with maturity and experiences (Sternberg and Sternberg 2016). Not all children have similar cognitive development as defined by the traditional theories. Behavioral changes and their reorganization and development of new abilities or skills, they all change as a function of an individual child or the context. These changes are more evident in school-age children; therefore a wide criterion is set to measure the cognitive development during infancy and early childhood. According to the theory by Piaget, cognition continues throughout adolescence, and research has shown that cognitive development in early childhood accounts for the academic and social outcome in adolescence (Mollborn and Dennis 2012). The language and working memory have been linked to academic performance in preschool children based on their age-related immediate elicited imitation performance (Haden et al. 2011). The environmental factors and development process can affect the stability of a child's implicit memory during infancy (3 months) and early childhood (3 years) which can predict their later cognitive abilities (Vöhringer et al. 2018).

13.5 Pedagogical Methods and Cognitive Development

Teacher-child (student) relationship, marked by trust, warmth, attachment, and respect, can have significant impact on social and cognitive outcomes in children at different levels of schooling, i.e., preschool, elementary, or high school (Davis 2003). Though limited by number of studies but evidently it has been shown that teacher-child interaction has an impact on children's cognitive process related to the executive function and working memory. These studies were found to be dependent on factors like children's education level, socioeconomic status, and gender. The meta-analysis review puts the teacher in the center to promote the cognitive process in children by creating a classroom environment which is structured, emotionally positive, and cognitively stimulating. The contribution of teachers in refining the emotive aptitude of children (Denham et al. 2012), emotional security (Thijs and Koomen 2008), vocabulary and pre-literacy outcomes (Wasik and Hindman 2011), internalizing and externalizing behavior problems (Baker et al. 2008; Buyse et al. 2008), and constructing peer culture (social and interpersonal growth) (Farmer et al. 2011) has been reported.

Similarly, the teaching method is critical to deliver the information and knowledge in a way which arouses the different dimensions of cognition, such as thinking, perception, and judgment. Different teaching approaches involving constructive approach to learning (theory by Piaget) and sociological theory of education (theory by Vygotsky) can have varying outcomes (Kalina and Powell 2009; Semmar and Al-Thani 2015). In a learner-centered method where students are the center of all activities, four different inventive instructional methods, such as information, transformation and reception, cognitive strategies and development of attitude, and cognition and motor abilities, were suggested, in particular to agricultural science (Modebelu and Duvie 2012). Instead of a teacher-oriented or student-oriented approach, some researchers recommend teacher-student interactive methods because of increased involvement of students in quest for knowledge and problem-solving (Ganyaupfu 2013). It was found that the mathematical problem-solving ability of elementary school students is enhanced combining learning of students in small groups and multiple intelligence (Işık and Tarım 2009). In today's multicultural environment, other than teaching, the teacher's contemporary and effective methods to inculcate the understanding and the application of different skills in students count more. It can be clearly understood that an educator or teacher's technical preparation like ability to plan and write lessons, choice of teaching method, utilization of resources or instructional aids, teaching skill, and their natural ability to actively involve in students and faculty affairs is essential for an effective instructional method.

In preschoolers, the early childhood curriculum impacts the aspects of psychological development (Bakken et al. 2017). Different pedagogical approaches involving inquiry-based and play-based methods are undertaken to deliver and improve the knowledge and skill in order to enhance the potential capabilities of children. The pre-primary or preschool education is meant for kids from 3- to 6-year age group, prior to the first phase of formal education. Considering the importance of education during the preschool years in cultivating different aspects of development, there are a number of approaches for preschool pedagogy. The three main approaches of preschool education which are reviewed in this paper are, namely, the kindergarten, Montessori, and the play-way (Manisha and Sunita 2013).

13.5.1 Montessori Approach and Cognitive Development

Montessori teaching involves a practical and scientific approach which emphasizes on the self-directed nature of learning. Through purposeful and gradual increase in complexity of activity, observation, and discovery, this unique approach emphasizes on learning through all the senses in order to develop social, emotional, physical, and intellectual skills in a child (Marshall 2017a, b). In this method, there are a series of prepared instructions and equipment appropriately set for a child's age thereby allowing each and every child to progress at their own pace (Isaacs and Green 2007; Tahir et al. 2013). Among the preschool children (4–5 years old), the Montessori method is known to extend the reflection or response time, which reduces the child's impulsive behavior and subject them to make fewer errors (Kayılı 2018). This aspect is important because the reflective personality is associated with the cognitively matured behavior. Also, including social skills training programs under this approach is known to develop a child's emotional feeling related to understanding and the ability to solve the social problems (Kayili and Ari 2016). The interplay of cognitive ability and physical activity in overweight children enhances executive functions (Crova et al. 2014), and in Montessori kids, the practical life activities enhanced the fine motor skills including speed, accuracy, and continuous use of the dominant hand and the eye-hand coordination (Bhatia et al. 2015). The impact of variations in Montessori implementation fidelity in cognitive development of children was evident. The children in classic Montessori programs exhibited exemplary social skill, such as problem-solving, and academic skills like reading, math, and vocabulary in comparison to low-fidelity and supplemented

Montessori programs (Lillard 2012). The readiness to join primary education was more evident in children who took Montessori method of education (Kayili and Ari 2011). Similarly, the use of Elkonin boxes, visually stimulating boards, colored rectangular pieces, and cube with eight prisms was found to be effective in enhancing the concentration, coordination between the eye and the hand, and development of senses regarding sound and sight in attention-deficit/hyperactivity disorder children (Dogru 2015). Despite cognitive benefits, this old method of teaching is criticized for its pre-planned materials and lack of group training which could possibly lead to lack of social cooperation and impeded imagination. Additionally, researchers conclude that children may lack motivation due to lack of extrinsic rewards like stars, limited playful learning, and lack of competition among peers (Lillard 2013; Marshall 2017a, b).

13.5.2 Kindergarten Approach and Cognitive Development

A "garden for children" or a "kindergarten" refers to a metaphorical garden, where teachers are gardeners and children are unfolding plants (Bryant and Clifford 1992). This style of teaching involves group activities, teamwork, and teacher-directed instructions, asserting that learning happens through expression and social cooperation. This much-sought and traditional system of education involves teacher-directed instructions and emphasizes education as the basic right of every child (Synodi 2010). Their approach involves group instructions (listening, watching, and reading) and self-activity; learning by playing which includes songs, stories, and other learning material; and social participation to inculcate teamwork, freedom, and discipline through love (Tahir et al. 2013). Academically this approach is known to enhance reading and math literacy (Loeb et al. 2007). Comparatively, there is a scarcity of studies exploring the cognitive benefits of kindergarten teaching methods. In kindergarten method of teaching, imparting of quality education with respect to social skills (Abbas et al. 2015) and proficiency in writing, reading, spelling, reasoning, and problem-solving skills was more profound in students from different race and family backgrounds (Gormley et al. 2005). Also, children who attended kindergarten for a full day were more academically, socially, and emotionally oriented (Carnes and Albrecht 2012). Burchinal et al. (2010) found that children from families with low income had better academic achievement and an increased participation in social activities when high-quality classrooms were used for the teacher-child interaction in pre-kindergarten programs. The kindergarten style of teaching involves group learning activities and teamwork and stresses on enhancement of academic skills like math literacy, which helps the children in smooth transition from preschool to school curriculum.

13.5.3 Play-Way Method and Cognitive Development

From a child's perspective, play and learning go hand in hand. The play-way simply refers to the learning acquired through uninterrupted play (Nadeem et al. 2013). Around the world, this practice is widely accepted because it stresses on a combination of physical activity and activities like arts, craftwork, storytelling, and pretend play (Prochner 2002). Some of the accepted child-initiated methods are *exploratory play* (exploring materials and tools just for the fun), c*onstructive play* (to build things), and *dramatic play* ("make believe" or pretend play) (Lockhart 2010). Also, the symbolic play (Slunjski and Ljubetic 2014), child-guided or teacher-supported play-way methods (Lockhart 2010), helps to develop different aspects of executive function like working memory and recall, cooperation, motivation, control of emotions, social, and cognitive competence. Instead of using classical method of learning and lecturing, the recognition of geometric shapes and fine motor can be enhanced by the geometric puzzle game (Sari et al. 2018). Even for the children with special needs and disabilities, play-way technique improves the academic skills like counting of numbers. Learning via play-way method increased the curiosity to learn, alertness, comprehension, and retention of the content in hearing-impaired children (Upadhyay et al. 2017) and subdued the aggressive behavior of disabled children when play-way and music therapy were combined (Jacob and Odafin 2016). Similarly, play-way in combination with guided discovery improved the child's academic performance in geometry (Adewale and Taiwo 2010). Though there is a positive effect of play-way on the development of a child, the lack of structured and formal education and low-level parental interaction raise the doubt on a child's easy transition to a highly structured environment of primary school.

Overall, teacher-directed and small-group instruction among preschool children generates positive outcomes on development of cognition and social aptitude in children (Camilli et al. 2010). Better social skills were observed in children of the kindergarten system, whereas children from Montessori showed proficiency in language (Abbas et al. 2015). Though play-way and Montessori approach were vastly different from traditional kindergarten teaching methods, play-way offered more choices when compared to Montessori (Lillard 2013). From studies, it can be gathered that an adoption of a combination of conventional/traditional and innovative teaching methods with emphasis on student-centered orientation and interactive sessions with teachers will enhance the students' academic performance and cognitive development.

13.6 Determinants of Cognitive Development and Interventions

Missing cognitive developmental milestones risks the child's overall development. According to the theory of cognition by Piaget, biological to circumstantial factors, such as maturation of the nervous system, experiences of the child, social transmission of information or teaching, and equilibration, can affect the cognitive functioning in children (Hurley 2005). Biological factors like sense organs, intelligence (Kafadar et al. 2015), heredity, and maturation (Tucker-drob et al. 2014) can affect the child's thinking process and language and reading skills. It is demonstrated that cognition is heritable and is maximized under improved social, economic, and educational opportunities (Briley and Tucker-Drob 2017). The neurological maturation in children improves their general intelligence, creativity, social behavior, emotional stability, awareness of the senses, and physical activity which further improves their cognition competence (Arain et al. 2013; Luna and Sweeney 2001). Quality education and learning opportunities cultivate knowledge and skill, increase the participation in intellectual activities, and improve cognition (Parisi et al. 2012). Socioeconomic status (SES), such as economic resources; parents' education, especially the mother's education; occupation; and status in society directly affect the health, nutrition, and quality education and improve parent-child interaction, which benefit the cognitive development in children (Noble et al. 2015; Duncan and Magnuson 2012). Similarly, the high-quality pretend play which involves act of pretense (Bergen 2002; Fein 2008); stress-free environment and exposure to a wide variety of toys and stimuli including blocks, books, tools, and play letters (Tucker-drob et al. 2014); physical activity (Bidzan-Bluma and Lipowska 2018); sleep patterns (Kocevska et al. 2017); and play exercises (Ahmad et al. 2016) enhance the creativity and abstract thinking. Parents, family members, and caregivers also help to develop cognitive competence in children (Landry 2017). Responsive parenting involving frequent interaction, display of warmth and affection, and activities with children help to evolve a sensitive and responsive personality. Mother's general well-being and healthcare during pregnancy leads to better cognitive development in children (Pem 2016; Ford and Stein 2017). Also, a balanced nutrition involving mother's milk during infancy (Anderson et al. 1999); combination of other foods like fruits, vegetables, and meat products during early childhood; and administration of supplements like folic acid, iron, and vitamins have indicated an association of diet and cognitive development in terms of higher intelligence quotient (IQ) in children (Nyaradi et al. 2013; Nurliyana et al. 2016). Other factors which influence the psychology of children are sociocultural variables involving family structure, cultural knowledge, ethnic values, religious practices, etc., which also guide their feelings, behavior, and problem-solving capabilities (Shute and Slee 2015). In the current situation, the prolonged and excessive use of digital media like the Internet has also been shown to affect cognitive development (Tripathi and Ahad 2017).

Identifying and assessing the risk factors are necessary to target the interventions at multiple levels to benefit the child in the long term. Meta-analysis review has shown a global and larger impact of early childhood interventions on IQ, academic performance, school readiness among preschool kids, and its persistent impact through higher grades (Camilli et al. 2010). The studies clearly indicate the areas of intervention like parent-child interaction, nutrition and health (Watanabe et al. 2005), and educational opportunities to have positive impact on child's cognitive development (Rao et al. 2017). The National Early Childhood Care and Education

(ECCE) initiative under the Govt. of India entitled children under 6 years age for eminent preschool education. Currently, a wide range of private schools, government program like Integrated Child Development Services through *Anganwadis*, and ECCE centers functioning under the Sarva Shiksha Abhiyaan offer preschool education, which practices various teaching methods (Ghosh 2014).

13.7 Conclusion

In young children, preschool education fosters the development of both cognitive and soft abilities. Therefore, understanding and evaluating the efficiency of different pedagogical methods including the structure of a program, teaching-learning process, teacher- or child-centric approach, and teacher's qualification is essential. In India, preschool education offers various teaching methods like traditional kindergarten program, Reggio Emilia, Montessori, and play-way, each with a unique style of teaching. However, parents, academicians, and teachers need to emphasize on the selection and suitability of preschool programs based on the nature and need of children. In this review, the presented details and comparison will be beneficial to parents who are preparing themselves to choose the preschool program for the development of psychological aspects in their child.

13.8 Limitations and Future Directives

While the present chapter pointed some interesting findings, limitations were also recognized in an effort to minimize misrepresentation of findings. The majority of studies reviewed in the present chapter have assessed the Montessori, kindergarten, and play-way teaching methods based on a number of different variables, with the associated vulnerability that unidentified factors may have contributed to any variation in cognitive outcomes of children. The present chapter does not provide an exhaustive comparison of all the elements of Montessori, kindergarten, and play-way methods of education that might be beneficial to preschool children. Another limitation observed is that the present chapter did not review studies encompassing other types of preschool programs, such as private family day care or child care. Besides, one aspect limiting the ability of the present chapter to draw complete statements regarding the comparisons among the three teaching methods is that the observational methods varied as in full-day or half-day Montessori, kindergarten, and play-way classes. Thus, studies on preschool environments need to more systematically assess which specific teaching programs (Montessori, kindergarten, and play-way) empirically support the extent to which cognitive outcomes for children are effective. Such studies will enable to identify specific types of programs that will most successfully improve experiences of preschoolers. Further, studies need to be conducted on a large scale to facilitate generalizations as well as allow examination regarding the suitability of these teaching methods among children depending on their need and nature.

References

Abbas, A., Ansari, S., & Rizvi, D. A. A. (2015). Comparative study of Montessori and Kindergarten system of education in terms of social skills of children. *The Sindh University Journal of Education-SUJE, 44*(2).

Adams, N. E. (2015). Bloom's taxonomy of cognitive learning objectives. *Journal of the Medical Library Association: JMLA, 103*(3), 152.

Adesope, O. O., Lavin, T., Thompson, T., & Ungerleider, C. (2010). A systematic review and meta-analysis of the cognitive correlates of bilingualism. *Review of Educational Research, 80*(2), 207–245.

Adewale, J. G., & Taiwo, G. R. (2010). *Effects of play-way and guided-discovery instructional strategies on pupils' achievement in geometry in Akure South, Ondo state: A study in school effectiveness*.

Ahmad, S., Ch, A. H., Batool, A., Sittar, K., & Malik, M. (2016). Play and cognitive development: Formal operational perspective of Piaget's theory. *Journal of Education and Practice, 7*(28), 72–79.

Anderson, J. W., Johnstone, B. M., & Remley, D. T. (1999). Breast-feeding and cognitive development: A meta-analysis. *The American Journal of Clinical Nutrition, 70*(4), 525–535.

Arain, M., Haque, M., Johal, L., Mathur, P., Nel, W., Rais, A., et al. (2013). Maturation of the adolescent brain. *Neuropsychiatric Disease and Treatment, 9*, 449.

Aras, S. (2016). Free play in early childhood education: A phenomenological study. *Early Child Development and Care, 186*(7), 1173–1184.

Ashari, Z. M., & bintiHushairi, N. A. (2018). Teacher's perception towards play-based pedagogy to promote cognitive and social skills amongst preschoolers with learning disabilities. In *2018 IEEE 10th International Conference on Engineering Education (ICEED)* (pp. 49–53). IEEE.

Baker, F. S. (2014). Teachers' views on play-based practice in Abu Dhabi kindergartens. *International Journal of Early Years Education, 22*(3), 271–286.

Baker, J. A., Grant, S., & Morlock, L. (2008). The teacher-student relationship as a developmental context for children with internalizing or externalizing behavior problems. *School Psychology Quarterly, 23*(1), 3.

Bakken, L., Brown, N., & Downing, B. (2017). Early childhood education: The long-term benefits. *Journal of Research in Childhood Education, 31*(2), 255–269.

Bautista, A., Ng, S. C., & Mu'n˜ez, D., & Bull, R. (2016). Learning areas for holistic education: Kindergarten teachers' curriculum priorities, professional development needs, and beliefs. *International Journal of Child Care and Education Policy, 10*(8), 1–18.

Bellman, M., Byrne, O., & Sege, R. (2013). Developmental assessment of children. *BMJ, 346*, e8687.

Bennett, N. (1997). *Teaching through play: Teachers' thinking and classroom practice*. McGraw-Hill Education.

Bergen, D. (2002). The role of pretend play in children's cognitive development. *Early Childhood Research & Practice, 4*(1), 1–13.

Bergen, D. (2014). *Foundations of play theory. The SAGE handbook of play and learning in early childhood* (pp. 9–21). Los Angeles/London/New Delhi/Singapore/Washington, DC: SAGE.

Berninger, V. W., Nagy, W., & Beers, S. (2011). Child writers' construction and reconstruction of single sentences and construction of multi-sentence texts: Contributions of syntax and transcription to translation. *Reading and Writing, 24*(2), 151–182.

Bhatia, P., Davis, A., & Shamas-Brandt, E. (2015). Educational gymnastics: The effectiveness of Montessori practical life activities in developing fine motor skills in kindergartners. *Early Education and Development, 26*(4), 594–607.

Bidzan-Bluma, I., & Lipowska, M. (2018). Physical activity and cognitive functioning of children: A systematic review. *International Journal of Environmental Research and Public Health, 15*(4), 800.

Brewer, J. A. (2007). *Introduction to early childhood education preschool through primary*. Boston: Pearson Educational Inc.

Briley, D. A., & Tucker-Drob, E. M. (2017). Comparing the developmental genetics of cognition and personality over the life span. *Journal of Personality, 85*(1), 51–64.

Brooker, E., Blaise, M., & Edwards, S. (2014). Introduction. In *SAGE handbook of play and learning in early childhood* (pp. 1–4). Los Angeles/London/New Delhi/Singapore/Washington, DC: SAGE.

Brown, C. P., & Lee, J. E. (2012). How to teach to the child when the stakes are high: Examples of implementing developmentally appropriate and culturally relevant practices in prekindergarten. *Journal of Early Childhood Teacher Education, 33*(4), 322–348.

Bryant, D. M., & Clifford, R. M. (1992). 150 years of kindergarten: How far have we come? *Early Childhood Research Quarterly, 7*(2), 147–154.

Bubikova-Moan, J., NæssHjetland, H., & Wollscheid, S. (2019). ECE teachers' views on play-based learning: A systematic review. *European Early Childhood Education Research Journal, 27*(6), 776–800.

Burchinal, M., Vandergrift, N., Pianta, R., & Mashburn, A. (2010). Threshold analysis of association between child care quality and child outcomes for low-income children in pre-kindergarten programs. *Early Childhood Research Quarterly, 25*(2), 166–176.

Buyse, E., Verschueren, K., Doumen, S., Van Damme, J., & Maes, F. (2008). Classroom problem behavior and teacher-child relationships in kindergarten: The moderating role of classroom climate. *Journal of School Psychology, 46*(4), 367–391.

Camilli, G., Vargas, S., Ryan, S., & Barnett, W. S. (2010). Meta-analysis of the effects of early education interventions on cognitive and social development. *Teachers College Record, 112*(3), 579–620.

Carnes, G., & Albrecht, N. (2012). Academic and social-emotional effects of full-day kindergarten: The benefits of time. *Emporia State Research Studies, 43*(2), 64–67.

CDC. (n.d.). *Developmental milestones*. Retrieved August 1, 2018, from https://www.cdc.gov/ncbddd/actearly/milestones/index.html

Cheng, D. P. W. (2001). Difficulties of Hong Kong teachers' understanding and implementation of 'play' in the curriculum. *Teaching and Teacher Education, 17*(7), 857–869.

Cragg, L., & Gilmore, C. (2014). Skills underlying mathematics: The role of executive function in the development of mathematics proficiency. *Trends in neuroscience and education, 3*(2), 63–68.

Crova, C., Struzzolino, I., Marchetti, R., Masci, I., Vannozzi, G., Forte, R., & Pesce, C. (2014). Cognitively challenging physical activity benefits executive function in overweight children. *Journal of Sports Sciences, 32*(3), 201–211.

Curby, T. W., Rimm-Kaufman, S. E., & Ponitz, C. C. (2009). Teacher–child interactions and children's achievement trajectories across kindergarten and first grade. *Journal of Educational Psychology, 101*(4), 912.

Cutter-Mackenzie, A., & Edwards, S. (2013). Toward a model for early childhood environmental education: Foregrounding, developing, and connecting knowledge through play-based learning. *The Journal of Environmental Education, 44*(3), 195–213.

Daiute, C., & Lee, C. D. (2019). Studying cognitive development in digital playgrounds. *Cognitive Development, 49*, 51–55.

Danniels, E., & Pyle, A. (2018). Defining play-based learning. *Encyclopedia on early childhood development* (pp. 1–5). Centre of Excellence for Early Childhood Development. http://www.child-encyclopedia.com/play-based-learning/according-experts/defining-play-based-learning

Davis, H. A. (2003). Conceptualizing the role and influence of student-teacher relationships on children's social and cognitive development. *Educational Psychologist, 38*(4), 207–234.

Denham, S. A., Bassett, H. H., & Zinsser, K. (2012). Early childhood teachers as socializers of young children's emotional competence. *Early Childhood Education Journal, 40*(3), 137–143.

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333*(6045), 959–964.

Dogru, S. S. Y. (2015). Efficacy of Montessori education in attention gathering skill of children. *Educational Research and Reviews, 10*(6), 733–738.

Dosman, C. F., Andrews, D., & Goulden, K. J. (2012). Evidence-based milestone ages as a framework for developmental surveillance. *Paediatrics & Child Health, 17*(10), 561–568.

Duncan, G. J., & Magnuson, K. (2012). Socioeconomic status and cognitive functioning: Moving from correlation to causation. *Wiley Interdisciplinary Reviews: Cognitive Science, 3*(3), 377–386.

Einrsdottir, J. (2008). Children's and parents' perspectives on the purpose of playschool in Iceland. *International Journal of Educational Research, 47*, 283–291.

Farmer, T. W., Lines, M. M., & Hamm, J. V. (2011). Revealing the invisible hand: The role of teachers in children's peer experiences. *Journal of Applied Developmental Psychology, 32*(5), 247–256.

Fedorenko, E. (2014). The role of domain-general cognitive control in language comprehension. *Frontiers in Psychology, 5*, 335.

Fein, G. G. (2008). Pretend play in childhood : An integrative review. *Child Development, 52*(4), 1095–1118.

Ford, N., & Stein, A. (2017). Risk factors affecting child cognitive development: A summary of nutrition, environment, and maternal-child interaction indicators for sub-Saharan Africa. *Journal of Developmental Origins of Health and Diseases, 7*(2), 197–217.

Frobel, F. (1967). *Pedagogies of the kindergarten*. Cambridge University Press.

Ganyaupfu, E. M. (2013). Teaching methods and students' academic performance. *International Journal of Humanities and Social Science Invention, 2*(9), 29–35.

Ghosh, A. (2014). *Indian school education system – An overview*. British Council White Paper. Retrieved from https://www.britishcouncil.in/sites/default/files/indian_school_education_system_-_an_overview_1.pdf

Goldstein, L. S. (2007). Beyond the DAP versus standards dilemma: Examining the unforgiving complexity of kindergarten teaching in the United States. *Early Childhood Research Quarterly, 22*, 39–54.

Gormley, W. T., Jr., Gayer, T., Phillips, D., & Dawson, B. (2005). The effects of universal pre-K on cognitive development. *Developmental Psychology, 41*(6), 872.

Graham, S., & Santangelo, T. (2014). Does spelling instruction make students better spellers, readers, and writers? A meta-analytic review. *Reading and Writing, 27*(9), 1703–1743.

Gullo, D. F., & Hughes, K. (2011). Reclaiming kindergarten: Part I. questions about theory and practice. *Early Childhood Education Journal, 38*, 323–328.

Haden, C. A., Ornstein, P. A., O'Brien, B. S., Elischberger, H. B., Tyler, C. S., & Burchinal, M. J. (2011). The development of children's early memory skills. *Journal of Experimental Child Psychology, 108*(1), 44–60.

Helou, M. M., & Newsome, L. K. (2018). Application of Lev Vygotsky's sociocultural approach to Foster students' understanding and learning performance. *Journal of Education and Culture Studies, 2*(4), 347–355.

Hesterman, S. (2018). Too young to fail: Standardising literacy in the early years of schooling. *Educational Practice and Theory, 40*(1), 5–28.

Hoque, M. (2017). Three domains of learning: Cognitive, affective and psychomotor. *The Journal of EFL Education and Research (JEFLER), 2*, 45–51.

Hurley, A. (2005). *Cognitive development: Overview*.

Ihekerenma, I. V. (2017). The effect of play-way teaching strategy on primary school pupils' acquisition of basic science concepts. *Advances in Social Sciences Research Journal, 4*(10).

Isaacs, B., & Green, S. (2007). *Bringing the Montessori approach to your early years practice*. London: Routledge. https://doi.org/10.4324/9780203931769.

Işık, D., & Tarım, K. (2009). The effects of the cooperative learning method supported by multiple intelligence theory on Turkish elementary students' mathematics achievement. *Asia Pacific Education Review, 10*(4), 465.

Jacob, U. S. & Odafin, O. P. (2016). Effect of music therapy and play-way method on reduction of aggressive behaviour among children with mild intellectual disability in Ibadan, Oyo State, Nigeria. Education for Today 1596-0773. 12.

Joubish, M. F., & Khurram, M. A. (2011). Cognitive development in Jean Piaget's work and its implications for teachers. *World Applied Sciences Journal, 12*(8), 1260–1265.

Kafadar, H., Akıncı, Z., & Çakır, B. (2015). Effects of the IQ up cognitive development method on the cognitive development of 10- to 12-year-old children. *Procedia - Social and Behavioral Sciences, 174*, 3243–3253.

Kalina, C., & Powell, K. C. (2009). Cognitive and social constructivism: Developing tools for an effective classroom. *Education, 130*(2), 241–250.

Kayılı, G. (2018). The effect of Montessori method on cognitive tempo of kindergarten children. *Early Child Development and Care, 188*(3), 327–335.

Kayili, G., & Ari, R. (2011). Examination of the effects of the Montessori method on preschool children's readiness to primary education. *Educational Sciences: Theory and Practice, 11*(4), 2104–2109.

Kayili, G., & Ari, R. (2016). The effect of Montessori method supported by social skills training program on Turkish Kindergarten children's skills of understanding feelings and social problem solving. *Journal of Education and Training Studies, 4*(12), 81–91.

Kocevska, D., Rijlaarsdam, J., Ghassabian, A., Jaddoe, V. W., Franco, O. H., Verhulst, F. C., & Tiemeier, H. (2017). Early childhood sleep patterns and cognitive development at age 6 years: The generation R study. *Journal of Pediatric Psychology, 42*(3), 260–268.

La Paro, K. M., Hamre, B. K., Locasale-Crouch, J., Pianta, R. C., Bryant, D., Early, D., et al. (2009). Quality in kindergarten classrooms: Observational evidence for the need to increase children's learning opportunities in early education classrooms. *Early Education and Development, 20*(4), 657–692.

Landry, S. H. (2017). The role of parents in early childhood learning. *Encyclopedia on Early Childhood Development*, 1–6.

Lillard, A. S. (2012). Preschool children's development in classic Montessori, supplemented Montessori, and conventional programs. *Journal of School Psychology, 50*(3), 379–401.

Lillard, A. S. (2013). Playful learning and Montessori education. *American Journal of Play, 5*(2), 157–186.

Lillard, A. S., & Else-Quest, N. (2006). Evaluating Montessori education. *Science, 313*, 1893–1894.

Lillard, A. S., & Heise, M. J. (2016). An intervention study: Removing supplemented materials from Montessori classrooms associated with better child outcomes. *Journal of Montessori Research, 2*(1), 16–26.

Lillard, A. S., Lerner, M. D., Hopkins, E. J., Dore, R. A., Smith, E. D., & Palmquist, C. M. (2013). The impact of pretend play on children's development: A review of the evidence. *Psychological Bulletin, 139*(1), 1.

Lockhart, S. (2010). Play: An important tool for cognitive development. *High Scope Extensions, 24*(3), 1–8.

Loeb, S., Bridges, M., Bassok, D., Fuller, B., & Rumberger, R. W. (2007). How much is too much? The influence of preschool centers on children's social and cognitive development. *Economics of Education Review, 26*(1), 52–66.

Luna, B., & Sweeney, J. A. (2001). Studies of brain and cognitive maturation through childhood and adolescence: A strategy for testing neurodevelopmental hypotheses. *Schizophrenia Bulletin, 27*(3), 443–455.

Macnamara, B. N., Moore, A. B., Kegl, J. A., & Conway, A. R. (2011). Domain-general cognitive abilities and simultaneous interpreting skill. *Interpreting, 13*(1), 121–142.
Manisha, S., & Sunita, M. (2013). *An evaluation of different types of teaching methods among the pre-schoolers* (A case study of Lucknow city).
Marshall, C. (2017a). Montessori education: A review of the evidence base. *npj Science of Learning, 2*(1), 11.
Marshall, C. (2017b). Montessori education: A review of the evidence base. *npj Science of Learning, 2*(1), 1–9.
Marwaha, S., Goswami, M., & Vashist, B. (2017). Prevalence of principles of Piaget's theory among 4-7-year-old children and their correlation with IQ. *Journal of Clinical and Diagnostic Research: JCDR, 11*(8), ZC111.
Ministry of Education and Research. (2010). *NOU 2010: 7. Diversity and competence*. Multilingual Children, Youth and Adults in the Educational System. Oslo. http://www.regjeringen.no/nb/dep/kd/dok/nouer/2010/NOU-2010-7.html?id=606151
Modebelu, M. N., & Duvie, A. N. (2012). Innovative methods and strategies for effective teaching and learning. *Mediterranean Journal of Social Sciences, 3*(13), 145–154.
Mohanty, A. (2015). Information processing and creative thinking abilities of residential and non-residential school children: A pilot study. *SAGE Open, 5*(4), 2158244015611452.
Mollborn, S., & Dennis, J. A. (2012). Ready or not: Predicting high and low school readiness among teen parents' children. *Child Indicators Research, 5*(2), 253–279.
Morris, J. (1990). *The Morris-Montessori word list*. London: London Montessori Centre.
Nadeem, N. A., Jabeen, G., & Bilquees, S. (2013). Use of play way method and creating healthy environment in pre-primary school of Srinagar district: An evaluative study. *Journal of Education Research and Behavioral Sciences, 2*(10), 167–176.
Nair, S. M., Yusof, N. M., & Arumugam, L. (2014). The effects of using the play method to enhance the mastery of vocabulary among preschool children. *Procedia-Social and Behavioral Sciences, 116*, 3976–3982.
Nicolopoulou, A. (1999). Play, cognitive development, and the social world: Piaget, Vygotsky, and beyond. *Lev Vygotsky: Critical Assessments, 2*, 419–446.
Nicolopoulou, A. (2010). The alarming disappearance of play from early childhood education. *Human Development, 53*(1), 1–4.
No Child Left Behind Act of 2001. (2002). Vol. 20. https://www2.ed.gov/policy/elsec/leg/esea02/index.html
Noble, K. G., Ph, D., Houston, S. M., Brito, N. H., Ph, D., Bartsch, H., et al. (2015). Family income, parental education and brain structure in children and adolescents. *Nature Neuroscience, 18*(5), 773–778.
Nurliyana, A. R., MohdShariff, Z., MohdTaib, M. N., Gan, W. Y., & Tan, K. A. (2016). Early nutrition, growth and cognitive development of infants from birth to 2 years in Malaysia: A study protocol. *BMC Pediatrics, 16*(1), 1–7.
Nyaradi, A., Li, J., Hickling, S., Foster, J., & Oddy, W. H. (2013). The role of nutrition in children's neurocognitive development, from pregnancy through childhood. *Frontiers in Human Neuroscience, 7*(March), 1–16.
OECD. (2015). *Early childhood education and care policy reveiw*. Norway: OECD. http://www.oecd.org/norway/Early-Childhood-Education-and-Care-Policy-Review-Norway.pdf
Orr, A. M., & Kukner, J. M. (2015). Fostering a creativity mindset in content area pre-service teachers through their use of literacy strategies. *Thinking Skills and Creativity, 16*, 69–79.
Parisi, J. M., Rebok, G. W., Xue, Q. L., Fried, L. P., Seeman, T. E., Tanner, E. K., et al. (2012). The role of education and intellectual activity on cognition. *Journal of Aging Research, 2012*, 416132.
Parker, A., & Neuharth-Pritchett, S. (2006). Developmentally appropriate practice in kindergarten: Factors shaping teacher beliefs and practice. *Journal of Research in Childhood Education, 21*(1), 65–78.

Pem, D. (2016). Factors affecting early childhood growth and development: Golden 1000 days. *Advanced Practices in Nursing, 1*(1), 1–4.
Popoola, A. A. (2014). Effect of play way method on the numeracy skills of early basic education school pupils in Ekiti State Nigeria. *Mediterranean Journal of Social Sciences, 5*(10), 318.
Prochner, L. (2002). Preschool and playway in India. *Childhood, 9*(4), 435–453.
Pyle, A., & Danniels, E. (2017). A continuum of play-based learning: The role of the teacher in play-based pedagogy and the fear of hijacking play. *Early Education and Development, 28*(3), 274–289.
Pyle, A., & DeLuca, C. (2013). Assessment in the kindergarten classroom: An empirical study of teachers' assessment approaches. *Early Childhood Education Journal, 41*(5), 373–380.
Pyle, A., DeLuca, C., & Danniels, E. (2017). A scoping review of research on play-based pedagogies in kindergarten education. *Review of Education, 5*(3), 311–351.
Pyle, A., DeLuca, C., Danniels, E., & Wickstrom, H. (2020). A model for assessment in play-based Kindergarten education. *American Educational Research Journal*, 0002831220908800.
Randolph, J. J., Bryson, A., Menon, L., Michaels, S., Rosenstein, D. L. W., & McPherson, W. (2016). PROTOCOL: Montessori education for improving academic and social/behavioral outcomes for elementary students. *Campbell Systematic Reviews, 12*(1), 1–32.
Rao, N., Sun, J., Chen, E. E., & Ip, P. (2017). Effectiveness of early childhood interventions in promoting cognitive development in developing countries: A systematic review and meta-analysis. *Hong Kong Journal of Paediatrics (New Series), 22*(1), 14–25.
Ray, K., & Smith, M. C. (2010). The kindergarten child: What teachers and administrators need to know to promote academic success in all children. *Early Childhood Education Journal, 38*(5), 5–18.
Rogers, S. (2010). Play and pedagogy. A conflict of Interst? In *Rethinking play and pedagogy in Early childhood education: Concepts, contexts and cultures* (pp. 5–18). London/New York: Routledge.
Russell, J. L. (2011). From child's garden to academic press: The role of shifting institutional logics in redefining kindergarten education. *American Educational Research Journal, 48*, 236–267.
Sari, Y. K., Sukartiningsih, W., & Jannah, M. (2018, December). The effect of geometric puzzle game towards children's recognition of geometric shapes and fine motor. In 2nd International Conference on Education Innovation (ICEI 2018). Atlantis Press.
Scarfo, C., & Littleford, J. (2008). *It's child's play*. Retrieved September 15, 2020, from http://www.etfo.ca/Publications/Voice/Voice%20Back%20Issues/Documents/February%202008/child's%20play.pdf
Scharf, R. J., Scharf, G. J., & Stroustrup, A. (2016). Developmental milestones. *Pediatrics in Review, 37*(1), 25–37.
Semmar, Y., & Al-Thani, T. (2015). Piagetian and Vygotskian approaches to cognitive development in the kindergarten classroom. *Journal of Educational and Developmental Psychology, 5*(2), 1.
Shaul, S., & Schwartz, M. (2014). The role of the executive functions in school readiness among preschool-age children. *Reading and Writing, 27*(4), 749–768.
Shute, R. H., & Slee, P. T. (2015). Child development: Theories and critical perspectives. In *International texts in developmental psychology* (2nd ed.).
Siegler, R., Carpenter, T., Fennell, F., Geary, D., Lewis, J., Okamoto, Y., …, & Wray, J. (2010). *Developing effective fractions instruction for kindergarten through 8th grade*. IES practice guide. NCEE 2010-4039. What Works Clearinghouse.
Simatwa, E. M. (2010). Piagets theory of intellectual development and its implication for instructional management at pre-secondary school level. *Educational Research and Reviews, 5*(7), 366–371.
Slunjski, E., & Ljubetic, M. (2014). Play and its pedagogical potential in a preschool institution. *Croatian Journal of Education-HrvatskiCasopisZaOdgoj I Obrazovanje, 16*(1), 127–141.
Smith, P. K. (2005). *Play: Types and functions in human development*. New York: Guilford Press.
Sternberg, R. J., & Sternberg, K. (2016). *Cognitive psychology*. Nelson Education.

Stipek, D., & Byler, P. (2004). The early childhood classroom observation measure. *Early Childhood Research Quarterly, 19*, 375–397.

Sullivan, B., Hegde, A. V., Ballard, S. M., & Ticknor, A. S. (2015). Interactions and relationships between kindergarten teachers and English language learners. *Early Child Development and Care, 185*, 341–359.

Sundsdal, E., & Øksnes, M. (2015). Tilforsvar for barns spontanelek. *Nordisk tidsskrift for pedagogikkogkritikk, 1*.

Suresh, P., Ayyappan, A., & Nandini, J. (2015). Cognitive deficits and behavioral disorders in children: A comprehensive multidisciplinary approach to Managemente. *Annals of Behavioural Science, 1*(6), 1–17.

Synodi, E. (2010). Play in the kindergarten: The case of Norway, Sweden, New Zealand and Japan. *International Journal of Early Years Education, 18*(3), 185–200.

Tahir, A. G., Abbas, A., Rizvi, A. A., Ghazali, G. A., & Saleem, S. (2013). System of Montessori education vs Kindergarten system of education. *Merit Research Journal of Education and Review, 1*(11), 259–263.

Thijs, J. T., & Koomen, H. M. (2008). Task-related interactions between kindergarten children and their teachers: The role of emotional security. *Infant and Child Development: An International Journal of Research and Practice, 17*(2), 181–197.

Torgerson, C., Brooks, G., & Hall, J. (2006). *A systematic review of the research literature on the use of phonics in the teaching of reading and spelling*. Nottingham: DfES Publications.

Tripathi, G., & Ahad, M. A. (2017). Impact of excessive use of internet on cognitive development of youngsters. *International Journal of Information Technology, 9*(3), 281–286.

Tucker-drob, E. M., Briley, D. A., & Harden, K. P. (2014). Genetic and environmental influences on cognition across development and context. *Current Directions in Physiological Sciences, 22*(5), 349–355.

Upadhyay, A. K., Malar, G., & Sharanaiah, M. M. (2017). Efficacy of play-way technique in promoting numeracy skills in preschool children with hearing Impairmen. *Journal of Disability Management and Rehabilitation, 2*(1), 34–38.

Vöhringer, I. A., Kolling, T., Graf, F., Poloczek, S., Fassbender, I., Freitag, C., et al. (2018). The development of implicit memory from infancy to childhood: On average performance levels and interindividual differences. *Child Development, 89*(2), 370–382.

Vorkapić, S. T., & Katić, V. (2015). How students of preschool education perceive their play competences–An analysis of their involvement in children's play. *Center for Educational Policy Studies Journal, 5*(1), 111–130.

Wallerstedt, C., & Pramling, N. (2012). Learning to play in a goal-directed practice. *Early years, 32*(1), 5–15.

Wasik, B. A., & Hindman, A. H. (2011). Improving vocabulary and pre-literacy skills of at-risk preschoolers through teacher professional development. *Journal of Educational Psychology, 103*(2), 455.

Watanabe, K., Flores, R., Fujiwara, J., & Tran, L. T. H. (2005). Early childhood development interventions and cognitive development of young children in rural Vietnam. *The Journal of Nutrition, 135*(8), 1918–1925.

Wolf, B., Abbott, R. D., & Berninger, V. W. (2017). Effective beginning handwriting instruction: Multi-modal, consistent format for 2 years, and linked to spelling and composing. *Reading and Writing, 30*(2), 299–317.

Wyse, D., & Styles, M. (2007). Synthetic phonics and the teaching of reading: The debate surrounding England's 'Rose Report'. *Literacy, 41*(1), 35–42.

Chapter 14
Importance of Brain-Based Learning in Effective Teaching Process

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14.1 Introduction

Neuroscience has been understood as the study of biological underpinnings of various cognitive processes such as learning, memory, and consciousness (Oktar 2006). It has been often referred to as neurobiology. It is the systematic and in-depth study of the nervous system which has the basic, structural, and functional unit as a neuron. So, in a way, neuroscience can be defined as the study of the neurons. Neuroscience is multidisciplinary by nature as it includes various fields like biology, psychology, and cognitive science. Extensive research has been happening in the past few years in this field in order to understand various cognitive processes like memory, consciousness, learning, perception, and their biological bases. While these researches have continued to happen, there are hardly any takeaways in terms of execution and implementation from these researches.

Although educational science and neuroscience seem far off in relation, they have a strong connection when it comes to use of cognitive science. Cognitions such as memory, attention, learning, reasoning, and problem-solving are very important in educational science to impart teaching and facilitate the learning process. Neuroscience, as mentioned earlier, deals with understanding the biological bases of these cognitive processes. The most important cognition of educational science being learning, this chapter exclusively explores the importance of including novel methods of teaching which are exciting to the brain. Further, these methods have been provided with evidence-based benefits such as enhancing cognitive processes that in turn facilitate meaningful learning processes. Firstly, learning and brain-based learning are explained. Following which neuroscience and teaching along

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with different strategies for teaching that enhance learning have been explored. The chapter closes with challenges and benefits which will be fruitful to inculcate these in classroom settings.

14.2 Learning

Learning is a process which is defined as the gaining of knowledge through various means like being taught, through experience, and through studying. It is also a process in which new information is acquired and modified with the existing information in our brain. It is a complex process which is found in humans and animals. One of the earlier studies related to the learning process in animals can be traced back to Skinner's studies (Winokur 1971).

It can be said that all learning can have a biological base. Our understanding about learning and the neural mechanisms that are involved in the process are increasing on a daily basis. This can be associated to the development in various technologies and researches that are extensively happening in the field of learning. The significance and meaning of the term "learning" vary depending on the context and the field in which it is used and applied (Howard-Jones et al. 2014).

We study extensively about the brain, neural systems, and various functions under the field neuroscience. In this field, "learning" is often equivalent to memory. We can say that memory is not localized to any particular brain region, but is spread throughout the brain. Along the same lines, it is also a fact that certain aspects of memory can be associated with particular areas/parts of the brain (Kalat 2016).

Neuroscientists opine that learning that happens through formation and development of memory is influenced by the changes in neural connectivity. It is also important to understand that forming neuronal connections/associations is not the same as that of forming connections/association between ideas. The former is supposed to happen in the brain, while the latter is supposed to happen in our minds.

14.3 Brain-Based Learning

According to Jenson (2011), brain-based learning is the ability to learn with respect to the brain's natural design (wiring) to learn. The ideas from brain-based learning can be adopted to increase comforts for students in learning. One of the underlying assumptions of brain-based learning is that the human influence has an impact on the ability to learn things. The brain always attaches an emotion to every event that takes place (Jenson 2011). This means that emotion plays a major role in learning. In order to enhance learning, teachers should give importance to the emotional content of each lesson. Furthermore, our emotional system drives our attentional system, which in turn drives all the other processes in our learning, including learning and memory. In short, it can be said that it is impossible to learn something to which we don't pay attention (Chapman and King 2005).

After multiple studies conducted in association with brain-based learning, experts have come up with 11 basic principles which underlie the brain-based learning. The first principle is regarding the brain's capability to parallelly process. This means that the human brain has the ability to perform multiple tasks simultaneously. The second principle is the involvement of entire physiology in learning. This means that in the process of learning, it is not only the brain which is involved; other parts of the body are also involved. For example, some people use hands to do simple math calculations. The third principle is that the search for meaning is innate. This means that whatever we learn or understand, when it is linked with meaningful and personal experiences, it tends to have an in-depth learning as a result of this. The fourth principle is about the patterns that help in search for meaning, which means that the brain is tuned in such a way that it makes and understands patterns. All information is stored in the form of a pattern in our brain. The brain cannot create meaningless patterns, nor does it accept meaningless patterns. The fifth principle is that emotions play a vital role in patterning. As mentioned before, no learning happens without us paying attention to it. The sixth principle is that the brain processes parts and wholes simultaneously. This statement means that even though the brain has two hemispheres and various parts in it, the brain is designed in such a way that it works together. The next principle is that both focused attention and peripheral perception play an important role in learning, which means that we have general ideas about our surroundings and we pay special attention to some parts of it. The eighth principle is that learning always involves conscious and unconscious processes. The ninth principle states that humans have two different types of memory at the least, which are autobiographical memory and taxon memory. Factual information is stored in taxon memory. The autobiographical memory establishes links between experiences, facts, etc. The tenth principle is that learning is developmental. The eleventh principle is that learning is inhibited by threat and enhanced by challenges (Caine et al. 2009). These principles can be of great help for teachers and can be implemented from preschool itself in order for the better and effective learning in students.

Neural plasticity is one of the significant features of the brain. Often referred to as brain plasticity, it enables the brain to make new neural connections and to keep up with the changes. All the experiences which we go through, be it good or bad, small or large, are said to transfer the connections between neurons, to help the brain to constantly undergo change. In neuroscience, plasticity plays a major role in primarily understanding development and learning (Dubinsky et al. 2013). The brain's capability to change is very important in growth mindset and learning equity. It has been found out that a growth mindset is associated mostly with increase in achievement, taking more challenges and adaptive responses toward those challenges, and consistent in terms of learning tasks (Rattan et al. 2015).

Brain-based learning studies throw light on the fact that despite differences, everyone can learn, despite each brain being unique and different people having different styles of learning (Stern 2017). It is very important for teachers to get trained in all these aspects and to use research-based training strategies so that the students learn effectively and the learning stays in their memory forever.

14.4 Neuroscience and Teaching Practice

According to Hart (1983), the brain is considered as the organ for learning, and teachers are considered to be the primary source that fosters learning in students. The process of learning happens extensively in the brain. So, it is important for courses offered to train teachers to include the brain in the syllabus. Even though this idea is strongly there in the modern-day world, there are very few programs which include neuroscience in their curriculum (Ansari and Coch 2006).

It has been only a very few years since the whole idea of neuroscience and its importance in the field of teaching practice have come up. There has been new advancement in this field. One such advancement is known as the technology-enhanced learning. Technology-enhanced learning is the practice of including technology to facilitate the learning process. The main idea of this approach is to enhance the process of learning using the various technologies available (Howard-Jones et al. 2014).

As teachers serve as one of the important sources of spreading knowledge to children, it is important that the teachers use effective methods and strategies for an effective learning process. Recent literature has pointed out the importance of brain-based teaching-learning practices for the teachers to spread knowledge with the help of effective teaching practices and students to gain knowledge in a more effective way. A brain-compatible teacher or, in short, an effective teacher relies on areas like cognitive neurosciences, psychology, educational research, etc. in order to provide an apt learning environment for the students as well as an effective way of learning (Alton-Lee 2006).

An important fact which should be understood regarding this area is that learning is both a conscious and an unconscious process. Most of the peripheral signals perceived by us undergo unconscious processing in our brain, i.e., we are not aware about these processes. It has been found out that after sometime, the unconscious processes are brought into our conscious part and it influences some aspects of the process (e.g., our motives, behaviors, etc. associated with what we have perceived) (Lozanow 1978). So, the process of teaching should benefit the students abundantly in terms of learning by giving more attention to the unconscious processes that in turn makes learning effective.

Adding on to these benefits, literature on brain-based learning have found out various methods that can be adopted by teachers in a classroom setting in order to make the process of learning more beneficial for the students. Some of those methods are discussed below.

14.5 Movements

Learning is a process that involves both the body and the brain. In the educational setup, the process of learning can be enhanced by using movement. This movement involves the physical movements of both the students and the teachers. Based on the recent studies, we now understand that the physical movements that take place in between the classes such as a teacher moving around the class while teaching, students moving to different parts of the room for activities, etc. are very effective in terms of increasing engagement and enjoyment in the process of learning as well as teaching (Benes et al. 2016). In the process of teaching, inculcating movement in their traditional classroom environment can be beneficial for the teachers as it leads to increased physical awareness, enhanced social interactions, and a sense of autonomy where they feel more responsible for improving in their teaching (Sevimli-Celik and Johnson 2015).

Therefore, movement or physical activity can be beneficial in the learning process. In terms of cognitive functioning, physical activity or motor movement has been proven to boost attention, memory, mood management, etc. that form an integral for each type of learning (Jenson 2011). Additionally, in the domain of physical health, engaging in motor activities prevents metabolic, cardiovascular, and respiratory diseases (Giorgio et al. 2018). Moreover, engaging in motor activity has been strongly correlated with the production of new brain cells – neurogenesis (Jenson 2011). Lastly, within the classroom, movement integration improves on-task behavior, boosts positive affect, and increases perceived effort and competence (Webster et al. 2015). In totality, we understand that movement proves to be beneficial in improving socio-emotional, physical, and mental health.

Furthermore, literature rooted in application of movement in the real-life settings reveals that physical activity or movement in the classroom settings reveals that since physically active classroom lessons are more interesting and enjoyable for both the students and teacher, they result in improved academic performance. Additionally, these lessons do not require more preparation on the part of teachers and are cost-effective (Donnelly and Lambourne 2011).

Therefore, while preparing for the classroom lectures, teachers can think about incorporating motor-based activities that can range from simple to complex ones such as having students stand up after every class to push-ups. And these can be modified based on several factors such as student capabilities, time constraint, etc. Moreover, by inculcating movement breaks which can include jumping jacks, toe touches, arm circles, one-legged hops, etc. in the school curriculum, stress levels can be reduced for both teachers and students (Reilly et al. 2012).

14.6 Emotions

Our earlier understanding that learning is independent of emotional and social domains of our lives has been challenged by new findings in the field of neuroscience. These findings suggest that the process of learning in the educational setup is deeply connected to the emotional and social aspects of an individual. Moreover, the fundamental reasons that drive the learning process are rooted in emotional and social factors. Students engage in the process of education for various emotional and social reasons such as pleasing the parent, escaping the punishment, or getting admission in a good college (Immordino-Yang 2011).

Emotions, therefore, are essential in the process of learning. Furthermore, the human emotional system is spread throughout the body, originating from the brain to the endocrine and the immune system. These systems have an impact on other parts of the body. One such impact of emotions can be found on the attentional system. Since emotions have a huge impact on attention, this in turn influences the process of memory and learning (Sylwester 1994). Additionally, emotions can also modulate the selectivity of attention which is closely linked to the process of learning and can aid the process of encoding and retrieval of information. The neuroimaging results show that the prefrontal cortex and the amygdala along with the medial temporal lobe work in an integrated manner which leads to the long-term retention of information and successful learning (Tyng et al. 2017).

Therefore, teachers need to understand that stressful class environments will inhibit the process of learning and a positive classroom atmosphere enhances the process of learning. Teachers can enhance the learning process by incorporating positive emotions in the class which will create a positive learning environment. For this, teachers can make students engage in activities like meditation, mindfulness, yoga, etc. and can employ appropriate humor to consolidate the learning process and decrease the stress levels in the students (Waters et al. 2014; Terrell 2014).

14.7 Music

In the past several decades owing to the technological advancements in the field of scientific enquiry, we have been able to explore at a deeper level the positive impact of music on human beings. Areas that have been of primary interest to these scientific studies include brain areas that are activated and responsible for the perception and processing of music, along with the cognitive and neural process that is involved in musical treatments. With the growing evidence from such studies and the rise of new scientific domains, there has been increased encouragement to utilize the benefits of music within the educational system (Stefanija and Aida 2015).

Therefore, we are now able to understand that music can be used to improve and enhance the process of learning. Furthermore, cognitive neuroscience reveals that music has an impact on enhancing the attentional system, improving brain plasticity, providing multi-sensory input, and improving memory (Curtis and Fallin 2014). In the domain of attention, music has been found to enhance attention by increasing arousal and improving mood and thereby improving visual attention (Chen et al. 2012). In the context of music and brain plasticity, studies reveal that even brief music training can induce brain plasticity (Moreno et al. 2011). Additionally, individuals who practice a musical instrument often perform better on working memory and reasoning tests (Nutley et al. 2014).

However, in the case of music, certain elements need to be monitored. The first factor that needs to be understood is the presence or absence of lyrics. Music with lyrics interferes with the visual focused attention and thus affects the performance as compared to music without lyrics (Shih et al. 2012). The second factor includes the type of music which enhances cognitive abilities. The genre of music also seems to influence the efficiency of focused attention. Sedative music increases the production of alpha rhythms in the brain and therefore increases the efficiency of focused attention (Boring 1981). Lastly, the tempo of the music is a factor that influences the performance speed. Listening to music with high temp seems to enhance the speed of the performance (Jamshidzad et al. 2018).

While considering the abovementioned factors, music can, therefore, be used as an educational tool in the schools. The schools can inculcate music as a part of learning by using music as a part of activities such as cooperative activities, throwing and catching, and jumping the rope. Furthermore, music can also be employed as a classroom management strategy which will lead to maximized learning and participating and a significant decrease in the student's misbehavior (Konukman et al. 2012).

14.8 Interactive Learning Environment

With the gradual paradigm shift owing to the brain-based model of learning, teaching models are now focusing on optimizing student learning. However, in the present situation, the process of learning is more focused on attaining curriculum goals rather than enhancing student's cognitive abilities. Owing to this, the process of learning only focuses on providing various information to the students rather than actively engaging them in learning, which does not yield positive responses from the students. Furthermore, the role of the students is reduced to passive receivers of information (Sesmairni 2015).

Therefore, by creating an interactive classroom environment, the teachers can stimulate the student's thinking ability. Furthermore, neuroscience reveals that students who actively engage or participate in the learning process by explaining their ideas and then engaging with other students' ideas have higher achievement scores (Ing et al. 2015). Additionally, using collaborative learning activities enhances student satisfaction and improves learning. However, in this process, the teachers need to be open to these interactive teaching strategies (Lo 2010). Therefore, the teachers must aim to create an active learning environment by incorporating games, puzzles, simulation, group discussions, etc. into the classroom settings to avoid making the classroom boring and uncomfortable (Sesmairni 2015).

14.9 Visual Stimulation

In the past decade, the field of education and teaching has been revolutionized by the research on neuropedagogy. The cross development in the fields of neuroscience, class teaching, and brain science has led to the changing trends in the field of education (Dai et al. 2018). Owing to these developments, the field of education has been transformed from traditional classrooms to active learning spaces. Moreover, the traditional chalkboard medium of instruction has been replaced by more technologically advanced methods such as the use of PowerPoint presentations which provides a platform to use multiple visuals such as videos, pictures, movies, animation, and words (Vazquez and Chaing 2014).

Therefore, visual stimulation became an integral part of the learning process. Furthermore, neuroscience reveals that using visual aids in teaching can substitute the monotonous teaching method and enhance the learning environment and stimulates thinking. Moreover, visual aids can be used to gain the attention and enhance retention of information and interest of students and can be used by teachers to explain the concepts more easily and clearly (Shabiralyani et al. 2015). Therefore, schools, as well as teachers, can inculcate visuals in their curriculum in the form of posters, charts, models, pictures, maps, diagrams, PowerPoint slides, and short videos or clips from YouTube to make the process of learning in the classrooms more interactive and interesting. Moreover, by using such visual aids, the teacher can cater to the needs of different types of learners in the classroom (Macwan 2015).

14.10 Throwing Challenges

Educational neuroscience is the scientific field that focuses on our understanding of how the brain operates in connection with the learning process (Mayer 2016). Gradually, brain-based education shifted its focus from the initial establishment of vocabulary needed to understand new knowledge to the establishment of various brain-based disciplines (Jenson 2008). However, over a period of time, one of the important contributions of educational neuroscience is the 12 fundamental principles that they propound underlie the learning process. The twelfth principle focuses on the need for challenges to enhance complex learning. This means that students can benefit optimally when the tasks assigned to them are challenging while the classroom environment is supportive and safe (Connell 2009).

Therefore, focus should be on building socio-emotional conditions where learning will thrive through challenges that are non-threatening (Gulpinar 2005, as cited in Gozuyesil and Dikici 2014). Furthermore, cognitive neuroscience reveals that incorporating challenges in the classroom setting can foster the growth of dendrites and therefore thickening of cerebral cortex in the learners. Additionally, challenges can be used as a strategy or technique for active learning which engages learners of varying learning styles and promotes the brain enhancement for learning. Henceforth, one of the ways through which teaching instructors can inculcate challenges in the classroom settings while keeping the stress level in check is by providing choices with assignments whenever possible and by not instilling fear of examination or tests (Craig 2003). Thus, the process of learning should be relevant, interesting, and challenging that will thereby inspire the students to actively participate and achieve success (Sesmairni 2015).

14.11 Challenges and Benefits

Brain-based learning, thus, seems to affect several areas involved in teaching and learning process and seems to be very beneficial. However, neuromyths have been identified as one of the challenges. Neuromyths are considered to be wrong assumptions or beliefs about the process of learning and teaching which is barely based on any findings (Geake 2008). One such is about the information that is put across to students in their preferred learning style. It was found out that over 97% of the teachers believed this to be true (Dekker et al. 2012) which in reality was not. To support this claim, there are different neuronal networks and pathways that work and process information for auditory, visual, etc., that work together. Additionally, there is no scientific evidence to prove that learning is enhanced significantly if delivered in the preferred style of the learner (Pashler et al. 2009).

Further, there are other challenges that are important to note about different strategies that were mentioned in the chapter for brain-based learning. While there is evidence about all the abovementioned strategies, practically implementing them might become a hurdle to the teachers as well as management. For instance, for movement inside the classroom, there might not be enough physical space, and to take all the children outside the class for a short break could divert attention and might not be suitable if the numbers are huge. Furthermore, using activities suggested with music could be possible for lower grades, while for higher grades, implementation could be difficult, and covering the syllabus could also be challenging. Adding on to these challenges, interacting with every student is practically not possible, and this opportunity will be made use of only by some students, while others tend to become silent spectators. Thus, all these activities are not as easy to implement although it is evidence-based. However, initiating such activities once in a while can be possible. For example, jumping and sitting on benches for physical activity, music activities once in a fortnight, or using aura technique to teach and/or as an activity for the students in class and reinforcements such as praise for interacting can be beneficial for other students to participate.

There have also been few benefits which have been identified in connecting neuroscience and teaching practice. One such benefit is the content of pedagogical knowledge. Shulman (1987) suggested that this novel information is a crossing point between a teacher's knowledge about teaching itself and their subject knowledge. Furthermore, in terms of the strategies mentioned above, they have great potential to enhance longer and meaningful learning processes that will make a difference in the learner's life. These will also alleviate boredom and make learning interesting.

14.12 Conclusion

Neuroscience has contributed enormously to understand the process of effective and impactful teaching and learning. Presently a lot more resources are available to make learning and teaching impactful. One such is technology, which has revolutionized learning space via smart classrooms and online learning. While incorporating neuroscience in education seems far off and challenging, it is quite simple and beneficial. Based on the learning principles and several strategies proposed in this chapter, it is quite easy to implement them in the actual classroom setting. For each of them, evidence-based advantage and ways to inculcate provide a roadmap for execution. Although there are some challenges in execution, ways to overcome the same have also been mentioned in the chapter. Thus, evidence clearly indicates that brain-based teaching has more benefits that outweigh challenges. Finally, "brain-based teaching" needs to be included in the curriculum that is used to train teachers so as to benefit the learning and teaching process.

References

Alton-Lee, A. (2006). How teaching influences learning: Implications for educational researchers, teachers, teacher educators and policy makers. *Teaching and Teacher Education, 22*(5), 612–626. https://doi.org/10.1016/j.tate.2006.01.002.

Ansari D., & Coch, D. (2006). Bridges over troubled waters: education and cognitive neuroscience. *Trends Cogn Sci, 10*(4), 146–51. https://doi.org/10.1016/j.tics.2006.02.007. Epub 2006 Mar 10. PMID: 16530462.

Benes, S., Finn, K., Sullivan, E., & Yan, Z. (2016). Teachers' perceptions of using movement in the classroom. *The Physical Educator, 73*(1). https://doi.org/10.18666/tpe-2016-v73-i1-5316.

Boring, J. E. (1981). The effects of sedative music on alpha rhythms and focused attention on high creative and low creative subjects. *Journal of Music Therapy, 18*(2), 101–108. https://doi.org/10.1093/jmt/18.2.101.

Caine, R. N., Caine, G., McClintic, C., & Klimek, K. J. (2009). *12 brain/mind learning principles in action: Developing executive functions of the human brain* (2nd ed.). Thousand Oaks, Cl: Corwin Press.

Chapman, C., & King, R. S. (2005). *Differentiated assessment strategies: One tool doesn't fit all*. Thousand Oaks, C.A.: Corwin Press Inc.

Chen, M.-C., Tsai, P.-L., Huang, Y.-T., & Lin, K. (2012). Pleasant music improves visual attention in patients with unilateral neglect after stroke. *Brain Injury, 27*(1), 75–82. https://doi.org/10.3109/02699052.2012.722255.

Connell, J. D. (2009). The global aspects of brain-based learning. *Phi Delta Kappa International, 88*(1), 28–39.

Craig, A. D. (2003). Interoception: the sense of the physiological condition of the body. *Current Opinion in Neurobiology, 13*(4), 500–505. https://doi.org/10.1016/s09594388(03)000904.
Curtis, L., & Fallin, J. (2014). Neuroeducation and music. *Music Educators Journal, 01*(2), 52–56. https://doi.org/10.1177/0027432114553637.
Dai, C., Lv, Y., & Hou, W. (2018). Creative teaching model of civil engineering classroom based on brain cognitive science. *NeuroQuantology, 16*(5). https://doi.org/10.14704/nq.2018.16.5.1289.
Dekker, S., Lee, N. C., Howard-Jones, P., & Jolles, J. (2012). Neuromyths in education: Prevalence and predictors of misconceptions among teachers. *Frontiers in Psychology, 3*(429), 1–8.
Donnelly, J. E., & Lambourne, K. (2011). Classroom-based physical activity, cognition, and academic achievement. *Preventive Medicine, 52*. https://doi.org/10.1016/j.ypmed.2011.01.021.
Dubinsky, J. M., Roehrig, G., & Varma, S. (2013). Infusing neuroscience into teacher professional development. *Educational Researcher, 42*(6), 317–329.
Geake, J. (2008). Neuromythologies in education. *Educational Research, 50*(2), 123–133. https://doi.org/10.1080/00131880802082518.
Giorgio, A. D., Kuvačić, G., Milić, M., & Padulo, J. (2018). The brain and movement: How physical activity affects the brain. *Montenegrin Journal of Sports Science and Medicine, 7*(2). https://doi.org/10.26773/mjssm.180910.
Gulpinar, A. M. (2005). The principles of brain-based learning and constructivist models in education. *Educational Sciences: Theory & Practice, 5*(2), 299–306.
Gözüyeşil, E., & Dikici, A. (2014). The effect of brain based learning on academic achievement: A meta-analytical study. *Educational Sciences: Theory & Practice*. https://doi.org/10.12738/estp.2014.2.2103.
Hart, L. A. (1983). *Human brain and human learning*. Oak Creek: Books for Educators.
Howard-Jones, P., Ott, M., van Leeuwen, T., & De Smedt, B. (2014). The potential relevance of cognitive neuroscience for the development and use of technology-enhanced learning. *Learning, Media and Technology, 40*(2), 131–151. https://doi.org/10.1080/17439884.2014.919321.
Immordino-Yang, M. H. (2011). Implications of affective and social neuroscience for educational theory. *Educational Philosophy and Theory, 43*(1), 98–103. https://doi.org/10.1111/j.1469-5812.2010.00713.x.
Ing, M., Webb, N. M., Franke, M. L., Turrou, A. C., Wong, J., Shin, N., & Fernandez, C. H. (2015). Student participation in elementary mathematics classrooms: The missing link between teacher practices and student achievement? *Educational Studies in Mathematics, 90*(3), 341–356. https://doi.org/10.1007/s10649-015-9625-z.
Jamshidzad, M., Maghsoudipour, M., Zakerian, S. A., Bakhshi, E., & Coh, P. (2018). Impact of music type on motor coordination task performance among introverted and extroverted students. *International Journal of Occupational Safety and Ergonomics, 26*(3), 444–449. https://doi.org/10.1080/10803548.2018.1455410.
Jensen, E. (2011). Brain-based education in action. *Educational Horizons, 90*(2), 5–6. https://doi.org/10.1177/0013175x1109000202.
Jensen, E. P. (2008). A fresh look at brain-based education. *Phi Delta Kappan, 89*(6), 408–417. https://doi.org/10.1177/003172170808900605.
Kalat, J. (2016). *Biological psychology* (12th ed.). New York: Cengage Learning.
Konukman, F., Harms, J., & Ryan, S. (2012). Using music to enhance physical education. *Journal of Physical Education, Recreation & Dance, 83*(3), 11–56. https://doi.org/10.1080/07303084.2012.10598736.
Lo, C. C. (2010). Student learning and student satisfaction in an interactive classroom. *The Journal of General Education, 59*(4), 238–263. https://doi.org/10.1353/jge.2010.0025.
Lozanov, G. (1978). *Suggestology and suggetopedy*. Retrieved Jan. 25, 2006 from http://lozanov.hit.bg/
Macwan, H. J. (2015). Using visual aids as authentic material in ESL classrooms. *Research Journal of English Language and Literature, 3*(1).
Mayer, R. E. (2016). How can brain research inform academic learning and instruction? *Educational Psychology Review, 29*(4), 835–846. https://doi.org/10.1007/s10648-016-9391-1.

Moreno, S., Bialystok, E., Barac, R., Schellenberg, E. G., Cepeda, N. J., & Chau, T. (2011). Short-term music training enhances verbal intelligence and executive function. *Psychological Science, 22*(11), 1425–1433. https://doi.org/10.1177/0956797611416999.

Nutley, S. B., Darki, F., & Klingberg, T. (2014). Music practice is associated with development of working memory during childhood and adolescence. *Frontiers in Human Neuroscience, 7*. https://doi.org/10.3389/fnhum.2013.00926.

Oktar, N. (2006). Theory of neuroscience. *Journal of Neurological Sciences [Turkish], 23*(3), 155–158. https://www.researchgate.net/publication/26445671_Theory_of_Neuroscience.

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2009). Learning styles: Concepts and evidence. *Psychological Science in the Public Interest, 9*(3), 105–119.

Rattan, A., Savani, K., Chugh, D., & Dweck, C. S. (2015). Leveraging mindsets to promote academic achievement: Policy recommendations. *Perspectives on Psychological Science, 10*, 721–726.

Reilly, E., Buskist, C., & Gross, M. K. (2012). Movement in the classroom: Boosting brain power, fighting obesity. *Kappa Delta Pi Record, 48*(2), 62–66. https://doi.org/10.1080/00228958.2012.680365.

Sesmiarni, Z. (2015). Brain based teaching model as transformation of learning paradigm in higher education. *Al-Ta Lim, 22*(3). https://doi.org/10.15548/jt.v22i3.141.

Sevimli-Celik, S., & Johnson, J. E. (2015). Teacher preparation for movement education: Increasing pre-service teachers' competence for working with young children. *Asia-Pacific Journal of Teacher Education, 44*(3), 274–288. https://doi.org/10.1080/1359866x.2015.1079303.

Shabiralyani, G., Hasan, K., Hamad, N., & Iqbal, N. (2015). Impact of visual aids in enhancing the learning process case research: District Dera Ghazi Khan. *Journal of Education and Practice, 6*, 226–233.

Shih, Y. N., Huang, R. H., & Chaing, H. Y. (2012). Background music: Effects on attention performance. *Work, 42*(4), 573–578. https://doi.org/10.3233/WOR-2012-1410.

Shulman, L. (1987). *Knowledge and teaching: Foundations of the new reform in Harvard Educational Review, 57*(1), 1–22.

Stefanija, Z. L., & Aida, I. (2015). The Significant Role of Music in the Educational System through the Various Scientific Disciplines. *International Journal of Sciences: Basic and Applied Research* (IJSBAR), *22*(1). pp. 354–359. ISSN 2307-4531

Stern, E. (2017). Individual differences in the learning potential of human beings. *npj Science Learn 2*, 2. https://doi.org/10.1038/s41539-016-0003-0

Sylwester, R. (1994). *How emotions affect learning. Educational Leadership, 52*(2), 60–65.

Terrell, S. (2014). LOL teacher! Using humor to enhance student learning. *Educational Horizons, 93*(2), 6–7. https://doi.org/10.1177/0013175x14561417.

Tyng, C. M., Amin, H. U., Saad, M. N., & Malik, A. S. (2017). The influences of emotion on learning and memory. *Frontiers in Psychology, 8*. https://doi.org/10.3389/fpsyg.2017.01454.

Vazquez, J. J., & Chiang, E. P. (2014). A picture is worth a thousand words (at least): The effective use of visuals in the economics classroom. *International Review of Economics Education, 17*, 109–119. https://doi.org/10.1016/j.iree.2014.08.006.

Waters, L., Barsky, A., Ridd, A., & Allen, K. (2014). Contemplative education: A systematic, evidence-based review of the effect of meditation interventions in schools. *Educational Psychology Review, 27*(1), 103–134. https://doi.org/10.1007/s10648-014-9258-2.

Webster, C. A., Russ, L., Vazou, S., Goh, T. L., & Erwin, H. (2015). Integrating movement in academic classrooms: Understanding, applying and advancing the knowledge base. *Obesity Reviews, 16*(8), 691–701. https://doi.org/10.1111/obr.12285.

Winokur, S. (1971). Skinner's theory of behavior an examination of b. f. skinner's contingencies of reinforcement: A theoretical analysis1. *Journal of the Experimental Analysis of Behavior, 15*(2), 253–259. https://doi.org/10.1901/jeab.1971.15-253.

Chapter 15
Brain-Based Learning Method: Opportunities and Challenges

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15.1 Introduction

The human brain is a dynamic and complex organ that is capable of numerous possibilities. One of these possibilities is learning, which is the conscious and unconscious process where new information is acquired or existing information is modified to accommodate the new information (Pool 1997). “Learning is a function of how the brain forms connections between synapses, which is largely a chemical process, where routes through synapses are laid down and then repeated to form stronger connections” (Meyer 2003). We constantly learn from various stimuli around the environment, but the rate of learning has several dynamics that are in play. The exploration of the dynamics of learning is nowhere greater needed than in the field of education. To facilitate efficient learning and thinking in educational settings, it is important to work constantly on improving the existing methods of teaching. Therefore, the current paradigm of brain-based learning to enhance learning capabilities in students is an advantageous move. The brain-based learning wave of teaching methodology which conceptualizes learning as the physical changes that take place in the brain cells following teaching has been around since the eighteenth century (Hartley 1749), but only a handful of teaching professionals side with the argument that the formation of neural connections in the brain facilitates learning (Owens and Tanner 2017). The focus of brain-based learning is to enhance learning by understanding the neural connection between our experience and stimuli to organize the information we perceive and make meaning out of it (Gozuyesil and Dikici 2014; Pool 1997).

Taking a closer look at the neural implicates in the process of learning, the most basic observation is that multiple neural connections are formed when new

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information is integrated with existing knowledge. The chapter helps in understanding learning as a developmental process that is enhanced in a challenging but less threatening environment (Pool 1997). The brain is the storehouse of all this information, and many factors perform a role in the learning process; many types of information are learned in different ways and stored in different locations with different factors contributing to it. Brain-based learning bridges the gap between neuropsychology and education while understanding how we can use our brain best to engage in meaningful learning (Gozuyesil and Dikici 2014). The strength of recall of each memory depends on the strength of the circuit that stores it, and a few of the many factors responsible are discussed below.

15.2 How the Brain Learns

The brain is said to be a natural learning ally – the seat of all human learning. Neurons, which are the nerve cells, handle the mental activity. Each neuron has a tail, called the axon, which is useful for the transmission of electrical and chemical charges to other neurons. Dendrites are small branching structures that act as a receptor of these charges. When dendrites receive a signal from an axis, the process is called an action potential. The more an individual is exposed to repeated stimuli, the stronger will be the formation of the synaptic connection for that particular stimulus. This leads to brain plasticity which focuses on how our brain constantly undergoes changes in synaptic connections, as we form new ones and lose out on those where the connections do not get repeated exposure to the stimuli (Tompkins 2007; Noback et al. 2005).

Learning is lifelong, and as we develop, we require complex sensory experiences when compared to the cortical circuitry we were born with (McGraw et al. 2009). Facilitating learning requires neuron growth and forming neural connections, nourishment, and synaptic growth to perceive and make sense of our experiences (Caine and Caine 1990). It is genetically programmed to facilitate learning which is seen via the various functions that it performs. The extent to which we learn something depends on the strength of that neural connection of a particular circuit that holds that information. The strength of the neural connection, in turn, depends on the number of times we perform a task that uses that circuit. This concept can be made clear with the analogy of a grass road, which, when frequently walked upon, becomes more distinguished than the one that is not walked on very often. Similarly, our commute to a familiar destination is almost effortless, whereas going to a new location puts a strain on our cognitive abilities. These examples suggest that repeated firing of neurons enhances the quality of neural connections (Bliss and Cooke 2011); the repeated firing of a particular pathway can make the postsynaptic neuron more sensitive to receiving and acting on incoming neural impulses. This process that is called the *long-term potentiation* is in a way made possible because the brain's reward pathway reinforces the firing patterns that lead to successful outcomes (Bliss and Cooke 2011; McGraw et al. 2009).

The book by McTighe and Willis (2019) also spoke about brain neuroplasticity which allows new neural connections to be made and old ones to be strengthened when engaging in a task; “The networks that fire together, wire together” – this refers to the neuroplastic response where usage of a circuit strengthens it. Plasticity is important to learn many skills, and this ability is present mostly during our childhood where we are naturally capable of learning almost anything. However, trying to extend the rate of plasticity present during childhood into adulthood will have its own consequences. These consequences are discussed by experts, and some of them are that the changes made due to plasticity in adults will not be solidified due to constant remodelling and the high metabolic requirements of the brain will not be met due to the demands of constant plasticity.

McTighe and Willis (2019) also suggest that the brain learns best in the forms of patterns; the brain employs different memory pathways from different storage areas while learning to better aid in the storage of information process. The performance of one task stimulates different regions of the brain responsible for memory, hence proving that stimulating different senses while doing something will increase the chances of successful recall in the future (McTighe and Willis 2019). The article by Ford (2011) suggests that the brain is usually more attentive to new and different stimuli. Therefore, when there’s new information presented to the brain, it goes into overdrive, trying to understand the discrepancy with the old information that is already present – if the new information contradicts the old one, it becomes a memory; otherwise, it is discarded as redundant information. The abovementioned literature can help to formulate techniques of teaching in educational settings that are grounded in the brain-based learning paradigm.

The model of a brain-based learning perspective has given a platform to explore different techniques that can be applied in the classroom to facilitate learning among students. Some of them include the following.

15.3 Physical Environment and Movement

Infants are encouraged to be provided with stimulating environments when they begin to explore their surroundings with their primary caregiver as the center of the field. This is said to facilitate their autonomy and, in the process, introduce them to different objects. This variety of stimulation that is introduced to babies is said to form new connections in the brain. This pattern can be observed throughout the human lifespan because our brain is capable of neuroplasticity, i.e., the ability to form new connections in response to something. Therefore, students also are bound to benefit from environments that stimulate various senses. The brain actively forms and reworks neural connections when new information is provided. The stimulation of various senses during this process leads to the strengthening of these connections and leads to multiple connections being formed from the single circuit that is primarily activated while processing a particular stimulus. Information is known to be stored in different parts of the brain – thus speaks the multi-modal model of memory, and different circuits are activated while trying to reach the information that is stored in these regions. This diverse activation that is facilitated by providing different stimuli like auditory and visual cues like colorful images, music, videos, and other different objects that could be found in a new environment outside the classroom will enhance the quality of connections that are formed, making retrieval much more efficient. The way an individual thinks and learns is a reflection of their process of memory, involving processing, revising, recalling, and retaining new information, and showcases one's learning preferences (Al Ghraibeh 2012). Gardner's theory of multiple intelligences (1983, 1998) – verbal-linguistic, logical-mathematical, spatial, bodily kinesthetic, musical, naturalistic, interpersonal, intra-personal, and existential – is another such example of brain-based learning which can be observed in a classroom setting. It is not necessary to use all nine multiple intelligence for a single class but spread out over the course so that it caters to the varied individual needs of the learners (Connell 2009). Brain-based learning is based on learning through experiential practices as the brain forms neural connections to create the meaning of a particular stimulus. This, in turn, helps in internalizing and individualizing the experience, therefore emphasizing the learning preferences of the students and the need to fulfill one's own purpose and search for meaning. It emphasizes the guided experiences approach by Caine et al. (2009) which moves away from the traditional style of learning of direct transmission of information where it flows from the one who knows the information (teacher) to the one who does not (learner). It prioritizes the learner's ability to process their experience (Degen 2014; Ozden and Gultekin 2008).

Our brain is constantly looking for stimuli that are different from the present stimulus under focus, making it seem almost fickle in the process. This brings to mind a rhetorical question: how is it that we can notice the most peculiar stimuli and that which does not fit into the situation more than the mundane and abundantly found stimulus around us? Incorporating classroom activities that cater to one's learning preferences helps in encouraging and improving the learning environment by eliminating persistent fear or anxiety in a classroom setting (Ozden and Gultekin 2008). This helps in immersing in an environment where students gain skills during the process which has been categorized into three phases: orchestrated immersion, relaxed alertness, and active processing (Gozuyesil and Dikici 2014; Caine and Caine 2002 as cited in Ozden and Gultekin 2008). Orchestrated immersion aims to help the learner understand the wholeness of a subject in a meaningful way using their sense organs. This will increase the likelihood of retention as well since the learner not only forms association but also undergoes the experiences personally to make these associations stronger. The relaxed alertness phase plays a role in creating a challenging but a secure learning environment for the learners. Learning happens easily and positively in an environment where the learner can perceive the setting as a minimal threat and hence the brain can be relaxed and open to new challenges unlike in a highly stressful environment, where learning gets suppressed due to perceived high threat. Csikszentmihalyi (1991) as cited in Degen (2014) explains the need for brain-based learning in creating an optimal learning experience where learners develop new skills in a challenging yet relaxed environment. If the environment is not challenging enough, it then leads to a lack of interest. If the environment is stressful, it leads to feeling anxious and stressed where the learner feels threatened due to various reasons like intimidation, fear of rejection, time constraints, and perceived lack of options, and hence there is a decline in performance. In such a situation, the brain focuses on selective attention. It causes a chain of action where the frontal lobe monitors the event and the amygdala sends a message to the hypothalamus which leads to secretions of cortisols and noradrenaline to prepare for the threatening situation. While this can be helpful for a short period, high levels of cortisol for a prolonged period can hamper memory, learning, and even our neurons. Obtaining the optimal level using brain-based learning serves as a tool for academic achievement. Taking a look at how this action affects learners, it can be observed that unrealistic and unhealthy expectations like a time limit on learning and unhealthy competition among peers are imposed in a traditional style of teaching, which causes distress (Degen 2014). Active processing is a continuous phase where the brain keeps making associations and evaluating the context to ensure that new stimuli can be incorporated into past experiences if relevant to the learner (Gozuyesil and Dikici 2014; Ozden and Gultekin 2008).

Applying this into context, it is advisable for teachers to incorporate and engage sensory organs in learning as well to help learners receive, process, and use meaningful information. Engaging sensory organs for brain-based learning allows perceiving different sensory cues for learning, thereby focusing on the individual needs of the learners. This helps in allowing the setting to be perceived as less threatening and increasing inclusion (Mahdjoubi and Akplotsyi 2012; Knowles-Yanez 2005). Teachers can use multisensory modalities and an active learning strategy to encourage brain-based learning by stimulating students' different senses. To stimulate visual learners, models, demonstrations, provide color in their setting, and incorporate drawing diagrams (Lujan and DiCarlo 2006). Auditory stimulation can be achieved through discussions, collaborative learning, debates, and public speaking, interactive games, answering questions, videos, and making students create songs out of learning material. A study has shown the importance of olfactory senses in encouraging memory as well. Certain aromas and smell help in recalling incidences from memory (Wilmes et al. 2008). For tactile learners, making models, handling objects related to the subject, etc. are beneficial (Lujan and DiCarlo 2006). Another method to enhance the connections made in the classroom is to link the current topic to previous knowledge. When students are made to recall what they have already learned in the context of the current topic, it is like stimulating experience for the student. They will feel more motivated to present in the discussion as they have perceived the relevance of the topic. When existing knowledge is recalled and connected with the current context, the particular neural circuit that is activated is modified to incorporate the new information alongside that circuit by forming new connections. This strengthens the older circuit and makes for better associations to be made in the brain, making recall easier in the process.

The incorporation of physical exercise or movement in the learning setting of a "classroom" is vital to boost cognitive functioning among students. A classroom can be wherever the learning occurs, and this "classroom" can be set up outside the typical environment of a closed room of four walls. This setting, which was practiced mostly in the Gurukul system in India, is optimum to ensure that learners get good ventilation, can move around, and even engage in role-playing, other forms of movement like dancing, and flashcards, which would help them to associate and apply theoretical knowledge (Lujan and DiCarlo 2006). Physical exercise is known to encourage neuroplasticity by triggering a chain of chemical and molecular mechanisms that we know to be responsible for learning to occur (Adcock et al. 2020; Thomas et al. 2012; Voss et al. 2011). The connection between the body and brain helps to elucidate the importance of physical movement – as muscles are controlled by the central nervous system, the feedback from these structures outside the brain like the muscles and sensory organs encourages brain activity in return (Lista and Sorrentino 2010). Just like a batsman who moves around on the pitch to increase concentration, students should be encouraged to engage in physical activities often to enhance focus and to be able to concentrate better. The importance of movement, in general, should also be implemented by the teacher, not because of implied personal benefits to the teacher, but to the students. Our brain is naturally able to attend to stimuli that are moving than to those that are static; therefore, when teachers move around, students may be able to focus better on what is being instructed in class because their brains are made to attend to the teacher because of his or her timed movement. This application can be understood when thinking of a task where a blank screen is presented to a participant and consequently the slightest hint of any marker on the screen is noticed by the participant.

While there is no dominant learning style or sensory organs, brain-based learning focuses on engaging multiple senses at the same time for a holistic understanding of the stimuli. A child who explores an object for the first time would repeatedly view the object from different angles and would engage in a tactile exploration of the object like feeling the texture of the object using their hands or putting it in their mouth. Based on the object, the child could also engage their auditory or olfactory senses. This shows a culmination of sensory organs being used by the child leading to experiential learning. The child is more likely to remember this incident than another incident where he was just instructed (auditory) about the same object without any visuals as only one modality of the sensory organ was engaged (McGraw et al. 2009).

15.4 Emotion and Learning

The positive or negative emotional connection that we make with our environment plays a significant role in brain-based learning. When we attach an emotion to a situation, we form a meaningful association that is stored in our brain. Depending on how strong this emotional connection is, it becomes easier to recall and retrieve the memory (Kaufman et al. 2008). Learning is also related to the emotional safety we receive in a setting. If the brain perceives an environment with a potential threat, logical thinking gets inhibited, which shuts down the hypothalamus, and the pituitary gland gets activated which releases adrenaline for a fight and flight response. This change then does not become conducive to an experiential learning process (Tompkins 2007; Noback et al. 2005).

The amygdala is perhaps the most well-known limbic area that is associated with emotions. However, this fame is well-earned by that brain region because its implication has been observed while applying the theory that began the wave of research in the area of learning, the classical conditioning theory. To be more specific, the amygdala's importance in memory and learning has been brought out through research on the conditioned fear response. The associations between the unconditioned and conditioned stimuli that are formed in the brain are explained through the involvement of the different nuclei that are present in the amygdala (Carrere and Alexandre 2015). Our learning ability gets influenced by emotions attached to particular stimuli. Emotions are interspersed with every instance of our life, and it may be difficult to recall any memory that is devoid of emotion because our brain is constantly making a neural connection between emotions and intellect (Connell 2009). Information that reaches the brain is integrated with emotions that are experienced at that moment, thanks to the amygdala which interacts with various cortical and limbic regions (Carrere and Alexandre 2015).

The study of the influence that emotions have on memory processes, learning in particular, is widely undertaken. The need for emotions to be considered in a learning setting is displayed by providing modern context through the study by Shen and associates (2009) where an affective e-Learning model was developed which provided customized learning material to students according to their emotional states. The study reported findings that showed a 91% increase in the performance of those interacting with the emotion-aware system than those who were not. These results were obtained in real-time settings greatly encouraging the inclusion of emotional information in learning settings. It is largely believed that positive emotions have a better impact on learning and various cognitive processes like information processing and problem-solving (Um et al. 2012). It is important to inculcate positive emotions during the learning process since negative emotions like previously mentioned can reduce relaxed alertness and lead to downshifting (Caine and Caine 1994; Hart 1983). It leads to an activation of a fight or flight response when the learner perceives a threat in the learning environment, for instance, students are asked to respond or participate without their will, etc. Thus, it becomes beneficial if the teacher establishes a positive environment and connection with the students before removing them from their comfort zone (Kaufman et al. 2008).

Emotions need to be accounted for in a classroom where a student's brain-based emotional system can be tapped in a stimulating and respectful manner (Connell 2009). Learners can experience positive and negative emotions while exploring and seeking knowledge (Kaufman et al. 2008). The dynamic relationship between emotion and learning is described in terms of attentional and motivational components (Tyng et al. 2017). Its implication here can be understood by reporting that emotionally salient information enhances our memory functions due to selective attention; the amygdala is observed to be providing top-down signals that place special "emotion attention" for emotional information (Vuilleumier 2005). Our emotional system allows us to understand how much importance needs to be given to remembering any kind of information (Connell 2009). The other brain regions that make this form of top-down attentional processing possible are the ventromedial prefrontal cortex, the superior temporal sulcus, and the primary visual cortex (Tyng et al. 2017). Emotional processing is known to consume a lot of attentional resources. This can be supported by evidence which attributes the negative effect of expressive suppression, an emotion-regulation strategy, to the exhaustion of the finite cognitive resources that we possess at a given time (Gross 2001; Liu et al. 2015; Richards 2004; Richards and Gross 2000). Therefore, improper emotion management in situations such as a classroom setting, which requires a considerable amount of cognitive resources to maintain concentration and adequately process information, could lead to inefficient learning. The overactivity of the *hypothalamic-pituitary-adrenal* (HPA) axis due to stress can impair synaptic plasticity and learning ability, although stress affects learning based on its intensity and duration (Joëls et al. 2004). Therefore, alleviating stress in the classroom through humor is a good way for teachers to help students maintain focus in class. This helps to deal with the various attentional and motivational components that are active during learning. Humor reduces stress and enhances attention and motivation among students (Capps 2006; Lei et al. 2005). Incorporating humor in class through funny anecdotes and cartoons will aid the memory of the students as it will provide to be something out of the ordinary and leaves a lasting impact, especially in alerting to new and unique stimuli.

15.5 Incorporating Problem-Solving

The brain also grows by constantly solving problems that are presented to it. By presenting real-world problems to students, they are given a platform to apply theory into practice. Problem-solving is a higher-order function among the executive functions that we perform, and the brain area responsible for this is the prefrontal cortex which is still developing amid adolescents (Arain et al. 2013; Mushiake et al. 2009). Experiences in different stages of our lives may have the highest influence on the development of the prefrontal cortex (Kolb et al. 2012) because the prefrontal cortex shows the slowest rate of synaptic pruning (Eiston et al. 2009). This form of neural plasticity that is displayed by the prefrontal cortex is encouraging research to study the various dynamics of prefrontal cortex development. In a study that corresponds with this notion, middle adolescents showed a consistent pattern of activating relevant prefrontal areas like the lateral prefrontal cortex, the right dorsolateral prefrontal cortex, and the left inferior frontal gyrus during successful creative problem-solving exercises (Kleibeuker et al. 2013). These patterns of activation were suggestive of performance that paralleled those with high divergent thinking capacities.

By encouraging students to indulge in problem-solving, the brain areas are in turn activated, and the neural connections that are formed during this period are reinforced and strengthened by this activity (Kolb et al. 2012). The study by Chan and Fong (2011) produced results that are supportive of the employment of problem-skills training to enhance the daily functioning of children with acquired brain injury (ABI). The study incorporated various themes of problem-solving like paying attention, remembering and organizing, defining the problem, gathering information and goal setting, planning, representing the problem, and monitoring. Open-ended questions, projects, and experiments that require students to think in real time are sure to stimulate the prefrontal cortex in the brain. Incorporating problem-solving exercises is not only advantageous in the classroom, but a collaborative problem-solving approach which requires the parents and their children to work together improves the children's executive functioning and parents' empathy (Heath et al. 2020).

Brain-based learning is a shift in paradigm where the strategies are derived from an understanding of the brain; this stipulates that the brain is meant for survival and it learns best in the ideal conducive environment (Jensen 2008). Students are capable of complex thought processes, and allowing them to explore their choices and voice their opinions in the presence of an adult who moderates the session will increase their sense of autonomy (Boud 2012). When students are given the provision of choice in their curriculum, they are reported to have greater intrinsic motivation (Evans and Boucher 2015). The relevance of choice to the current topic is that choice among students was also reported to enhance task motivation and performance (Patall et al. 2008). A review paper by Murayama et al. (2016) elucidates that the ventromedial prefrontal cortex and striatum display changes in activation when people are indulged in choice-based experiments.

15.6 Unconscious Learning

Learning is as much an outcome of the unconscious as is conscious processing. Unconscious processing includes forming associations and activating associative memory networks while incorporating personal beliefs and motives (as cited in Kuldas et al. 2013). Unconscious processing is triggered sooner in cases of an emotional stimulus (Bargh and Morsella 2008). The knowledge acquisition processes that involve integrating both conscious and unconscious processes in acquiring information, retrieving memories, forming connections between current and older information, retaining them, and using them in the future are said to be influenced by emotional/motivational processes (Kuldas et al. 2013). To deal with this, they predict that an educational program may require that its students become constant conscious learners. But as conscious learning cannot occur all the time, it is suggested that unconscious learning processing be encouraged to take the load off.

The article by Kuldas et al. (2013) elaborates on the various dynamics of unconscious learning and encourages the exploration of unconscious learning processes to understand how students form mental representations of learning material. The role of associative memory is highlighted in the information-processing stages. According to them, unconscious activation of these memory networks produces an emotionally valent state that facilitates learning. However, this result can vary depending on the intensity of the emotional state elicited. Learning is said to occur in the presence of positive emotional states like curiosity, and it can be inhibited by negative emotional states like anxiety. It is reported that the unconscious activation of associate networks results in implicit learning due to a process which is called unconscious spreading activation (Ratcliff and McKoon 1981). The implicit learning helps people cope with many of their presenting problems because they unconsciously allow them to grasp the complexities of the learning tasks (Lewicki et al. 1992). This is backed by supportive notions that state that indulging in social interactions, learning the native language, and also engaging in problem-solving sometimes require unconscious learning (Sweller and Sweller 2006).

Unconscious processing is seen as an aid to lessen the burden that is placed on the conscious learning processes. The associative networks that are in play by unconscious processes make it possible for mental representations to occur in the absence of conscious interference (Cohen et al. 1996). The imagery style of learning, which is a form of mental representation, helps to assimilate the use of verbal and visual information in terms of maps, charts, diagrams, pictures with texts, and computer-based instructions. This form of integration can facilitate the formation of unconscious representation which will accelerate the rate of learning, provided that the pictorial concepts are coherent with the contextual meaning (Paivio 2007). Suitable illustrations of concepts help students to visualize the conceptual matter. Students will be quick to grasp relevant information while being presented with these visual illustrations because unconscious mental representations can decrease the conscious effort that is required to integrate visual and verbal information (Lewicki et al. 1992). Thus, presenting familiar information that will help them employ the association networks employed by unconscious processing will help them rehearse and retain the concept even better. In this way, the methods advised to adopt the paradigm of brain-based learning seem to be tied together.

15.7 Conclusion

Various studies as cited in Gozuyesil and Dikici (2014) have shown a robust relationship between brain-based learning and academic accomplishment when compared to the traditional style of teaching. It also encourages relaxed alertness, a concept mentioned by Caine and Caine (1994) which promotes a better learning environment for learners. They become aware of their preferences and relate to the content easily as they feel confident and relaxed in that environment. This leads to improving self-concept, increasing motivation, and creating a positive mood for better learning (Bandura 1997; Goleman 1995 as cited in Duman 2010). While there are a lot of controversies on learning styles, learning preferences that come under brain-based learning have been widely looked into the field of education and psychology. It is beneficial to use techniques that are compatible with the individual needs of the learners and focuses on an integrated learning-teaching model (Duman 2010).

References

Adcock, M., Fankhauser, M., Post, J., Lutz, K., Zizlsperger, L., Luft, A. R., Guimaraes, V., Schattin, A., de Bruin, E. D., & de Bruin, E. D. (2020). Effects of an in-home multicomponent exergame training on physical functions, cognition, and brain volume of older adults: A randomized controlled trial. *Frontiers in Medicine*, *6*. https://doi.org/10.3389/fmed.2019.00321.

Al Ghraibeh, A. M. (2012). Brain based learning and its relation with multiple intelligence. *International Journal of Psychological Studies, 4*(1), 103.

Arain, M., Haque, M., Johal, L., Mathur, P., Nel, W., Rais, A., Ranbir, S., & Sharma, S. (2013). Maturation of the adolescent brain. *Neuropsychiatric Disease and Treatment, 9*, 449–461. https://doi.org/10.2147/NDT.S39776.

Bandura, A. (1997). The anatomy of stages of change. *American Journal of Health Promotion: AJHP, 12*(1), 8–10.

Bargh, J. A., & Morsella, E. (2008). The unconscious mind. *Perspectives on Psychological Science, 3*(1), 73–79. https://doi.org/10.1111/j.1745-6916.2008.00064.x.

Bliss, T. V. P., & Cooke, S. F. (2011). Long-term potentiation and long-term depression: A clinical perspective. *Clinics, 66*(SUPPL.1), 3–17. https://doi.org/10.1590/S1807-59322011001300002.

Boud, D. (Ed.). (2012). *Developing student autonomy in learning*. Routledge.

Caine, R. N., & Caine, G. (1990). Understanding a brain-based approach to learning and teaching. *Educational Leadership, 48*(2), 66–70.

Caine, G., & Caine, R. (1994). *Making connections: Teaching and the human brain*. New York: Addison Wesley.

Caine, R. N., Caine, G., McClintic, C., & Klimek, K. J. (2009). *12 brain/mind learning principles in action: Developing executive functions of the human brain*. Corwin Press.

Capps, D. (2006). The psychological benefits of humor. *Pastoral Psychology, 54*(5), 393–411. https://doi.org/10.1007/s11089-005-0007-9.

Carrere, M., & Alexandre, F. (2015). A pavlovian model of the amygdala and its influence within the medial temporal lobe. *Frontiers in Systems Neuroscience*, *9*(MAR). https://doi.org/10.3389/fnsys.2015.00041.

Chan, D. Y. K., & Fong, K. N. K. (2011). The effects of problem-solving skills training based on metacognitive principles for children with acquired brain injury attending mainstream schools: A controlled clinical trial. *Disability and Rehabilitation, 33*(21–22), 2023–2032. https://doi.org/10.3109/09638288.2011.556207.

Cohen, M. S., Kosslyn, S. M., Breiter, H. C., Digirolamo, G. J., Thompson, W. L., Anderson, A. K., Bookheimer, S. Y., Rosen, B. R., & Belliveau, J. W. (1996). Changes in cortical activity during mental rotation: A mapping study using functional MRI. *Brain, 119*(1), 89–100. https://doi.org/10.1093/brain/119.1.89.

Connell, J. D. (2009). The global aspects of brain-based learning. *Educational Horizons, 88*(1), 28–39.

Csikszentmihalyi, M. (1991). *Thoughts about education. Creating the future: Perspectives on educational change*, 83–86.

Degen, R. (2014). Brain-based learning: The neurological findings about the human brain that every teacher should know to be effective. *Amity Global Business Review, 9*(1), 15–23.

Duman, B. (2010). The effects of brain-based learning on the academic achievement of students with different learning styles. *Educational Sciences: Theory and Practice, 10*(4), 2077–2103.

Eiston, G. N., Oga, T., & Fujita, I. (2009). Spinogenesis and pruning scales across functional hierarchies. *Journal of Neuroscience, 29*(10), 3271–3275. https://doi.org/10.1523/JNEUROSCI.5216-08.2009.

Evans, M., & Boucher, A. R. (2015). Optimizing the power of choice: Supporting student autonomy to foster motivation and engagement in learning. *Mind, Brain, and Education, 9*(2), 87–91. https://doi.org/10.1111/mbe.12073.

Gardner, H. (1983). *The theory of multiple intelligences*. London: Heinemann.

Gardner, H. (1998). A multiplicity of intelligences. *Scientific American, 9*(4), 19–23.

Gross, J. J. (2001). Emotion regulation in adulthood: Timing is everything. *Current Directions in Psychological Science, 10*(6), 214–219. https://doi.org/10.1111/1467-8721.00152.

Gozuyesil, E., & Dikici, A. (2014). The effect of brain based learning on academic achievement: A meta-analytical study. *Educational Sciences: Theory and Practice, 14*(2), 642–648.

Hart, L. A. (1983). Programs, patterns and downshifting in learning to read. *The Reading Teacher, 37*(1), 5–11.

Heath, G. H., Fife-Schaw, C., Wang, L., Eddy, C. J., Hone, M. J. G., & Pollastri, A. R. (2020). Collaborative problem solving reduces children's emotional and behavioral difficulties and parenting stress: Two key mechanisms. *Journal of Clinical Psychology, 76*(7), 1226–1240. https://doi.org/10.1002/jclp.22946.

Jensen, E. P. (2008). A fresh look at brain-based education. *Phi Delta Kappan, 89*(6), 408–417.

Joëls, M., Karst, H., Alfarez, D., Heine, V. M., Qin, Y., Van Riel, E., Verkuyl, M., Lucassen, P. J., & Krugers, H. J. (2004). Effects of chronic stress on structure and cell function in rat hippocampus and hypothalamus. *Stress, 7*(4), 221–231. https://doi.org/10.1080/10253890500070005.

Kaufman, E. K., Robinson, J. S., Bellah, K. A., Akers, C., Haase-Wittler, P., & Martindale, L. (2008). Engaging students with brain-based learning. *ACTE online*. Retrieved September, 2, 2011.

Kleibeuker, S. W., Koolschijn, P. C. M. P., Jolles, D. D., Schel, M. A., De Dreu, C. K. W., & Crone, E. A. (2013). Prefrontal cortex involvement in creative problem solving in middle adolescence and adulthood. *Developmental Cognitive Neuroscience, 5*, 197–206. https://doi.org/10.1016/j.dcn.2013.03.003.

Knowles-Yánez, K. L. (2005). Children's participation in planning processes. *Journal of Planning Literature, 20*(1), 3–14.

Kolb, B., Mychasiuk, R., Muhammad, A., Li, Y., Frost, D. O., & Gibb, R. (2012). Experience and the developing prefrontal cortex. *Proceedings of the National Academy of Sciences of the United States of America, 109*(SUPPL.2), 17186–17196. https://doi.org/10.1073/pnas.1121251109.

Kuldas, S., Ismail, H. N., Hashim, S., & Bakar, Z. A. (2013). Unconscious learning processes: Mental integration of verbal and pictorial instructional materials. *Springerplus, 2*, 1–14. https://doi.org/10.1186/2193-1801-2-105.

Lei, S. A., Cohen, J. L., & Russler, K. M. (2005). Humor on learning in the college classroom. *Journal of Instructional Psychology, 37*(4), 326–332. Retrieved from http://simple.onmason.com.

Lewicki, P., Hill, T., & Czyzewska, M. (1992). Nonconscious acquisition of information. *American Psychologist, 47*(6), 796–801. https://doi.org/10.1037/0003-066X.47.6.796.

Lista, I., & Sorrentino, G. (2010, May 30). Biological mechanisms of physical activity in preventing cognitive decline. *Cellular and Molecular Neurobiology, 30*, 493–503. https://doi.org/10.1007/s10571-009-9488-x.

Liu, F., Cui, L., & Zhang, Q. (2015). The influences of reappraisal and suppression instructions on memory for neutral words in negative background. *Neuroreport, 26*(17), 1023–1031. https://doi.org/10.1097/WNR.0000000000000462.

Lujan, H. L., & DiCarlo, S. E. (2006). First-year medical students prefer multiple learning styles. *Advances in Physiology Education*, *30*, 13–16.

Mahdjoubi, L., & Akplotsyi, R. (2012). The impact of sensory learning modalities on children's sensitivity to sensory cues in the perception of their school environment. *Journal of Environmental Psychology, 32*(3), 208–215.

McGraw, P. V., Webb, B. S., & Moore, D. R. (2009). Introduction. In: *Sensory learning: From neural mechanisms to rehabilitation*. London: Royal Society.

McTighe, J., & Willis, J. (2019). *Upgrade your teaching: Understanding by design meets neuroscience*. ASCD.

Meyer, K. A. (2003). The implications of brain research for distance education. *Online Journal of Distance Learning Administration, 6*(3).

Murayama, K., Izuma, K., Aoki, R., & Matsumoto, K. (2016). Your choice motivates you in the brain: The emergence of autonomy neuroscience. *Advances in Motivation and Achievement, 19*, 95–125. https://doi.org/10.1108/S0749-742320160000019004.

Mushiake, H., Sakamoto, K., Saito, N., Inui, T., Aihara, K., & Tanji, J. (2009). Involvement of the prefrontal cortex in problem solving. *International Review of Neurobiology, 85*, 1–11. https://doi.org/10.1016/S0074-7742(09)85001-0.

Noback, C. R., Ruggiero, D. A., Demarest, R. J., & Strominger, N. L. (Eds.). (2005). *THE human nervous system: structure and function* (No. 744). New York: Springer Science & Business Media.

Owens, M. T., & Tanner, K. D. (2017, June 1). Teaching as brain changing: Exploring connections between neuroscience and innovative teaching. *CBE Life Sciences Education, 16*, 1–9. https://doi.org/10.1187/cbe.17-01-0005.

Ozden, M., & Gultekin, M. (2008). The effects of brain-based learning on academic achievement and retention of knowledge in science course. *The Electronic Journal for Research in Science & Mathematics Education.*

Paivio, A. (2007). *Mind and Its Evolution: A Dual Coding Theory Approach*. Mahwah, NJ: Lawrence Erlabaum Associates.

Patall, E. A., Cooper, H., & Robinson, J. C. (2008). The effects of choice on intrinsic motivation and related outcomes: A meta-analysis of research findings. *Psychological Bulletin, 134*(2), 270–300. https://doi.org/10.1037/0033-2909.134.2.270.

Pool, C. R. (1997). Brain-based learning and students. *The Education Digest, 63*(3), 10.

Ratcliff, R., & McKoon, G. (1981). Does activation really spread? *Psychological Review, 88*(5), 454–462. https://doi.org/10.1037/0033-295X.88.5.454.

Richards, J. M. (2004). The cognitive consequences of concealing feelings. *Current Directions in Psychological Science, 13*(4), 131–134. https://doi.org/10.1111/j.0963-7214.2004.00291.x.

Richards, J. M., & Gross, J. J. (2000). Emotion regulation and memory: The cognitive costs of keeping one's cool. *Journal of Personality and Social Psychology, 79*(3), 410–424. Retrieved from http://psycnet.apa.org/fulltext/2000-05317-008.pdf.

Shen, L., Wang, M., & Shen, R. (2009). Affective e-learning: Using "motional" data to improve learning in pervasive learning environment. *Educational Technology and Society, 12*(2), 176–189.

Sweller, J., & Sweller, S. (2006). Natural information processing systems. *Evolutionary Psychology, 4*(1), 147470490600400. https://doi.org/10.1177/147470490600400135.

Thomas, A. G., Dennis, A., Bandettini, P. A., & Johansen-Berg, H. (2012, March 23). The effects of aerobic activity on brain structure. *Frontiers in Psychology, 3*, 86. https://doi.org/10.3389/fpsyg.2012.00086.

Tompkins, A. W. (2007). *Brain-based learning theory: An online course design model*. Lynchburg: Liberty University.

Tyng, C. M., Amin, H. U., Saad, M. N. M., & Malik, A. S. (2017). The influences of emotion on learning and memory. *Frontiers in Psychology, 8*(August). https://doi.org/10.3389/fpsyg.2017.01454.

Um, E. R., Plass, J. L., Hayward, E. O., & Homer, B. D. (2012). Emotional design in multimedia learning. *Journal of Educational Psychology, 104*(2), 485–498. https://doi.org/10.1037/a0026609.

Voss, M. W., Nagamatsu, L. S., Liu-Ambrose, T., & Kramer, A. F. (2011). Exercise, brain, and cognition across the life span. *Journal of Applied Physiology, 111*, 1505–1513. https://doi.org/10.1152/japplphysiol.00210.2011.

Vuilleumier, P. (2005). How brains beware: Neural mechanisms of emotional attention. *Trends in Cognitive Sciences, 9*(12), 585–594. https://doi.org/10.1016/j.tics.2005.10.011.

Wilmes, B., Harrington, L., Kohler-Evans, P., & Sumpter, D. (2008). Coming to our senses: Incorporating brain research findings into classroom instruction. *Education-Indianapolis Then Chula Vista, 128*(4), 659.

Chapter 16
Brain-Based Teaching: A Tangible Burgeoning Technique in Our Present Educational Scenario

M. Raghavendran and A. Jahitha Begum

16.1 Introduction

Teachers and educationalists of this information age are facing several multifarious hitches nowadays in their profession. Every teacher is supposed to discern exactly the mechanism of learning that takes place in the brain. This knowledge helps their students to maximize the learning. An acquaintance of the knowledge of the way our brain learns naturally is a decisive feature for the realization of the education fraternity (Sousa 2011a, b). Teaching constructed on the principles of brain-based learning (BBL) can be a useful technique to know the pattern of learning (Tokuhama-Espinosa 2011; Kaufman et al. 2008).

16.1.1 BBT Modus Operandi

BBT is proper and the most operative tactic of the brain's knowledge contrivance (Jensen 2005a, b). It follows the pattern which goes matching to the original way of the brain's absorbing mechanism. The main focal points of BBT are appreciation of human brain, its encryptions, creating learning significant, comprehensive and changing teaching techniques which suits the natural absorbing codes of the brain (Jensen 2006). It is an encouraging, helpful manner to get the most out of teaching and learning. It is grounded on the theory that suits the best way our brain learns (Sousa 2015).

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Hileman (2006) provided us with a wonderful explanation of B-R-A-I-N B-A-S-E-D teaching and its implications as follows:

"B	for	Brain Timer" – Preserve tempo by sporadic structural and rhetorical tasks
"R	for	Recurrence" – Use showing and revising schemes
"A	for	Active Education" – Increasing bodily effort
"I	for	Imageries" – Deepen the pictorial education setting
"N	for	Newness" – Arouse the intellect with novel strategies
"B	for	Be Flamboyant (color)" – Enable mental recognition and inclination
"A	for	Automatic Erudition" – Encouragement of pictorial statement
"S	for	Shared Brain" – Activities for symbiotic learning
"E	for	Elicit Excitements" – Occasions for passionate commitment
"D	for	Developing Thinking Expertise" – Involve students in investigative activities

Caine and Caine (2005) formulated 12 doctrines of BBL as given below:

1. Learning demands bodily functioning.
2. The human brain is group-oriented.
3. Meaning-seeking is a natural and inborn characteristic.
4. Meaning-making is done through patterns.
5. Emotions are base for meaning-making through patterning.
6. The human brain functions instantaneously part and whole.
7. All learning comprises attentive responsiveness and peripheral insight.
8. Both conscious and unconscious efforts make learning meaningful.
9. Spatial memory and rote memory are the kinds of memory organization.
10. Learning is progressive in manner.
11. Composite learning is boosted by challenge and repressed by intimidation.
12. The brain is distinctive.

16.1.2 Need for BBT

One of the main questions from today's teachers and educators is as each education is based on accomplishments in the brain, why should a teacher possess the knowledge of BBT? BBT explains the functions of brain pertaining to learning superlatively and rationally and one can escalate the learning to the core level (Grover 2015). For the past two decades, neuroscientists keep researching the brain and its system through researches using magnetic resonance images, electroencephalograms, positron emission testing, and computer axial tomography scans, and it's obvious that BBT is having shreds of evidence of playing role in maximizing the learning of students. Numerous studies steered using BBT approach with English

Teaching (Bayindir 2003), knowledge progression and pedagogy (Serap Tufekcil & Demirel 2009), Spiritual instruction (White 2004), Science Teaching (Schiller 2003), Social Studies (Duman 2006), Philosophical Perspectives (Serap Tufekcil & Demirel 2009), and Mathematics in Complex Schooling (Rehman 2011) and found to be effective.

Some researchers like Cengelci (2005) in Social Studies, Wortock (2002) in Science courses, Ozden and Gultekin (2008) in Science Education, Serap Tufekcil and Demirel (2009) in Science, Duman (2006) in Social Studies, Aydin and Yel (2011) in Biology education, Akyurek and Afacan (2013) in Science, Haghighi (2013) in English as an Alien language, Rehman (2011) in Mathematics, Phangwan et al. (2015) in Animation, Bonomo (2017) in Reading Habit, and Morgan and Fonseca (2004) and Gozuyesil and Dikicl (2014) in Academic Achievement have done researches in their corresponding variables and found the BBT as very effective method.

Researches across the globe had been conducted by various researchers on BBT approach with many schools and college-level educational subjects and psychological subjects, but no such studies are realized in mathematics. There are a few kinds of research available at school education. School math is basic for further edification and future life. Hence, the investigators intended to examine the effectiveness of embracing BBT procedures in uplifting the MPSA.

16.2 Purpose of the Study

The purpose of this study is to determine the effects of the BBT approach and its role in augmenting the MPSA among 8th grade pupils, and to examine if any noteworthy difference comparing to Orthodox teaching tactics and its effects on MPSA.

16.2.1 Investigation

Subsequent is the inquiry of this current study:

1. Is there any relationship existing between BBT and MPSA among 8th grade learners?
2. Does the BBT approach differ from Orthodox teaching techniques on enhancing MPSA?
3. Does the comparison group differ from the treatment group in the MPSA?
4. Does the comparison group vary from the treatment group concerning the BBT?
5. What is the opinion of the low achievers of the comparison group on learning mathematics?
6. What is the opinion of the low achievers of the treatment group on learning mathematics?

7. What is the opinion of the moderate achievers of the comparison group on learning mathematics?
8. What is the opinion of the moderate achievers of the treatment group on learning mathematics?
9. What is the opinion of the high achievers of the comparison group on learning mathematics?
10. What is the opinion of the high achievers of the treatment group on learning mathematics?

16.3 Methods

The investigators adapted the quasi-experimental design in this research. Average scores of students in both the BBT and MPSA concerning the treatment and comparison groups were compared. Mixed methods research – a mixture of both quantitative and qualitative practices of data collection – is used in this study. Mixed methods proved to be effective where complex traits like human behavior are assessed. Quantitative techniques include the careful implementation of the test, collection of data, etc. There is a little place for human bias in quantitative studies as it attempts to study each individual identically. "Mixed methods research is relatively new in the social and human sciences as a distinct research approach, it is useful to convey a basic definition and description of the approach in a method section of a proposal. The rationale for the choice of mixed methods as an approach for the *general level* is because of its strength of drawing on both qualitative and quantitative research and minimizing the limitations of both approaches. At a *practical level*, mixed methods provide a sophisticated, complex approach to research that appeals to those on the forefront of new research procedures. It also can be an ideal approach if the researcher has access to both quantitative and qualitative data" (Creswell 2014). The researchers used Embedded Mixed Methods Design as provided by John Creswell.

Data from the quantitative studies are analyzed directly with available statistics and interpreted. Qualitative studies are having the possibilities of change, probing, and insisting more keen observations on the experimenter part. Qualitative studies are open and responsive to the subjects observed (Best and Kahn 2006; Koul 2014). Both the methods are continuum not mutually exclusive trends. The investigators adopted mixed methods, both quantitative and qualitative techniques, in data gathering and data exploration.

16.3.1 Participants and Pedagogy

The investigators used stratified random sampling to choose the sample from the population in this study. The researchers divided the students as the comparison group and treatment group. Each group was having 30 8th grade students from

Murukkampatti school as the treatment group and Guddapatti school as the comparison group. The same teacher taught both groups. Both groups have the same maturity level, background, age, and training. The investigators compared the academic scores using "t"-test and found the treatment and comparison groups were equivalent on measure. The investigators trifurcated the groups such as low achievers, moderate achievers, and high achievers, and the trifurcation was similarly divided between them. The investigators followed the teaching techniques formulated from the BBL theory to teach the treatment group students and Orthodox (conventional) teaching techniques to teach the comparison group students.

16.3.2 Tools

16.3.2.1 Quantitative Tools

The investigators used the attainment exam in MPSA as one of the tools. It was containing 20 questions, each possessing 2.5 marks with a total of 50 marks. An expert-prepared scoring key was used to value the answer scripts. The efficacy of the assessment was proven using proper scrutiny. As the second tool, a questionnaire of BBT factors, having 50 test questions and apiece item, had one mark for the right answer and zero marks for the wrong answer. It is for the procedure for evaluating positive item and reverse procedure should be adopted for correcting negative questions. The tool consisted of nine sub-domains. It had 18 negative items and 32 positive items. The BBT tool was having nine sub-domains which where recommended by Politano and Paquin (2015), and was authenticated by the subject specialists. The BBT element was arranged by the investigators. The validity of the BBT questionnaire was established by the investigators as 0.72 using Cronbach's alpha.

16.3.2.2 Qualitative Tool

The investigator prepared a case report format and administered it to six participants. Three participants from the comparison group and three from the treatment group were part of the respondents. The three participants of each group were each one from high achievers, moderate achievers, and low achievers at various times of the experimentation. The questions are:

- What is your *opinion* about *mathematics*?
- What is your *opinion* about your *mathematics teacher*?
- How do you feel about your *classroom atmosphere*?
- Tell me about your *relationship with your mathematics teacher*?
- Tell me your *enjoyment* in the *mathematics classroom*?
- How is your *feeling* in the mathematics class *time*?

16.3.3 Treatment Process

The investigators administered a test in MPSA as a pre-test for both the groups. The investigators applied the principles 1, 3, 4, 6, and 12 of brain-based principles devised by Caine and Caine for practicing in the classroom directly during teaching, and the remaining principles 2, 5, 7, 8, 9, 10, and 11 were applied to students by creating an enriched environment in the classroom. The investigator researched for six continuous weeks. The investigator adopted conventional method as a teaching tactic for teaching the students of the comparison group, but for the treatment group, the teaching procedure grounded on the BBL theory was followed.

Some dedicated structures of BBT in the experimentation procedure are as follows:

- Integration of possible lessons
- Provision of rich resource with technological support
- Encouraging individual opinions
- Provision of threat-free situation
- Colorful, attractive class environment
- Significance to music amidst the lesson
- Experiential and activity-oriented learning
- Equal chance for each student for participating in classroom activities
- Cooperative work throughout the class
- The place for students' emotions and feeling
- Real-life content

The researchers ensured brain-based research settings through the following points: creating a zero-threat learning environment, grouping students, incorporating the ideas of each member of groups, using positivity in the classroom, encouraging inquiry, incorporating music in teaching sessions, encouraging physical movements in the classrooms, inter-linking of subjects, immediate and instant feedback by teachers and peer, connecting real-life situations, encouraging creativity, asking suggestions from students at times, etc.

Once the experimentation was completed, both the comparison and treatment groups were asked to perform an MPSA test, and it was considered as post-test. Data were collected by conducting post-test in Brain-Based Mathematics Teaching Questionnaire to both the groups. The treatment groups showed much interest in doing mathematics problem-solving by showing interest, high motivation, speed, accuracy, lesser time to complete activities, etc.

16.4 Exploration and Elucidation

Once the research procedure concluded, the investigators acquired data from the tests, and it was used to analyze the influence of BBT in uplifting the MPSA. Data were analyzed using quantitative and qualitative data analysis techniques.

Quantitative Analysis

- *Percentage Analysis* – to calculate the distribution of sample among groups and distribution of level of achievers in each group
- *Independent Sample "t"-Test* – to find a significant difference between mean scores between groups, i.e., comparison and treatment groups
- *Pearson's Correlation Analysis* – to calculate whether a correlation exists between independent and dependent variables

The researchers used the Statistical Package for Social Sciences to analyze the data. The significance of "p" was resolute to 1% and 5% level of confidence.

Qualitative Analysis

Phases of Qualitative Data Analysis

(i) Data Organization – Organizing the data collected with sequence and according to the respondents
(ii) Data Description – Describing the data in the viewpoints of the participants
(iii) Data Interpretation – Concluding based on the data collected

16.4.1 Validity of the Qualitative Data

The internal validity of the data collected through the case study is verified by collecting the data in two different times of the experimentation. *Data triangulation* was adopted by the researcher to verify with several different data sources to add credibility to the findings. Of the three types of data triangulation, i.e., time, space, and investigator, the researcher adapted time data triangulation, in which data was collected from the sample at different times of research and analyzed in light of neutral aspect.

16.5 Findings from Quantitative Analyzing Techniques

16.5.1 Descriptive Analysis of Sample (Table 16.1)

Both the treatment and comparison groups had 30 pupils. The treatment group consisted of 14 girls and 16 boys, and the comparison group contained 21 girls and 9 boys (Table 16.2).

Table 16.1 Distribution of sample

S. No.	Cluster	Sex	Occurrence	Proportion %
	Treatment	Boys	16	53
		Girls	14	46
	Comparison	Boys	9	30
		Girls	21	70

Table 16.2 Allocation of students

	Groups			
	Comparison		Treatment	
Level of achievers	Frequency	Percentage	Frequency	Percentage
Low	10	33.33	10	33.33
Moderate	10	33.33	10	33.33
High	10	33.33	10	33.33

Table 16.3 Variation in the comparison and treatment groups: Pre-test of MPSA ("t"-test)

	Pre-test of MPSA	"t"		
Group	Mean	SD	"P"	
Comparison	53.43	11.51	0.167	0.868
Treatment	52.99	8.90		

The investigators trifurcated each group into three sub-groups containing three levels of achievers equally (Table 16.3).

Research Question Do the comparison and treatment groups vary in the scores of MPSA concerning the pre-test?

The P-value obtained from the "t"-test is 0.868; hence, it is recognized that the comparison and treatment groups are the same concerning pre-test in MPSA. Hence, the groups were equal and don't differ in all aspects. Thus, the equality was maintained (Table 16.4).

Research Question Does the comparison group vary from the treatment group regarding the BBT?

As all the P-values are below 0.001 concerning BBT including the overall usage, it is visible that there is a substantial dissimilarity. The treatment group has outperformed the comparison group.

The reason for the difference in the treatment group was because of adopting the teaching techniques adopting BBT than the comparison group concerning sub-domains of BBT. Since all the other intervening factors are minimized in this study, the researchers concluded that the reason for the difference between the two groups is because of BBT (Table 16.5).

Table 16.4 Variation in comparison and treatment groups regarding BBT ("t"-test)

BBT	Group	"t"			"P"	
	Comparison		Treatment			
	Mean	SD	Mean	SD		
Individuality	2.27	0.39	5.47	0.48	28.289	<0.001 **
Sense	3.63	0.64	6.73	1.14	13.138	<0.001 **
Versatility	2.20	0.32	4.73	0.50	24.034	<0.001 **
Feelings	2.37	0.46	4.57	0.52	17.78	<0.001 **
Neuro-physical association	2.60	0.58	6.23	0.95	18.124	<0.001 **
Retention and erudition	1.37	0.46	2.87	0.44	13.212	<0.001 **
Sequence and tempos	1.47	0.48	3.60	0.52	16.545	<0.001 **
Removal of menace	1.63	0.58	4.57	0.52	21.027	<0.001 **
Valuation	2.80	0.71	5.90	1.23	12.101	<0.001 **
Total factors of BBT	1.953	2.42	43.87	4.13	28.356	<0.001 **

**Significant at 0.01 level

Table 16.5 Relationship among the factors of BBT and MPSA: Comparison group (Pearson's coefficient)

BBT Comparison group	Pearson's correlation		
	MPSA test		
	Pre-test	Post-test	Gain percentage
Individuality	0.063	0.104	0.245
Sense	0.035	0.013	−0.124
Versatility	0.119	0.141	0.114
Feelings	0.178	0.168	−0.061
Neuro-physical association	−0.025	0.027	0.286
Retention and erudition	−0.057	−0.087	−0.176
Sequence and tempos	−0.079	−0.088	−0.055
Removal of menace	0.253	0.248	−0.016
Valuation	0.175	0.162	−0.069
Total usage of BBT	0.146	0.147	0.014

Research Question Do the factors of BBT have any relationship with MPSA concerning the comparison group students?

It is deduced from the statistics of correlational analysis table that the elements of BBT do not have a relationship with the MPSA. Since the Orthodox, traditional teaching tactic was adopted for the comparison group, this type of difference was witnessed. There is no chance of getting knowledge of the brain-based concepts and its importance and hence no progress in MPSA among the pupils of the comparison group (Table 16.6).

Research Question Does BBT have a relationship with MPSA concerning the pupils of the treatment group?

Table 16.6 Relationship among the elements of BBT and MPSA regarding the treatment group

BBT Treatment group	Pearson's coefficient		
	MPSA test		
	Pre-test	Post-test	Gain percentage
Individuality	0.461*	0.483**	0.089
Sense	0.466**	0.658**	0.266
Versatility	0.588**	0.442*	0.070
Feelings	0.532**	0.390*	0.074
Neuro-physical association	0.260	0.496**	0.283
Retention and erudition	0.247	0.375*	0.169
Sequence and tempos	0.462*	0.646**	0.258
Removal of menace	0.305	0.370*	0.111
Valuation	0.394*	0.677**	0.350
Total factors of BBT	0.627**	0.833**	0.303

*Significant at 0.05 level

Table 16.7 Variation among the comparison and treatment groups in the post-test of MPSA ("t"-test)

Group	Post-test – MPSA	t value	P-value	
	Mean	SD		
Comparison	54.09	11.62	8.742	<0.001**
Treatment	78.87	10.29		

It is evident from the above table that BBT has a healthier positive correlation in the pre- and post-tests of the students of the treatment group. Hence, it is clear that the MPSA is heightened by implementing the BBT (Table 16.7).

Research Question Do the comparison and treatment groups vary in the scores of post-test regarding MPSA?

"t"-test statistics indicate that the P-value is less than 0.1%. So the investigators assure that there is a substantial variation among the scores in the post-test of the comparison and treatment group students concerning the MPSA. Therefore, the treatment group students outperformed the comparison group students.

These findings from quantitative data analysis revealed that the BBT techniques do uplift the MPSA. BBT concentrates and provides its importance on every individual student. It stresses the process of learning. It is the natural way of boosting learning. It concentrates on higher-order thinking skills and problem-solving ability which are the product of real learning. It focuses on the thinking process, intuition, internalization of learning, and meaningful learning.

Findings from Qualitative Techniques in Comparative Form

- Research Question: What is the opinion of the low achievers of the comparison group on learning mathematics?

- Research Question: What is the opinion of the low achievers of the treatment group on learning mathematics?

Comparison group – Low achiever	Treatment group – Low achiever
Teacher on the student perspective The mathematics teacher did not use any special items in the class to teach mathematics. He always taught by explaining the problems that were given in the book, especially in examples. He used the blackboard to write the sum. The teacher orally explained doubts asked and often doesn't permit to ask doubts during teaching. The mathematics teacher is daring and boring. Reading and learning are only for performing in the exams and securing marks as far as the case is concerned. Mathematics is to be learned as memorization of the formulae. Daily home work was given from book exercises. There is nothing special in the mathematics classroom except the silence. There are no specialized tool like computers. There were only chalk piece in the classroom. Computers are used to play games and watch movies and hear songs	Teacher on the student perspective The mathematics teacher is a flexible, nice, and free person to talk with. The mathematics teacher used many supportive teaching-learning materials to teach mathematics lively and lovely. The case was having respect among the peer and the class. If the teacher was approached for clarity of the doubts, he was very interested and cleared the doubts at any point in time. The case was also allowed to ask doubt and say any polite words during the class hours. It was allowed to criticize the peer performance to some extent
Emotional climate The mind was filled with fear when mathematics was taught in the class. The case was feeling stress and bored during the mathematics class and expects the clock to run quickly when the mathematics teacher comes in	Emotional climate I feel much motivated and I have no stress when I do mathematics if I will be asked to solve the problems individually also. Nowadays, I like mathematics as it was taught using various materials and is useful in practical life also. It has many connections with all subjects like science, history, computer science, etc.
Mathematics Mathematics was a bore and daring subject but it has relevancy to life and the same problems in books were not asked in life situations. The case 1 was taught mathematics by sitting in a single line daily and the place was static	Mathematics The students of the group were experiencing joy while learning mathematics. Fun was prevailing inside the classroom. The students were longing for the Mathematics class and wanted to extend the time when mathematics class was going.

Comparison group – Low achiever	Treatment group – Low achiever
Classroom atmosphere He was not asked to speak in the middle part of the class. The teacher will ask the person to get out of the class who interferes inbetween the teaching. The teacher will not allow the case to speak with students sitting beside. The classroom has a single blackboard and no other facilities. No extra furniture or color wash was done in the classroom. No break was given while the class is going on. There is no way of learning mathematics through recreational mathematics. If a problem in mathematics was given to the case 1 for the solution, he would be feeling worried, stressed, and scared and sweating. It was one of the toughest works to solve a mathematical problem for the case. There is no time to have fun in the mathematics class as they were under the supervision of the teacher and were asked to work out the problems individually in the classroom. The case had not got any idea on growing tiny plants inside the classroom and noted it as impossible. The only place for learning in the classroom was the blackboard and no other place was not utilized. There is no chance for changing the sitting order inside the classroom as the teacher insisted the students to sit in a permanent place.	Classroom atmosphere Mathematics was learned in groups, and every member of the group has their contribution to the group's performance. Classwork, as well as homework, was given, and it was based on real-life problems. The mathematics teacher explained the brain and the role of food in detail. Every food has a direct impact on the functioning of the brain. As the brain is responsible for all the activities in our body, learning also happens in it. In a nutshell, the mathematics class was enjoyable and the student learned more from the teacher.
Personal relationship The case used to eat food provided by the school in the afternoon and drink water rarely during school hours. Drinking water is not allowed because it leads to urination frequently	Personal relationship Healthy food habits and regularly following exercises are important to successful learning. Yoga and brain exercises were performed in the class during break times. All the children are allowed to go for a walk around the classroom for 2 to 3 minutes. The teacher allowed students to drink water whenever they need it. The students were asked to bring water bottles of their own. A food and healthy habit chart was depicted inside the classroom. We clarified that the chart of food and healthy habits is needed only in for science classroom and not for mathematics, but the mathematics teacher answered that it is essential for our health and to our brain functioning well, and then only everything will go well

Comparison group – Low achiever	Treatment group – Low achiever
Enjoyment Fun math was not included. Puzzles were asked only in the language classes. He often asked us to memorize the formulae and rewrite them several times without explaining how it has arrived	Enjoyment Fun was prevailing in the classroom while we learn in groups. Puzzles were given to us before the problems are discussed in the class. Learning by doing was the main theme. When we do, we can understand what happens in the mathematics problem

- *Research Question*: What is the opinion of the moderate achievers of the comparison group on learning mathematics?
- *Research Question*: What is the opinion of the moderate achievers of the treatment group on learning mathematics?

Comparison group – Moderate achiever	Treatment group – Moderate achiever
Teacher on student perspective The mathematics teacher was very strict and rigid. No flexibility was felt in the classroom. Blackboard and chalk piece were used to teach mathematics. The mathematics teacher always teaches orally with hand-waving technique	Teacher on student perspective Many materials were used by the teacher to explain a single concept. The teacher gave all the students responsibility in learning. All of us had a chance to discuss, ask questions, clear the doubts of the other groups, praise others, etc. The case has also had a chance to present the problem before the class students and was praised by their mates. The teacher told the students to understand the given mathematical problem, the factors contributing to find the solution, demand, ways to solve the problem. The mathematics teacher provided us with many puzzles, riddles, and fun mathematics and uses of mathematics around us. For example, he told us that the whole galaxy is under one principle, that is, the Fibonacci series. The leaves that grow in a plant are also following a mathematics principle of Fibonacci series. This made us very interested, and the motivation that the teacher gave us was nice. He made us study mathematics with interest

Comparison group – Moderate achiever	Treatment group – Moderate achiever
Emotional climate If the case were presented with a mathematical problem, then it would be the toughest task to do, and it will feel very worst	Emotional climate The students felt happy and confident of doing mathematics by group work, discussing the factors, and solving
Mathematics Mathematics is a tough subject, and it is considered always easy by the rank holders. The participant liked language classes very much than other subjects. The case learned mathematics by individual effort. The mathematics teacher gave an individual assignment. Mathematics has a lot of meaning in real life. It is used in many places. Mathematics is studied for doing higher studies and to get a fair job	Mathematics Learning mathematics was fun and had a lot of activities which made us understand the problem very much easier. The mathematics class was full of jokes and laughter
Classroom atmosphere No group work is given in the mathematics class. There is no chance for the students to interact inside the classroom. The mathematics teacher would not allow for any conversation or interaction. The mathematics teacher clarified doubts if time permits. Otherwise, there is no chance for talking inside the room. The seating arrangement of the case in the classroom was fixed and not changed. There was no grouping in the mathematics class. The classroom has one table-chair for the teacher and benches and desks for students and nothing more than this. There was no break either long or short during class time. No colors were inside the classroom where mathematics was taught. The place for learning and writing is only on the blackboard. The classroom had nothing to do for any other work. The teacher has the sole responsibility of presenting the answer to the problem. No special tools were used inside the classroom for teaching mathematics. There was no group formed, so there was no chance for discussing, explaining, and doubt clearing. Home work was given daily from the book exercises and asked regularly to do. Computers and cell phones are the costly devices used for hearing songs, seeing movies, and playing games. The case could not contact anybody inside the classroom for any assistance in learning mathematics, and there is no chance for communication out of the classroom too. Growing plants and trees would be useful for the fresh air, but it was not practically applicable inside the classroom and the school premises because the students would damage the plants	Classroom atmosphere The class was divided into five groups, and each group can sit anywhere inside the class. The place was not static for any group inside the classroom. The teacher advised to sit to shift from seating at any part of the learning, but we were asked to maintain discipline while doing so. The class was full of learning materials like charts, color pictures, papers, models, pens and pencils, computers, laptops, tablets, and interactive whiteboard. I liked the interactive whiteboard very much as it was new to me and it had many functions and resembling the touch screen in the smart mobile. Puzzles and riddles made us think, and thinking helped to solve many problems presented before us. The teacher asked a topic to choose and the homework was given from that and that was also from the daily life problems. Quick response code was the item which I liked more. The mathematics teacher had followed many methods of presenting the same concepts to us. On the whole, the case liked learning mathematics and was then confident of doing mathematics in the group also and individual also not for mark scoring in examinations but for gaining knowledge in mathematics

Comparison group – Moderate achiever	Treatment group – Moderate achiever
Personal relationship The case used to take the food items given by the parents, and the teacher would not give any advice on food habits. None had advised how to cope with stress and alternatives for facing stress. Water was not kept in the classroom, but it was in the noon-meal room	Personal relationship The teacher used many techniques and taught the techniques to us also regarding stress management. The calm and cool mind will work and tensed and worried mind won't work; this was the statement given by the teacher. This made me composed and I will follow these rules in my life also
Enjoyment Laughing and playing were out of the classroom	Enjoyment All of us enjoyed learning mathematics with fun. Puzzles and riddles were presented to us to solve before and in the interim stage of doing mathematics

- *Research Question*: What is the opinion of the high achievers of the comparison group on learning mathematics?
- *Research Question*: What is the opinion of the high achievers of the treatment group on learning mathematics?

Comparison group – High achiever	Treatment group – High achiever
Teacher on the student perspective The teacher used chalk and board to explain problems in mathematics. He explained orally all the sum. The case learned mathematics individually inside the class. The assignments were also given on an individual basis. The only place in the mathematics classroom was for the class teacher, and nobody is superior to him. The authoritative climate was inside the classroom. The class teacher may allow one or two doubts at times, but not frequently. The teacher spoke loudly and toughly. Oral method is the only method followed inside the classroom. The oral method was adopted to teach mathematics. The teacher did not encourage interaction inside the classroom	Teacher on the student perspective The mathematics teacher was simply superb and encouraged each of us to do activities related to mathematics using many tools. He introduced many tips, like pranayama, hook activities, walk around, crossovers, etc., before learning mathematics. He divided the class time and gave small breaks for natural callings. The mathematics teacher is friendly and approachable for study-related works and can be communicated at any time

Comparison group – High achiever	Treatment group – High achiever
Emotional climate The case also felt stressed when the mathematics period is allotted. If a mathematical problem is given to the case, it would be hard to solve it because it needs a lot of practice	Emotional climate The curiosity of the students was high and motivated. The mathematics teacher permitted the fast achieving students extra computer, laptop handling time as incentive. The case wasn't feeling bored or dejected at any point of time inside the classroom. The case felt very happy and motivated to learn mathematics. The inner anxiety toward mathematics has vanished through the mathematics teacher. The work he provided us made us very strong in solving the problems under any circumstances. If we couldn't solve the problem, then we were able to find possible ways of solving them in alternative ways, because every problem has many ways to find solutions
Mathematics Mathematics is a hard subject and the mathematics teacher was strict in the classroom. Mathematics is liked after language and science subjects. Mathematics is a hard subject. Mathematics has relevance but when it is understood in real-life situation because it is life-oriented. Mathematics is a subject which provides higher job with a good salary	Mathematics Mathematics is the subject that I like the most. It has full of life. Many ideas and thoughts were shared in groups as all of them contributed to learning. Group work was allotted as an assignment to find the area of the quadrilateral by direct visit to the field surveying. Once the case was asked to go the surveyor of the revenue department and ask how a quadrilateral was surveyed and area calculated. On the next day, the teacher explained by using a video lesson of calculating area after constructing a quadrilateral. It was very enjoyable and it was unforgettable. Hope all of the teachers teach like this

Comparison group – High achiever	Treatment group – High achiever
Classroom atmosphere The classroom in which the mathematics was taken had no special features other than windows, benches, and desks. There was no color wash inside the classroom. The case also had a static place, and they were asked to sit in the same place for the whole time. Though the participant needs water, it depends upon the teacher to or not to allow to drink during class time. Growing plants inside the classroom was not permitted as it will die. There was no special corner inside the classroom for performing any other tasks. There was no chance for discussion, presentation, and doubt clarification among students. No communication except direct contact was prevailing inside the classroom. Home work was given daily from the book and the teacher asked to memorize it the next day. Computer and mobile phones were used to play games and watch movies at home and other places but not in the classroom	Classroom atmosphere The participant learned mathematics by using many ICT tools like computers, laptops, tablets, Android applications, projectors, music speakers, etc. and enjoyed handling the tools very much. It was also expected when the teacher would call and ask to operate the computer to perform activities. The case learned mathematics by doing and solving problems in the group. All of the participants of the group were allowed to discuss, criticize, correct, and present the task joyfully. Laughter was one of the activities in learning. The case was allowed to enjoy through laughing inside the classroom meaningfully. The mathematics teacher developed an evaluation Android application that helped in testing strengths and weakness and checks the learning according to that. He also provided quiz programs. He used advanced approaches in handling tools. The classroom looked very colorful with saplings and had learning corners inside the classroom. Every part of the room was used to learning. Sweet aroma was felt and the mathematics teacher taught us brain exercises and pranayama in Padmasana which helped for active learning. Music was played then and there in the classroom which made us relax often. Mathematics is an integral part of human life; it is everywhere. So one should learn mathematics for developing the skill of problem-solving in life situation
Personal relationship The teacher did not advise about food habits. There was no chance for allowing students outside while the class is going on, may it be for water break or toilet break. There was no advice from the teacher about health habits. There was no friendly treatment inside the classroom. Water is not provided during class hours	Personal relationship Whenever the case asked for going out to drink water and urination, the teacher would allow. Colorful pictures of food habits and food chart were pasted inside the classroom. There were some pictures of the brain and its parts and functions of the parts of the brain inside the classroom. Water purifier was used for drinking water, and the mathematics teacher repaired it and allowed the students to drink water at regular intervals. He also stressed the importance of water for the smooth functioning of the brain. The mathematics teacher gave me an awareness of eating healthy food for the well-functioning of the brain

Comparison group – High achiever	Treatment group – High achiever
Enjoyment Puzzles and riddles were not utilized in classroom teaching. Laughing was strictly prohibited inside the classroom because there was no time to laugh and students would be writing and doing sums	Enjoyment Freedom was given with maintaining the discipline and classroom atmosphere was smooth. The teacher gave many fun math to all of the participants; it was very interesting to have fun math while we learn the lessons. For example, the mathematics teacher introduced 3*3 magic squares, multiplication of 15,873 by 7 and its multiples, and that reverse images of square numbers 10, 11, 12, and 13 will be equal to the reverse square, i.e., squares of 1, 11, 21, and 31

16.6 Findings from the Qualitative Analysis: Comparison Group

The participants of a case study from the comparison group gave a detailed explanation of the teacher behavior in the class and about the teaching practices held in the classrooms of teaching mathematics.

Each level of the participants expressed that they were under stress during the mathematics class. There were no supportive tools for teaching abstract mathematical concepts. The teacher orally explained the problems and used the blackboard and the students were asked to copy. The idea of mathematics from students' point of view is that the subject is daring. The students are scared of the mathematics teacher. The teacher was strict and rigid. No students were allowed to talk, question, and have fun inside the class. All the students of the class were remained silent while the teacher was talking and giving notes. The students were asked to sit in a line and it was permanent throughout the class.

The students learned mathematics individually. Assignments were also given individually not in groups. No student was assigned responsibility in the mathematics class. The students were not permitted to ask questions during the mathematics class. There was no room for suggestions and clarification of doubts. The teacher maintains strict rules in the classroom. The classroom had nothing special items except blackboard and furniture. There was no friendly advice from the teacher regarding health, food habits, diet, and exercises. The teacher followed the rigid rules only for teaching mathematics. No students were allowed to go for a break in between teaching.

The classroom looks very monotonous and no colorful pictures and atmosphere inside.

The students of the comparison group felt that learning mathematics was for only securing marks, to get a job, and for earning money. The student of the comparison group felt that little part of mathematics has relevancy in life. Drinking water was not permitted in the classroom management. The students find it difficult when they were presented a mathematical problem. If anybody laughs inside the classroom, they will be sent out immediately from the classroom. The students felt that growing greenery in the classroom has no relevance for learning. The only blackboard of the class was utilized for learning. No student was given a chance for speaking during class time.

There were no place for puzzles, riddles, brain exercises, pranayama, brain activities like crossovers, hook activities, walk around… etc. There was no place for fun math in the classroom. Memorization of the formulae and concepts are the tasks given to the students. The students of the comparison group find no place for advanced tools to teach mathematical concepts.

16.7 Findings from the Qualitative Analysis: Treatment Group

The treatment group students felt that the mathematics teacher was friendly, approachable, kind, and smooth in the teaching of mathematics. He was flexible to some extent.

He used many options to introduce, explain, interrogate, evaluate and assign works to the students regarding mathematics. The mind was full of eagerness, interest, and curiosity prevailing when the mathematics teacher came into the class. The students were enjoying every minute of the class. Mathematics is a hard subject to some extent having tough areas in it, but after the teacher taught the tough concepts using various tools, they felt much easier. They liked mathematics very much.

They were formed under groups and learned mathematics and did an assignment in groups. The group members contributed to each other and learned many things by sharing their ideas in doing assignments.

Every student has a good opinion about the teacher, and the teacher respected the students too. Responsibility was given to each student in performing the task assigned to them. The students questioned meaningfully whenever they felt. The teacher answered in many ways to the doubts raised. The students were given full right to discuss the answer to the questions raised by other students. There were no stress worries inside the classroom. The mathematics teacher was a very nice person. He was very kind to all.

The groups were allowed to learn with other groups if it is needed. The students had no fixed place for sitting inside the classrooms. They can move and change the place and sit wherever they felt. All space in the class was used for learning by creating every space as a learning corner. The teacher advised students on food habits, water drinking habits, exercise habits, and stress management habits. The teacher also taught pranayama in Padmasana, doing crossovers, hook, super brain yoga, etc. to prepare the brain for active learning. The students felt energetic as they follow the advice by the teacher. The mathematics teacher allowed the students to go for a break at regular intervals. Water drinking was stressed by the teacher. Learning by doing was the method of learning mathematics.

The classroom looked very colorful and was occupied with small plants grown inside. The greenery looked beautiful and made the students feel cool. All the students felt that mathematics is an integral part of daily life. The main aim of mathematics according to this treatment group case report was to attain the skill of problem-solving. Nobody felt scared or stressed to solve the problems. Music, laughter, and aroma were the part of learning inside the classroom. Fun mathematics was also part of learning. Puzzles and riddles were given parallelly to develop the aesthetic sense of the students.

16.8 Discussion and Implications

BBT is an impressive technique than the old traditional teaching technique on augmenting the MPSA. The results of this study coincide with the results in the following researches conducted by the following researchers Cengelci (2005) in Social Studies, Wortock (2002) in Science courses, Ozden and Gultekin (2008) in Science, Serap Tufekcil and Demirel (2009) in Science, Duman (2006) in Social Studies, Aydin and Yel (2011) in Biology Education, Akyurek and Afacan (2013) in Science, Haghighi (2013) in English as a Second language, Rehman (2011) in Higher Education Mathematics, Phangwan et al. (2015) in Animation, Bonomo (2017) in Reading Habit, and Morgan and Fonseca (2004) and Gozuyesil and Dikicl (2014) in Academic Achievement.

The investigator found that BBT has a positive and significant relationship with MPSA in this study. Adel M Eladi (2019), Lia Sari Rahmatin, Slamet Suyanto (2019), L. Riskiningtyas, M N Wangid (2019), Alfilimbani (2014), Khattab (2013), Aziz-ur-Rehman (2011), Bilal Duman (2010), Samuel Adijare Samuel (2010), Doris, M. Bello (2007) studied on the effectiveness of BBT in improving the mathematics achievement students and found the positive and significant effect.

The positive effect was found by the following researchers who studied BBT and its effectiveness on Science Achievement. Altiti (2014), Dr. Rashida and Kapadia (2014), Erkan Akyurek, Ozlem Afacan (2013), Solmaz Ayudin; Mustafa Yel (2011), Prasart Nuangchalerm, Duangkamon Charnsirivattana (2010), Salmiza Saleh (2011), Shabatat & Al-Tarawnch (2016), and proved significant.

Various researchers like Gokhan BAS (2010), Maryam Haghighi (2013), Jane Arnold Morgan and M Carmen Fonseca (2004), Bilal, Duman (2006), Pannee Banchonnattakit, Rujira Duangsong, Niramon Muangsom, Theppamon Kamsong, Krittiya Phangwan (2015), Saltmarsh (2005), Eda Gozuyesil, Ayhan Dikici (2014), Bunge & Zealazo (2006), Smith & Sara (2007), Maynard (2016), Kiedinger (2011), Amanda Pociask; Jeri Settles (2007), Anita Miller (2011), Freeman, Greta G and Wash, Pamela D (2013), Serap Tufekcil, Melek Demirel (2009) investigated the effect of BBT on various academic subjects and revealed that BBT is effective. These results are in compliance with the results which are obtained by the investigator in this study.

Mixed methods – quantitative and qualitative used mutually – added values to the findings of this study. Both methods were complementary. Quantitative techniques filled the vacuum that is created by the qualitative techniques and vice versa. Both the techniques proved BBT technique as fruitful in boosting MPSA among school pupils.

16.9 Conclusion

The present study toured around the influence of BBT on MPSA among school pupils. From the results grouped over, both the quantitative and qualitative methods revealed that BBT is an effective burgeoning technique which boosts MPSA. So the investigators determined that pupils imparted mathematics via the BBT approach had a fair MPSA when compared to the students who were instructed using Orthodox teaching techniques.

16.9.1 Endorsements for Advance Studies

Outcomes of the present study inferred the subsequent ideas that may be concentrated for future research purpose.

- BBT is a great choice for teaching mathematics right from the earlier stages to higher classes to boost academic success and retention rate.
- Modules based on BBT can be prepared and followed for all the classes on par with subjects.
- Pre- and in-service training can be delivered on BBT approach for all the prospective and working teachers.
- Adequate funds may be allocated to schools run by the government for familiarizing BBT tactic.
- Adequate infrastructure facilities may be arranged for schools.
- Records and accomplishments can be equipped and delivered to educators to follow the techniques appropriately.
- Instructive Cognitive-Neuroscience can be included in the 2-year teacher education programs.
- BBT and Learning courses online and offline, like Certificate Courses, Diploma Courses, Post-Graduate Diploma Courses, etc., may be introduced for teachers.
- In-depth researches may be done mingling with BBT on the following cognitive areas such as attitude, higher-order thinking skills, self-regulation, essential regulatory skills, meta-cognition, etc.

References

Akyurek & Afacan. (2013). Effects of Brain Based Learning Approach on Students' Motivation and Attitude levels in science Class. *Mevlana International Journal of Education. 3*(1), 104–119.

Alfilimbani. D. (2014). *The impact of Brain Based Learning training program and level of mastering on the development of skills of para learning and academic achievement in Saudi Arabia*. Unpublished Doctoral Dissertation. University of Cairo. Egypt.

Altiti. (2014). The impact of brain based teaching programme on improving the achievement of 5th grade students in sciences. *Journal of Islamie University, 22*(1), 111–138.

Aydin, S., & Yel, M. (2011). The effect of BBL biology education upon academic success and attitude. *Energy Education Science and Technology- Social and Educational Studies, 3*(1), 87–98.

Bayindir. (2003). An Investigation of students' attitude towards Brain Based Applications in English Composition Skills II course - A Study

Bello, D. M. (2007). *The effect of brain based learning with teacher training in division and fractions in fifth grade students of a private school*. PhD Thesis, Capella University.

Best, J. W., & Kahn, J. V. (2006). *Research in Education*. New Delhi: Prentice Hall India.

Bonomo, V. (2017). Brain Based Learning Theory. *Journal of Education and Human Development, 6*(1), 27–43.

Bunge. S. A., & Zealazo, P. D. (2006). A Brain based account of the development of rule use in childbood. *Current Directions in Psychological Science, 15*(3), 118–121.

Caine, R. N., & Caine, G. (2005). *12 Brain/ mind learning principles in action: The field book for making connections.* Thousand Oaks: Corwin Press.

Cengelci, T. (2005). *The effects of BBL to success and retention in social studies.* Eskisehir: Unpublished Master's Thesis.

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches* (4th.ed.). Thousand Oaks, CA: Sage.

Duman, B. (2006). The effect of brain-based instruction to improve on students' academic achievement in social studies instruction. In *9th international conference on engineering education* (pp. 1–9). San Juan: Mugla University of Faculty of Education.

Duman, B. (2010). The effects of Brain Based Learning on the Academic Achievement of students with different learning styles. *Educational Sciences: Theory and Practice, 10*(4).

Eladi. (2019). Effect of a Brain Based Learning Program on Working Memory and Academic Motivation among Tenth Grade Omanis students. *International Journal of Psycho-Educational Sciences, 8*(1), 42–50.

Freeman, G. C., & Wash. P. D. (2013). You can lead students to the classroom and you can make them think: Ten Brain Based Strategies for college teaching and learning success. *Journal on Excellence in College Teaching, 24*(3), 99–120..

Gozuyesil, E., & Dikicl, A. (2014). The effect of BBL on academic achievement: A Meta-analytical study. *Educational Sciences: Theory & Practice, 14*(2), 642–648.

Grover, V. K. (2015). BBT: Rethinking on teaching strategies. *Indian Streams Research Journal, 5*(1), 1–6.

Haghighi, M. (2013). The effect of BBL of Iranian EFL Learners' achievement and retention. *Procedia-Social and Behavioral Sciences*, 508–516.

Hileman, S. (2006). Motivating students using BBT strategies. *The Agricultural Education Magazine, 78*(4), 18–20.

Jensen, E. (2005a). *Enriching the brain*. Alexandria: ASCD.

Jensen, E. (2005b). *Teaching with the brain in mind*. Alexandria: Association for Supervision and Curriculum Development.

Jensen, E. (2006). *Brain Based Learning.* Virginia: ASCD.

Kaufman, E. K., Robinson, J. S., Bellah, K. A., Akers, C., & Penny Haase-Wittler, L. M. (2008). Engaging students with BBL. *Research Gate*, 49–55.

Khattab. (2013). *Enabling Education, Integrated Educational Model in classroom*. Jordan: Dar Al Furqan.

Kiedinger, R. (2011). *Brain Based Learning and its effects in reading outcome in elementary aged students*. University of Wisconsin- stout.

Koul, L. (2014). *Methodology of Educational Research*. Noida: Vikas Publishing House Pvt.Ltd.

Maynard, M. (2016). *Effect of a Brain Based Learning Programme on students' use and recognitiion of self-advocacy skills*. Unpublished Doctoral Thesis. Philadelphia College of Osteopathic Medicine-Psychology.

Miller, A. (2011). *Brain Based Learning with Technological support*. Unpublished project paper. Dominican University.

Morgan, J. A., & Fonseca, M. C. (2004). Multiple intelligence theory and foreign language learning; a brain-based perspective. *International Journal of English Studies, 4*(1), 119–136.

Nuangchalerm, P., & Charnsirirattana. D. (2010). A Delphi study on Brain Based Instructional Method in Science. *Canadian Social Science, 6*(4), 141–146.

Ozden, M., & Gultekin, M. (2008). The effects of BBL on academic achievement and retention of knowledge in science course. *Electronic Journal of Science Education, 12*(1), 1–17.

Phangwan, K. et. al.. (2015). Effectiveness of Brain Based Learning and Animated Cartoons for Enhancing Healthy Habits among school children in Khon Kaen, Thailand. *Asia Pacific Journal of Public Health. 27*(2), 2028–2039.

Pociask, A., & Settles, J. (2007). *Increasing students achievement through brain based strategy*. Unpublished masters dissertation. Saint Xavier University, Chicago, Illinois.

Politano, C., & Paquin, J. (2015). *BBL with class*. Victoria: Peguis Publishers.

Rahmatin, L. S., & Suyanto, S. (2019). The use of Brain Based Learning Model in Classroom. *The International Journal on Bioscience & Biological Education, 1241*(2019), 012027.

Rashida, H., & Kapadia. (2014). Level of awareness about knowledge, belief and practice of Brain Based Learning of school teachers in Greater Mumbai Region. *Procedia-Social & Behavioral Sciences, 123*.

Rehman, A. U. (2011). *Effectiveness of BBL method and conventional method in teaching of mathematics at secondary level in Pakistan: An treatment study*. Islamabad.

Riskiningtyas, L., & Wangid, M. N. (2019). Students' Self-efficacy of Mathematics through Brain Based Learning. *Journal of Physics:Conference Series, 1157*(4).

Saltmarsh, A. G. (2005). *Exploring BBL as a basis for develop technology education curriculum*. Bemidji: Bemidji State University.

Saleh, S. (2011). The effectiveness of Brain Based Teaching Approach in dealing with the problems of students' conceptual understanding and learning motivation towards Physics. *Educational Studies, 38*(1), 19–29.

Samuel, A. A. (2010). Effect if Brain Based Learning strategy on students' achievement in senior secondary school mathematics in Oyo state, Nigeria. *Cypriot Journal of Educational Sciences, 6*(2).

Schiller. (2003). *Brain-based learning and standards based elementary science*. (report). Grand Rapids. MI: School of Education. Grand Valley State University.

Serap Tufekeil & Demirel, M. (2009). The effect of BBL on achievement, retention, attitude and learning process. In *World conference on educational sciences 2009* (pp. 1782–1791). Ankara: Elsevier.

Shabatat, K., & Al-Tarawneh, M. (2016). The impact of a teaching-learning program based on a BBL on the achievement of the female students of 9th grade on chemistry. *Higher Education Studies, 6*(2), 162–171.

Smith & Sara. (2007). Using Action Research to evaluate Brain Based Teaching Strategies in the classroom. *The International Journal of Learning -Annual Review, 13*(9), 121–126.

Sousa, A. D. (2011a). Mind, brain and education: The impact of educational neuroscience on the science of psychology. *Learning Landscapes*, 1–25.

Sousa, D. A. (2011b). *How the brain learns*. Thousand Oaks: Corwin Press.

Sousa, D. A. (2015). *How the brain learns mathematics*. Thousand Oaks: Corwin Press.

Tokuhama-Espinosa, T. (January 2011). Why mind, brain and education science is the new brain-based education. *New Horizons in Education*, 1–10.

White. (2004). *Implications of brain based learning theory for the development of a pedagogical framework for religious education*. Unpublished Doctoral Thesis.

Wortock, J. (2002). http://proquest.umi.com/pqdweb?did=765069251. Retrieved from http://www.proquest.umi.com

Chapter 17
Nature, Nurture and the Learning Brain

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17.1 Introduction

> A devil, a born devil, on whose nature
> Nurture can never stick; on whom my pains,
> Humanely taken, all, all lost, quite lost;
> Shakespeare *Tempest*

> It is needless to insist that neither is self-sufficient; the highest natural endowments may be starved by defective nurture, while no carefulness of nurture can overcome the evil tendencies of an intrinsically bad physique, weak brain, or brutal disposition.Francis Galton

There is general agreement that the brain is the seat of all learning. The Pythagoreans in the sixth and fifth centuries BCE understood the brain as the seat of the mind. Aristotle (fourth century BCE) however held the view that the brain acted as a cooling agent for the heart where mental activities took place. Galen, the first Century (CE) Roman physician came back to the conclusion that it was in fact the brain that was the seat of intelligence. It may be of interest to note that the operation of trephination (trephining or trepanation) by making drill holes in the skull to drive away evil spirits was practised by prehistoric people as far back as in the Neolithic period.

The polemics on 'nature vs nurture' have a long history going back to Socrates, Plato and Shakespeare. Francis Galton, the Victorian polymath (and Darwin's cousin) believed that it was our inherited traits that solely decided our physical and intellectual abilities. He coined the term eugenics that advocated weeding out undesirable physical and mental diseases and disabilities in the population by preventing people with such negative traits from mating and improving the human species by selectively breeding people with desirable hereditary characteristics. Stephen Gould

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provides an engaging account of craniometry (measuring the volume of the human cranium) and the methods to assess the weight and volume of the brain with the aim of categorizing human beings practiced in the nineteenth and early twentieth centuries (Gould 1981). Data from craniometry were applied to people of different races as a practical tool to calculate their intellectual capacity. Based on such studies, human races were neatly graded and depicted hierarchically – Caucasians at the top and Africans, Egyptians, Chinese, Asians and Malays at the bottom!

The practice of dissection of the human body during the Renaissance provided opportunities to study the structure of the brain. In his search for the 'seat of the soul,' Leonardo da Vinci made detailed studies on the structure of the brain. His investigations and sketches of the brain continue to attract the attention of neurologists, neuroscientists and scholars even today (Pevsner 2019; Capra 2007). In da Vinci's contemporary Michelangelo's famous painting The *Creation of Adam* (CE 1512), American physician Frank Meshberger pointed out the close similarity of the image of God on the background to a sagittal section of the human brain (Meshberger 1990). Reiterating how the larger image involving God is consistent with the human brain, Meshberger interpreted the painting symbolically as God bestowing on Adam (and the future humanity) intellect to enable him to plan and execute "the best and the highest." This has relevance to the lines from a sonnet Michelangelo had written that Meshberger quotes in the article:

> Only after the intellect has planned
> The best and highest, can the ready
> hand
> Take up the brush and try all things
> received.

"Only after the intellect has planned can the ready hand take up its function" – Michelangelo is reminding us here of an important learning objective recognized as psychomotor skill in modern parlance. Although educational theories include psychomotor skills in the taxonomy of learning objectives, in the overarching importance accorded to cognitive functions in educational performance, the role of physical skills and manual dexterity is all too easily forgotten when learners are trained and assessed. This is therefore taken up here as an important component for our discussion on the nature-nurture discussion.

Elizabeth Simpson of the University of Illinois, Urbana has published a practical classification of psychomotor domain objectives demonstrated by physical skills, dexterity, coordination, grace, speed, etc. (Simpson 1972). Although much has been written and said about Intelligence Quotient (IQ) and Emotional Quotient (EQ), objective assessment of psychomotor proficiency has not attracted the same interest among investigators. It may be argued that after all, in today's world of digital technology there is little that moving the cursor on the screen and clicking the mouse cannot achieve. Even that may sound redundant when all that is needed is a voice-activated virtual assistant in our smart homes that will carry out verbal instructions and keep our hands free from any effort; leaving us with the disquieting feeling that in the not too distant future, our infrequently used hands might, like the diminutive wings of Archaeopteryx, the extinct bird of the Jurassic period, enter a phase of disuse atrophy!

Thankfully though, humanity has not reached that stage, not yet at any rate. There is increasing awareness of the need for brain-brawn coordination in many walks of life. This concept has been approached from three perspectives: One, the need for nurturing the development of psychomotor skills as an essential prerequisite for specific tasks such as flying an aircraft and performing laparoscopic surgery. Second, how aerobic exercises alter brain structure and cognitive function by the release of neurochemicals such as endocannabinoids and brain-derived neurotrophic factor (BDNF). The third is a hypothesis that suggests how neurobiology for its evolution depended to a large extent on natural selection acting on features unrelated to cognitive performance (Raichlen and Polk 2013).

The importance of perceptual psychomotor proficiency for aircraft pilots was recognized as a major area for study soon after World War II. The findings of a major research project initiated by the US Air Force were released in 1966 as a 245-page report that included a historical review of perceptual and psychomotor tests followed in the aircrew selection process with an account of some of the advanced concepts (Passey and Mc Laurin 1966). The objectives of the study were two-fold: one was to develop processes and procedures for improving the efficacy of selection, appraisal and utilization of Air Force personnel, and the other for the development of tools and techniques for the evaluation of the performance of the officers and the analysis and improvement of the tools and techniques employed for the selection and training process. Included for the study was a long list of competencies in the cognitive domain, manual dexterity and psychomotor speed and postural and psychomotor coordination. A quote in the report on the desirable attributes of a 'good pilot' in the emotional and psychomotor domains ascribed to Morris Viteles[1] testifies to the overarching importance accorded to the emotional strength in addition to psychomotor skills and coordination mentioned above. The 1966 report was followed by similar reports on psychomotor and perceptual requirements for aircrew performance.

The implication of manual skills for commercial pilots in the age of digital technology and automation has been the topic of several recent studies on air transport safety and prevention of accidents. Robert Arnold, Quality Assurance Manager of US Air Force, presented the findings in five aircraft accidents three of which were fatal in the AHFE[2] conference in Las Vegas in 2015. In all the five cases, there was evidence of deficiency of manual skills in controlling the flight path on the part of the pilots (Arnold 2015). Valerie Gawron, an engineer at MITRE Corporation, USA reported on the analysis of twenty-six cases of aviation accidents between 1972 and 2013 involving human errors related to automation. Ten of the twenty-six cases were fatal and in most of these there was a reference to inappropriate cognitive and manual responses to unexpected events (Gawron 2019). Literature on aviation safety carries several reports analysing the causes of adverse events and stressing

[1] Morris Viteles was an expert researcher and writer in the field of industrial and organizational psychology.

[2] Applied Human Factors and Ergonomics.

the need for sustained efforts to provide training in cognitive and psychomotor skills to the flight crew.

Talking about the need to integrate cognitive ability and manual skills, the landmark story of Captain Chesley Sullenberger (Captain Sully) making an emergency landing of a US.

Airways plane (Flight 1549) on the Hudson river under the most hazardous circumstances comes to mind. The episode that happened in January 2009 has created a lasting impact in aviation history and Captain Sully's narration of the incident in a 12-min YouTube video continues to be a great source of inspiration. "I had learned my craft so well and I knew my airplane and my profession so intimately I could set clear priorities…I have the discipline …I'm well-read and I knew about neurobiology and I knew that multitasking is a myth…" He mentions that most of the communication in the flight deck at that point in time proceeded wordlessly, not forgetting to add how the cheering and comforting words of Flight Officer Jeff Skiles eased those moments of impending disaster. Listening to Sullenberger recapitulating the episode, it is not difficult to sense the resonance of his learning brain privileged by nature and nurtured in an atmosphere of discipline and human excellence confronting those moments of threat and triumph with unruffled objectivity (Captain Sully's... n.d.) ?. Captain Sully's mention of neurobiology in the video is particularly striking.

The ever-growing application of high-tech tools in medicine has witnessed a similar stress on the need for medical practitioners to keep their manual dexterity and psychomotor skills honed on an ongoing basis. The neurophysiological basis of learning psychomotor skills in areas like laparoscopic surgery, ultrasonography and other endoscopic procedures such as colonoscopy has evoked a great deal of interest in recent years (White et al. 2016; Nicholls et al. 2014). The recent paper of Arun Nemani and colleagues on the use of optical neuroimaging in the objective assessment of the acquisition of bimanual motor dexterity in trainees of laparoscopic surgery for surgical certification is noteworthy (Nemani et al. 2018). Psychomotor skills are likewise important in minimally invasive and robot-assisted surgical procedures.

The Brain The weight of the human brain has been calculated as approximately 1.4 kg. It has a volume of 1260–1500 cm^3 and a surface area of about 2200 cm.^{2} The brain contains 80 to 100 billion neurons each of which communicates with thousands of other neurons. It works 24X7. Although there is a slight gender difference between male and female brains in size (male brains are 8 to 13% larger), this is not reflected in their functionality.

The human brain has attracted wonder and admiration from all walks of life from the earliest times. Aristotle wrote that man has the largest brain among all animals compared to his size. But an understanding of the brain's functions remained shrouded in mystery for the best part of medieval and pre-renaissance periods. Although the anatomical features of dissected brains were described during the renaissance and post-renaissance periods, systematic understanding of the brain's physiological functions dates back not more than the last two centuries. In this connection, the names of four pioneers and their painstaking work that paved the way for establishing the foundations of modern neuroscience are considered below.

Korbinian Brodmann (1868–1918) Was a German Neurologist recognized for his original work on the fine cellular architecture of the brain. His findings describing the 'cytoarchitectonics' of the cerebral cortex was published in 1909. Brodmann proposed the division of the cerebral grey matter into 52 areas and assigned specific functions for these. His methodology depended on small differences in the types and distribution of nerve cells in the cortex viewed under the microscope. These have come to be known as Brodmann's areas. Based on his work on the cellular architecture of the brain, Brodmann concluded that the identification of well-demarcated structural zones in the cerebral cortex as "specific morphological organs" could be explained only by assigning specific functions to such zones wherein each zone subserved an exclusive and specific function different from all the others (Brodmann 1909).

Brodmann's work paved the way for the odd-looking, mushy human brain with its four lobes and the cerebellum to be recognized as a finely crafted mechanism that orchestrates the exquisite neural symphony of intelligence, thought and action. This was a period when the grey matter of the cerebral cortex containing mostly cell bodies with very few myelinated axons was considered almost wholly responsible for initiating and controlling cognitive and motor functions. The white matter with few cell bodies, made up predominantly of myelinated axons for long-range impulse transmission, was relegated to a less important role in the overall scheme of things. Recognition of its cardinal role in whole-brain network connectivity had to wait for the arrival of functional brain imaging techniques almost a century later.

Wilder Penfield (1891–1976) Was an American Canadian neurosurgeon interested in the treatment of epilepsy. In the early 1900s, as a Rhodes Scholar in Oxford, Penfield came under the tutelage of William Osler and Charles Sherrington. This was followed by an internship in neurosurgery under Harvey Cushing, a legendary name in American neurosurgery at Harvard Medical School. This unique experience prompted him to pursue a career in neurosurgery and subsequently as an academic neurosurgeon to take up research in neuroanatomy and neurophysiology and follow his passion to study the brain as the 'undiscovered country.' (Snyder and Whitaker 2013) Penfield's greatest contribution was his experiments on the mapping of different regions of the cerebral cortex by direct electrical stimulation of the brains in patients during operations performed under local anaesthesia for the treatment of seizure disorders. Penfield described his findings during the operations: "Electrical stimulation of the human brain, while patients are conscious, has sometimes activated the neuronal record of past experience…The experiences recalled are chiefly auditory or visual, or else they are combined auditory and visual" (Penfield 1961). Areas on the cortex that deal with various functions like vision and hearing as well as the appreciation of sensations and control of voluntary movements at specific areas of the body were localized and tagged. His life-long commitment to studying the workings of the human brain resulted in Penfield founding the renowned Neurological Institute at the McGill University in Canada in 1934 of which he became the first director.

A word about Penfield's cerebral cartography and the 'homunculus.' In his ground-breaking article co-authored with his resident Edwin Boldrey in 1937, the findings in 126 patients in whom electrical stimulation of different regions of the brain was carried out were described. The article carried several diagrams illustrating the observations and photographs of the exposed brain during the operation. What catches the reader's eye here is the drawing of a grotesque creature dubbed 'homunculus' with the highly expanded thumb, face and lips. Penfield had sought the help of an artist to create this image. The obvious incongruity of the image was explained as a reflection of the disproportionate extent of representation of each part rather than by the number of times responses were documented (Penfield and Boldrey 1937). A modified image of the homunculus spread over the convexity of a coronal section of the brain by the same artist was included in Penfield's book on the cerebral cortex of man published in 1950 (Penfield and Rasmussen 1950). Penfield's gargoyle-like images have earned a conspicuous niche in the annals of neurological literature. Generations of students of medicine today will have no difficulty recollecting the image of Penfield's homunculus from their early lessons in neurophysiology.

The twenty-first century saw the brain mapping techniques pioneered by Brodmann and Penfield undergoing unprecedented levels of precision and sophistication from their narrow neuroanatomic sense to incorporate a multitude of anatomical, physiological, biochemical, molecular and genetic data transcending many of the limitations in our understanding of brain functions. This is considered under 'Connectome Studies.'

Santiago Ramón y Cajal (1852–1934) The discovery of the nerve cell or neuron by the Spanish neuroscientist Santiago Ramón y Cajal, recognized as the father of modern neuroscience, led the way for a precise understanding of the mechanisms of communication in the nervous system. He identified the nerve cell as a discreet cell bounded by a cell membrane capable of communicating with other neurons at specialized points of apposition. His findings followed the discovery of specialized silver staining technique by Camillo Golgi, the Italian biologist in 1873. Cajal shared the Nobel Prize with Golgi in 1926 for his discovery.

Under the microscope, the neuron shows a cell body, nucleus, a longish cytoplasmic projection known as axon and multiple branched projections called dendrites. Electrical and chemical signals across the axon terminals are communicated to the dendrites of other neurons through specialized junctions known as synapses. Describing Cajal's first encounter with the microscope as a momentous event in the history of neuroscience, Alberto Portera-Sánchez, an eminent Spanish Neurologist, has described Cajal's discovery of the neurone in glowing terms. He compares the discovery to the opening of a magic door that allowed him to look into the intricate microarchitectural and functional details of the human brain considered to represent the most perfected system towards which evolution of life on earth has progressed (Portera-Sánchez 2001a).

A curious twist in Cajal's early life may be pointed out here. As a child, he developed a great deal of admiration for nature and found comfort and solace in art. His inborn artistic sensibility resulted in an enduring fascination for making sketches of whatever captured his imagination – peasants, carriages, horses and so on. His ambition was to become an artist. This was resisted by his father who felt he lacked maturity and his school was therefore interrupted. "As a punishment I had to accept a job in a barber shop…" Cajal wrote in his autobiography adding that before the end of the school year he was again sent to work as an apprentice to a shoemaker (Portera-Sánchez 2001b). Thankfully, however, in his case, lack of a nurturing environment failed to extinguish his innate gift. In his professional career as a pathologist, Cajal brought his inborn talent to fruition and made exquisite drawings of the neuron that haven't been excelled even today. *The Beautiful Brain: The Drawings of Santaigo Ramon y Cajal* (2017) explores the creative and artistic spirit of Cajal. The book presents a study of his 2900 drawings of the nervous system in light of contemporary neuroscience. The authors compare Cajal's achievement with those of Charles Darwin, Louis Pasteur and Leonardo da Vinci (Newman et al. 2017).

Sir Charles Sherrington (1857–1952) Was an English neurophysiologist and histologist who was greatly attracted by Cajal's work. What caught his attention was the mechanism of communication between nerve cells demonstrated in the highly coordinated action of the nervous system. He highlighted the need for a dedicated nervous system with special cells for communicating biological signals and integrating the functions of the organism as life evolved from simple unicellular to complex multicellular entities. Sherrington considered the elongated configuration of the neuron with its axon ideally suited to carry out this function and described how electrical signals were transmitted across nerve cells without the need for direct cell-to-cell contact. He proposed a small gap where the axon terminal of one neurone meets the dendrite of another cell – a specialized surface that separates the cells. He introduced the new term 'synapse' (derived from the Greek word súnapsis, or synapsis which means 'conjunction') for this structure and hypothesized that transmission of electrical impulses across the synapse occurred by a physicochemical process (Sherrington 1906). Sherrington was awarded the Nobel Prize for Physiology or Medicine for his discovery in 1932. This was several years before the nature of the chemical released by the neuron known as a neurotransmitter that caused excitation or inhibition of a neighbouring cell was discovered.

Sherrington was an avid athlete in his younger years and participated in winter sports and rowing. He was also a member of his college rugby team. But what brought him to the world's attention apart from his contribution to the science of neurology was his philosophical approach to scientific enquiry. Sir John Eccles and William Gibson have described him as "The Philosopher of the Nervous System" (Eccles and Gibson 1979). In his much-acclaimed book *Man on His Nature* based on his Gifford Lectures (1937–1938) one comes face to face with his philosophical thoughts on the brain, mind, human existence and God (Sherrington 1940). We see in his sparkling depiction of the myriad goings-on in the brain during its sleeping and waking hours a glimpse of his philosophical mind. Drawing a parallel of the waking brain and the returning of activities of the mind with a "cosmic dance of the Milky Way" Sherrington fantasizes the brain as an 'enchanted loom': "Swiftly the head-mass becomes an enchanted loom where millions of flashing shuttles weave a dissolving pattern… a shifting harmony of subpatterns. Now as the waking body rouses, subpatterns of this great harmony of activity stretch down into the unlit tracks of the stalk-piece of the scheme."[3]

Genes Genetic and environmental influences play complementary rather than contradictory roles in shaping our physical and cognitive abilities. Christian de Duve, Belgian cytologist and biochemist, who won the Nobel Prize in 1974 for his work on the organization of the cell highlights the fierce debates and controversies surrounding the nature-nurture problem, "…with, at one end of the spectrum those who believe that 'it is all in our genes,' and, at the other, those who claim that the environment does it all" (de Duve 2002). Thanks to newer understandings from human genome studies and the development of functional neuroimaging techniques, many of the earlier assumptions on the relative contributions of nature and nurture in human brain growth and development have been critically reviewed, paving the way for greater clarity.

The human genome has 20,000 genes. More than one-third of these are primarily expressed in the brain. Psychological and physiological studies of 100 sets of twins reared apart by Thomas Bouchard and colleagues at the University of Minnesota found genetic inheritance and environmental influence playing equal roles in the development of personality, temperament, interests and attitudes in the reared-apart and reared-together groups (Bouchard et al. 1990).

As Joan Stiles, Emeritus Professor of Cognitive Science at the University of California, San Diego, explains, until about four decades ago, brain growth and development were viewed in a deterministic way, in a unidirectional sense. Modern investigative tools of neurobiology have changed this view. In the case of the nature-nurture debate today, she points out that "at no point in brain development can the effects of inherited and experiential factors be separated. Rather, throughout development intrinsic and extrinsic factors interact continuously." (Stiles 2011). In other words, while on the one hand critical genetic signalling is required for normal brain development, equally important are environmental inputs. Francis Crick, the discoverer of the DNA molecule wrote: "Thus the mature brain is the product of both Nature and Nurture." And, taking the example of the unique (and inherent) ability of the human mind to learn a complex language, he adds: "Yet the actual language we learn is obviously heavily dependent on where and how we were brought up" (Crick 1995).

The effects of gene expression in the development and evolution of the brain and on human behaviour have attracted a large amount of interest in contemporary research. Countless journal articles and publications devoted exclusively to this

[3] Sherrington's captivating account of the brain asleep and the brain waking up in *Man on his Nature* has been drastically shortened here.

topic abound in current literature. Byoung-Il Bae, Divya Jayaraman and Christopher Walsh, scientists from Boston, have recently reviewed the publications on the genetic changes that affect brain development and evolution as well as advances made in brain transcriptome studies. Genomic studies on the brain have been to a large extent prompted by the need to gain newer insights into more precise diagnosis and management of neurological and neuropsychiatric disorders, such as autism and schizophrenia (Bae et al. 2015).

Epigenetics Two factors need to be considered when explaining nature-nurture influence on learning – epigenetics and neuroplasticity. Epigenetics refers to the process by which an organism can modify the expression of specific genes (without modification of the DNA sequence) in response to environmental changes that could arguably be passed on to succeeding generations. The British developmental biologist Conrad Waddington's elegant experiments on the fruit fly in the 1950s demonstrated that organisms can acquire new structures/functions in response to changes in the environment by a process he termed 'genetic assimilation.' This, Waddington argued, resulted from the exploitation of genotypic plasticity already existing in the population that can be expressed by a change in the environment (Noble 2015). Christian de Duve we saw earlier is of the opinion that the "wiring of the brain cannot be written into the genes" and argues that this must take place epigenetically during the development of the organism. Genes no doubt provide a general framework that defines the characteristic brain structure of the species. "All the details of the inter-neuronal connections are created, within the limits of this framework, under the influence of inputs that reach the brain both from the body itself and from the outside world" (de Duve 2002).

Newer investigative techniques such as analysis of DNA/histone markings promise fresh insights into the phenomena of developmental plasticity and epigenetics. In a recent article, Fiona Barlow of the University of Queensland, Australia has highlighted the necessity of an approach that recognizes the contributions of genetic, social and developmental factors in learning and personality development. Rather than weakening the strength accorded to parenteral, social or environmental effects in the development of our personalities and behaviour, she argues that acknowledging the role that genetic influences play adds refinement and subtlety to our understanding (Barlow 2019).

Neuroplasticity Clinical and laboratory studies during the latter part of the twentieth century discounted the earlier notion that the adult brain hardwired at birth cannot be made to change in response to extraneous influences. Neuroplasticity refers to the capacity of the brain to change its structure and function in response to experiential and environmental factors. This may be described as the brain's way of healing. Neuroplasticity continues throughout life as the brain keeps learning new cognitive and motor skills and forms new memories. Clinical and laboratory studies have confirmed the role of neuroplasticity in learning new cognitive and behavioural skills. Neuroplasticity allows healthy parts of the brain to take over lost functions of parts damaged by injury or removed during surgical operations. Patrice

Voss and colleagues at the Montreal Neurological Institute at McGill University have reviewed recent research that has shown that several influences such as individual genetic, molecular, cellular and environmental factors are capable of enhancing experience-dependent neural plasticity to varying degrees throughout life (Voss et al. 2017). A significant amount of research has also looked at the role of neuroplasticity in delaying the onset of cognitive decline in the elderly (Shaffer 2016). Researchers have shown that the brain retains a high degree of plasticity even in advanced age. The five basic requirements for a healthy brain to realize its neuroplastic potential have been identified as newness, challenge, exercise, diet and love. Neuronal structure and function are also known to change in response to stress, hormones, physical activities, neurotransmitters, growth factors, drugs, environmental stimulation, learning, and ageing. These include structural changes in brain areas, alterations in the morphology of neurons, changes in neural pathways and neuronal connectivity as well as production of new neurons (neurogenesis) and changes in neuro-biochemistry (Fuchs and Flügge 2014).

An anecdote relating to an episode in Francis Crick's later years that touches on brain plasticity may be mentioned here. It was narrated by Vilayanur Ramachandran, Distinguished Professor at the University of California Santiago (UCSD) during the Francis Crick memorial lecture he delivered at the Centre for Philosophy & Foundation of Science in New Delhi. Ramachandran tells us that a lady approached Crick during a cocktail reception at UCSD and, referring to the interesting work on the brain that was going on, asked him whether he could name any specific discovery that had led to really significant implications. "Well, my dear," Crick is reported to have replied, "One thing we have now learnt is that the brain is really plastic" (Ramachandran 2004).

An interesting observation on the adaptation of the brain to changed environmental conditions has been reported in studies on London taxi drivers. Eleanor Maguire and Katherine Woollett from the University College London's Institute of Neurology conducted structural MRI studies and neuropsychological analysis in licenced taxi drivers of London against a control group of bus drivers and demonstrated changes in the hippocampus of their brains. London taxi drivers have to keep in mind the whereabouts of 25,000 streets in the city and track down countless places of interest. They also have to undergo intense training and pass stringent tests before obtaining an operating licence (Maguire et al. 2006; Woollett et al. 2009). The report emphasizes the importance of intensive training and sustained efforts in achieving excellence in cognitive and psychomotor skills. Positive behaviour results from such efforts are also associated with corresponding changes in neuropsychological and structural brain mechanisms. In a later paper, Woollett and Maguire speculate on the reasons for the structural changes in the brain such as the 'ballooning' of the hippocampus in the London taxi drivers. Whereas the hippocampal response might be the result of the growth of more neurons and other supporting cells, the formation of richer connectivity among the existing nerve cells could be an added factor. A notable proportion of drivers in their study group had failed to get qualified in the knowledge and memory tests after their training. They have attributed this to the existence of a possible genetic predilection that made positive responses to environmental stimuli possible only by a certain proportion of adult brains. This, they feel, leaves the nature-nurture debate still open for further studies (Woollett and Maguire 2011). For us, living in an age of Satellite Navigated (Sat Nav) learning systems, it is not surprising if thinking about the London cabbies' exceptional proficiency evokes images of a 'biological GPS' in the days when its modern electronic counterpart had not arrived!

The Sanskrit Effect One of the features of the human brain in response to biological evolution is its highly developed capacity to acquire and store semantic memory. A strange if not curious observation in this regard has come to be known as the 'Sanskrit effect.' In their anatomical MRI volume studies in a group of eleven Vedic priests, Giridhar Kalamangalam and Timothy Ellmore showed increased cortical thickness in specific areas of the priests' brains compared to a similar group of non-priests. Their observations point to a unique ability of the human brain as in this case, where the Vedic priests trained in the oral traditions acquired the ability to retain semantic memory incorporated by hearing vast tracks of religious couplets in Sanskrit (Kalamangalam and Ellmore 2014). Similarly, a team of neuroscientists from the University of Trento, Italy and the National Brain Research Centre, in Gurgaon, India, showed evidence of brain organization (increased grey-matter thickness and cortical density) in a group of professional Sanskrit Vedic Pandits and memory specialists in response to intensive oral memorization/recitation of mantras (Hartzell et al. 2016). Energization of the brain and body in Benedictine monks by Gregorian chants was reported by Alfred Tomatis French physician, psychologist and ear specialist in 1967. A recent review of neuroimaging studies by a team of investigators in Brazil showed positive effects on the brains of volunteers practicing singing and chanting. There was evidence of participation of specific neural networks in different areas of the brain during the process of learning music and the production of meaning and musical quality of the song (de Amorim et al. 2017). More recently, researchers from the Centre of Buddhist Studies, University of Hong Kong and the Faculty of Psychology, University of Bergen, Norway, studied twenty-two participants of Buddhist chanting using electrophysiological and neuroimaging techniques. Their findings were two-fold: Religious chanting increased the activity of some specific areas of the brain such as the posterior cingulate cortex (PCC) which has strong connectivity with several areas of the brain and plays a significant role in the brain's Default Mode Network, learning and cognitive functions. Secondly, the changes were not related to the language (Sanskrit, Indic Prakrit, Japanese or Chinese) in which the chanting was performed (Gao et al. 2019).

Diet, Nutrition Nutrients play an important role and influence a broad range of brain functions. It is agreed that nutrients act on various cellular and molecular mechanisms in the brain (Gómez-Pinilla 2008). As in the case of any expensive vehicle, the brain also needs high-quality fuel for effective functioning! Food rich in vitamins, minerals, and antioxidants has a nourishing effect on the brain in addition to protecting it from oxidative stress. Consumption of food high in fat and sugar on the other hand is known to cause changes in brain regions dampening learning and memory. Neuroplasticity in response to nutrition has been attributed to changes affecting neurons in several specific brain regions. These include the hippocampus, prefrontal cortex and amygdala (Reichelt et al. 2017). Among the several dietary constituents that have been reported as modulators of neuroplasticity in the brain, Cristy Phillips of Arkansas State University, USA highlights the neuroprotective effects of polyunsaturated fatty acids such as Omega-3 fatty acids that have a role in normal neuronal functioning. Specifically, DHA (docosahexaenoic acid), one of the Omega-3 fatty acids, is a principal structural constituent of the human brain (Phillips 2017). Several studies in recent years suggest a link of diet-associated gut microbiome with impairment in the function of the hippocampus which has an important role in short-term, long-term and spatial memory (Tengeler et al. 2018). A raging controversy continues in the meanwhile on the merits or otherwise of plant-based diet on brain health with reports suggesting both positive and negative effects. Evelyn Medawar and colleagues at the Max Planck Institute in Leipzig, Germany reported on a systematic review of studies on the known effects of plant-based diet on metabolism and cognitive functions. Compared to the conventional Western diet, they noted favourable effects of plant-based diet in brain health and cognitive functions in healthy participants as well as in obese people and those with type-2 diabetes. The beneficial effects were seen in several areas such as weight status and energy metabolism. Their literature review, however, showed a paucity of studies designed for investigating the underlying mechanisms of these effects (Medawar et al. 2019).

Physical Activity The positive role of physical activities in promoting the health of body and mind has been known from ancient times. In Ayurveda, physical exercise is recommended for maintaining bodily health whereas yoga is suggested for mental health. Sušruta, the ancient Ayurvedic surgeon, cautions against vigorous exercises like excessive walking which could bring about weakness and emaciation of the body but advocates moderate exercise for improvement of memory and the functions of the sense organs. “A gentle walk or stroll, which is not very fatiguing to the body, tends, on the contrary, to improve his memory, strength, digestive capacity (*Agni*) and the functions of the sense-organs. It increases also the duration of life” (Sushruta Samhita 2008). Charles Tipton, professor emeritus of Physiology at the University of Arizona Health Sciences, describes Sušruta as ‘an unrecognized contributor to the history of exercise physiology’ and points out that Sušruta advocated moderate exercise because it “gives the desirable mental qualities of alertness, retentive memory, and keen intelligence” (Tipton 2008).

Several laboratory and field studies have identified the benefits of physical exercise on brain development. Engagement in physical exercises is recommended not only for improving physical fitness but also for enhancing cognitive and motor skill development and learning. Mirko Schmidt and co-workers from the University of Bern, Switzerland have proposed a three-way mechanism wherein achievement of executive function in the brain links academic achievement of children with their physical activity (Schmidt et al. 2017). Invoking the adage ‘use it or lose it’ is justified as much in relation to mind development as in the growth of muscle. In her paper on modulators of neuroplasticity, Cristy Phillips we saw earlier (Phillips 2017) has reviewed several experimental studies on changes in the microscopic structure and organizational complexity of neurons in response to prolonged physical activity in mice. Neuroplasticity is what makes such changes possible. Microstructural changes such as these have been related to the production of brain-derived neurotrophic factor (BDNF), a growth factor produced in the brain in response to physical exercise. Carl Cotman, professor of neurology at the University of California, Irvine School of Medicine is a pioneering researcher on the effects of physical exercise on cognitive function. Cotman has described BDNF as a "brain fertilizer." In their observations on human subjects and inexperimental studies in animal models, Cotman and associate Nicole Berchtold recorded increased levels of brain-derived neurotrophic factor in response to voluntary exercise. They are of opinion that in addition to stimulating the growth and development of nervous tissue, physical exercise mobilizes gene expression to promote neural plasticity (Cotman and Berchtold 2002).

Carlo Di Liegro and colleagues at the University of Palermo, Italy have looked at the possible mechanisms of improvement of brain health by exercise and how physical activity modulates the release of hormones and neurochemicals and the pathways that regulate the expression of the genes involved. They have also identified the key role played by BDNF in this. Among the wide range of exercise-related neurochemicals discussed by them are the endogenous opioids such as endorphins and enkephalins and the endocannabinoid, N-arachidonoylethanolamine, the "bliss molecule" – also known as anandamide (Di Liegro et al. 2019). Another intriguing observation is the beneficiary effects of electrically stimulating muscles compared to voluntary exercise reported by Japanese workers. Takehide Kimura and associates of Sapporo Medical University in Japan measured serum BDNF levels in eleven adult male volunteers after their thigh muscles were stimulated to a measured stimulus intensity and found that neuromuscular electrical stimulation was more effective in increasing serum BDNF levels than the voluntary performance of exercise (Kimura et al. 2019).

Connectome Can be defined as a simple wiring diagram of the brain – how the billions of neurons are connected by nerve fibre pathways in the various brain regions. For the best part of the last century, studies on brain structure and function remained confined to the 'grey matter' as it was considered the deciding component of neural activities. The 'white matter' composed of myelinated axons and nerve fibres involved in functional integration and interaction of the different subunits in the brain was relegated to a subordinate role. Advances in non-invasive imaging for white matter connectivity and data analysis in the last three decades changed all that and made real-time delineation of such connectivity and reconstruction of white matter tractography possible (Sotiropoulos and Zalesky 2017; Zhang et al. 2020). The Human Connectome Project was a 5-year non-invasive neuroimaging scheme instituted in 2009 by the National Institutes of Health (USA) to facilitate an integrated approach towards the collection, pre-processing, analysis and sharing of data and enable a better understanding of brain functions in healthy and pathological states (Glasser et al. 2016). Studies on the structural interconnections and functional linking of the brain and the neural network across scales call for an approach from cells to systems and necessitate a complex set of investigative tools and modelling approaches.

An interdisciplinary team of Danielle Bassett and Marcelo Mattar at the University of Pennsylvania have explored the future possibilities of such a neuroscience of learning. A vast number of studies, they point out, have looked at associations in the brain during learning at the microscopic scale such as forming of new synapses or the strengthening or weakening of the existing ones. At the same time, there is an emerging neuroscience that looks at changes happening in the brain at a grosser level – between entire brain regions. From the point of view of achieving unique insights on the role of neuroscience in human learning, they advocate integrating the lessons learned from advances in network approaches to neuroscience with the rich sources of neuroimaging data (Bassett and Mattar 2017).

Another team of scientists from Poland, USA and Germany investigated the adaptive changes in the functional brain networks during working memory training. Their study involved functional magnetic resonance imaging (fMRI) scans on participants while they performed a working memory task over a period of 6-weeks training. Phrased though in heavy technical language, their paper provides tangible insights into the dynamic connectivity of the functional neural network and its capacity for continually adapting to changing demands in the environment. Drawing on the work of several earlier investigators, they explain how the modular structure of the brain supports its adaptability in learning and performing tasks over varying time scales – spread over seconds to minutes during the performance of tasks and days to weeks during the process of learning. In some instances, such adaptability may be spread over years during growth and development (Finc et al. 2020).

Not surprisingly, an understanding of current neuroscience literature calls for a multidisciplinary perspective. By the same token, what is needed for future progress in the field is an integrative platform with participation by academics and researchers for the exchange of ideas, tools and techniques customarily restricted to individual fields – brain anatomy and physiology, physics, engineering, psychology, cognitive neuroscience, evolutionary and developmental biology, cellular and molecular biology, computational science, medical imaging science, philosophy, mathematics, algebraic topology, big data science and so forth. That network neuroscience was poised for such a multidisciplinary journey became obvious after Donald Hebb the Canadian psychologist introduced his postulate of computable approximation of communications between nerve cells and cell-assemblies more than 70 years ago. “When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it”, Hebb wrote in his magnum opus *The Organization of Behavior* “some growth process or metabolic change takes place in one or both cells such that A’s efficiency, as one of the cells firing B, is increased” (Hebb 1949).

Multidisciplinary participation remains the hallmark of a vast majority of investigations and publications in network neuroscience. The recent paper by an international team of investigators on the need to expand the understanding of the brain through multidisciplinary research initiatives amply illustrates this message. This calls for efforts to be initiated in several new directions such as fostering new ideas and creating new tools as well as training researchers capable of integrating experimental neuroscience with a host of other disciplines (Quaglio et al. 2017). The paper describing different forms of implementation of Hebb's rule to model a wide variety of problems by scientists at the Salk Institute of Biological Studies USA (Moldakarimov and Sejnowski n.d.), the chapter on Hebbian Learning and Plasticity by Wulfram Gerstner of the Swiss Federal Institute of Technology Lausanne, (Gerstner 2016) and the article on Hebbian Learning by Gianluigi Mongillo, a researcher at the French National Centre for Scientific Research, Paris (Mongillo 2012) are other examples. There are many more.

Cerebral Lateralization and Learning In 1981 Roger Sperry, Caltech neuropsychologist, shared the Nobel Prize for his work on what has come to be known as 'split-brain' research. Sperry subjected patients who had undergone surgical section of the corpus callosum (the dense fibrous bridge that connects the right and left halves of the brain) in patients with uncontrolled epilepsy. The callosum integrates the functions of the hemispheres in the normal brain. Although the patients were apparently unaffected in most of their daily activities following the operation, Sperry and his colleagues were able to demonstrate subtle changes in their cognitive, visual and motor functioning by specially designed psychoneurological tests. They concluded that the right and left cerebral hemispheres show specialization in their functions in terms of thinking, cognitive styles, language and executive capacity. Whereas the left hemisphere showed a predilection for linear, analytical and sequential thinking, the right hemisphere appeared specialized for intuition, inspiration and imagination, was more artistic, spatial and synthetic.

Sperry's work created considerable excitement among educationists and the general public in the 1980s and 1990s. There was a stream of media reports, books and monographs, not to mention articles in journals and magazines describing people (that included many celebrities like Einstein and Picasso) as 'left-brained' or 'right-brained.' Educational institutions were reproved for imparting 'left brain teaching.' A host of tools for 'right brain'/'whole brain' teaching appeared purporting to replace the skewed educational approach with 'scientifically' correct methods. The observation of Sperry in his Nobel Lecture that "The left-right dichotomy in cognitive mode is an idea with which it is very easy to run wild" (Sperry 1982) was overlooked in the flurry of the newfound theory of a dichotomous mind. Swayed by the passing tide of enthusiasm in Sperry's split-brain research, the present author was moved to portray the theme on canvas (Fig. 17.1).

It was soon recognized that fascination with right-brain teaching was another instance of misapplication of scientific theory in the social setting. Papers started to appear warning against the application of 'mindless' neuroscience not just in education but in other fields such as economics, marketing, law, politics, etc. Annukka

Fig. 17.1 *Harmony:* Acrylic on canvass Rangaswami (1987) Inspired by Roger Sperry's 'Split-brain research'

Lindell of the La Trobe University in Australia and Evan Kidd of the Manchester University, UK wrote a paper critiquing the trend of educators to blindly follow the neuromyth of brain dichotomy and identify people as right- or left-brained. This, they argue, would be counter-productive in the planning and development of curricula and teaching-learning strategies (Lindell et al. 2011). They advocate the inclusion of basic understanding of neuroscience as part of teacher training to enable teachers to more effectively evaluate the widespread claims of programs on 'brain-based' learning. Teachers also need to be empowered to search for and adopt tools verified and validated by independent research rather than follow ideas based on pseudoscience. Tom Billington of the School of Education, University of Sheffield, UK has drawn attention to the possible creation of "politized visions of normalcy and pathology" by the blind application of neuroscience in education. He cautions researchers, practitioners and educational policymakers against hurried acceptance of prevalent theories of educational neuroscience that focus on the susceptibility of young education seekers to psychological variations, thus paving the way for educational and social practices of exclusion (Billington 2017). One senses faint echoes of gender-based "jealous exclusion" in Mary Kendal's poem quoted below.

The importance of neurobiology in education gained heightened awareness after the 'Decade of the Brain' started in 1990. Neuroscience-education alliance remains a much-investigated topic today under different labels such as Neuroeducation, Educational Neuroscience and Mind, Brain and Education (Thomas et al. 2018). Despite a few dissenting voices against educational neuroscience as an interdisciplinary research field, there is a growing discourse on the legitimate connections of cognitive neuroscience, psychology and education. Formation of Societies, task forces and groups such as International Mind, Brain and Education Society (IMBES) and 'Neuroscience and Education' the special group formed by the European Association for Research on Learning and Instruction (EARLI) have been actively involved in several areas in the neuroscience-education scenario. There has been a parallel growth of new journals that attract original research papers and articles exploring the contributions of neuroscience to education. What is more, there is a perceptible trend towards creating awareness about the misinformation on the purported benefits of 'brain-based education.' The Task Force formed under the National Science Foundation facility (USA) took up as its mission the exploration of the 'black box' of biological and cognitive processes that underpin learning and highlighted the need for collaboration of scientists and educators that would promote attempts to rely on research on teaching and learning rather than following scientifically unacceptable myths about "brain-based education" (Fischer et al. 2010).

Gender Dichotomy No less noteworthy is the debate on gender dichotomy. Individuality in male-female behaviour has a long history dating back to myths and legends. The nineteenth century saw the emergence of two pseudoscientific beliefs: phrenology that claimed to predict mental abilities by measuring bumps on the skull and craniometry we saw earlier that categorized human intellectual attainment based on the measurement of the weight and volume of the brain. The strongly held belief on the inferiority of the female sex during the middle ages shored up by such pseudoscientific theories found powerful expression in social discourse and literary works in the nineteenth century. Among the many such works that carried significant weightage in Western thinking was the book *Mental Differences Between Men and Women* by George Romanes (1848–1894) Canadian-Scott biologist and physiologist. Based on mainly anecdotal evidences, Romanes claimed that the average weight of women's brain was less than that of men by about five ounces (approximately142 grams). Referring to some of Darwin's statements in *The Descent of Man* he gave an evolutionary twist to his postulate. He wondered how long it would take for the "woman of the future" to make up for the loss in the psychological race borne by the "woman of the past" and on a condescending note added, "but we may predict with confidence that, even under the most favourable conditions… it must take many centuries for heredity to produce the missing five ounces of the female brain" (Romanes 1887). Romanes' compelling misogynist arguments, however, didn't go uncontested even in his times. There were several voices that challenged the prevailing gender stereotypy. One of them was the Victorian poet May Kendall (1861–1943) who published satirical poems in Punch magazine some of them mocking at the male chauvinistic attitude.

> Though jealous exclusion may tremble to own us,
> Oh, wait for the time when our brains shall expand!
> When once we're enthroned, you shall never dethrone us —
> The poets, the sages, the seers of the land! (May Kendall, *Woman's Future* 1887) [4]

Katy Birch of Aberystwyth University, UK has explored Kendall's poems with her eyes on the poet's facetious portrayal of the anthropocentric and patriarchal values prevalent in Victorian society that conveniently leaned on some of Darwin's statements on evolution (Birch 2019).

[4] *Woman's Future* appears as the final poem in the "Science" section of Kendall's collection of poems *Dreams to Sell* (1887).

The 1930s and 1940s saw the emergence of another brain-mind-behaviour issue. This was related to the discovery of the influence of hormones on the brain and human thinking. Although the effects of ablation of gonads on sexual performance and behaviour in male animals and man were known from ancient times, precise understanding of the effects of 'secretions' from glands on behaviour and the overall wellbeing had to wait for experimental studies in animals and man in the first half of the twentieth century.

Brown-Séquard, Mauritian physiologist and neurologist, did precisely that. Brown-Séquard had a turbulent childhood and youth. Though he wanted to be a writer he was considered unsuitable for this and was forced to study medicine. He gained his medical degree in Paris in 1846 and is described to have grown up as an "impulsive, intuitive but erratic scientist" (Aminoff 2017). In 1856 he conducted several experiments in animals by removing their adrenal glands which were believed to be vestigial structures without any function. He showed that the internal secretions of these glands containing essential principles entered the bloodstream and acted at distant sites producing several effects. The concept of 'hormones' was born. Brown-Séquard is known for the outrageous experiments he carried out by injecting into his own body testicular extracts of dogs and guinea pigs – on ten separate occasions within a period of 3 weeks! In addition to an overall feeling of increased energy, he experienced perceptible beneficial effects of the hormonal extracts such as the restoration of his decreasing intellectual strength and cognitive performance to their earlier levels. This, he wrote was noticed after the first 2 or 3 days after starting the experiments (Brown-Séquard 1889). Brown-Séquard was 72 years old then!

Ernest Starling (1866–1927) the British physiologist was the first researcher to give a scientific explanation for the 'chemical control' of the functions of the body as opposed to the 'nervous control' and to name the chemical messenger as 'hormone.' The word hormone means 'I excite or arouse' in Greek. In the first of a series of four Croonian Lectures delivered before the Royal College of Physicians of London in 1905, Starling explained how these chemical messengers are repeatedly secreted and circulated through blood in response to the changing physiological needs of the body. He stated that the secretions, though small in quantity, entered and circulated in the bloodstream and exerted their effects in organs located distantly (Starling 1905).

The explanations based on astute clinical and experimental observations provided by Starling and his successors on the action of hormones on human physiology and behaviour left little doubt in the minds of succeeding generations of physicians and investigators. Public perception on the issue nonetheless continued to remain muddled in doubts and erroneous interpretations well into the middle of the last century.

In this connection, it will be informative to take a look at the thought-provoking sonnet *A Dream of Surreal Science* by Sri Aurobindo (1872–1950), the celebrated mystic poet-philosopher of modern India. The sonnet written in 1939 is a satirical portrayal of historical instances of human behaviour under hormonal influence adorned in engaging metaphorical language (Sri Aurobindo 1939). We get glimpses of Shakespeare, Homer, Gautama Buddha and Napoleon Bonaparte ending with a present-day scientist – all of them through the prism of poetics, philosophy and behavioural endocrinology and all of them acting under the injunctions of chemical secretions of glands. William Shakespeare is presented as a 'gland' that drank at the *Mermaid* and wrote *Hamlet* (the *Mermaid Tavern* was Shakespeare's favourite pub in London). Next comes Homer, depicted as "a committee of hormones on the Aegean's brink" that composed the *Iliad* and the *Odyssey*. Here, by "a committee of hormones" the poet is obviously alluding to the disputes surrounding the authorship of the Greek Classics. The Buddha is referred to as a "thyroid, almost nude, meditating under a Bo-tree," speaking of the Wheel and eightfold Path. Similarly, the critical decisions of Napoleon Bonaparte who "Thundered through Europe, conquered, ruled and fell" were made by a brain driven by a disordered stomach.[5] In his book *Life Divine* (Book I) Sri Aurobindo reiterates the theme and wonders how "a play of electrons, of atoms, of cells, and their resultant molecules, glands, chemical secretions and physiological processes manages by their activity on the nerves and brain of a Shakespeare or a Plato to produce … a Hamlet or a Symposium or a Republic" (Sri Aurobindo n.d.). A similar view (not stated in poetic language though) was expressed by Graham Wallas, British educationalist and social psychologist in his 1926 book *The Art of Thought*. Wallas, describing a four-stage model of creative process, made a passing reference to a range of emotional experiences set off by the secretions of endocrine glands. The words he chose to describe such hormone-induced emotional changes were: "euphoria or dysphoria – elation or discomfort, energy or inertia" (Wallas 1926).

The role of pheromones in communications between members of the same species may be mentioned here. Pheromones are chemicals with actions similar to those of hormones. But the difference is that pheromones secreted by one member and *carried in the air* are perceived by *other* members as smell and elicit specific responses. Pheromones are well-known messenger molecules that influence animal behaviour including sexual and mating behaviour. Ants and other social insects, for example, can distinguish members of their own colonies from aliens from other colonies based on pheromone-sensing. Information on the role of pheromones in human behaviour in the literature is controversial. The several investigations in this area have not yet been able to provide consistent inferences.

The vagaries of public perception notwithstanding, the first half of the twentieth century saw the blossoming of clinical and experimental studies on the role of hormones in health and disease. As Bruce McEwen of The Rockefeller University points out, several reports on the effects of steroid hormones on the brain took cognitive and behavioural sciences a step closer to the "Nature and Nurture" debate (McEwen 1988). New academic disciplines such as Behavioral Neuroendocrinology and Psychoneuroendocrinology were established with their exclusive societies for professional communications and interactions. Journals like *Psychoneuroendocrinology* and *Hormones and Behavior* attract scientific papers in these fields.

[5] The full text of the present author's 2008 article *A Sonnet for Hormones* can be accessed at: http://www.sriramachandra.edu.in/srjm/pdf/aug_2008.pdf

The issue of sex difference in the brain entered contemporary social discourse after Louann Brizendine, neuropsychiatrist and researcher published her much-acclaimed book *The Female Brain* in 2006. She highlighted the role of several hormones with known influence on the human brain discussed in neuro-literature and added several others less recognized that dictated the distinctiveness of behaviour in women. Brizendine's book *The Male Brain: A breakthrough understanding of how men and boys think* published 4 years later reinforced her message of hormone-dependent singularities in male-female attitudes and behaviour. Modern literature on the biology of sex differences is a rapidly expanding field with a burgeoning list of research articles on animal and human studies. *Biology of Sex Differences*, for example, is a peer-reviewed journal that focuses on sex differences in physiology, behaviour and disease from the level of molecules to the mature organism and publishes articles on basic and clinical research. Melissa Hines and colleagues of the University of Cambridge have reviewed a number of experimental studies on the relationship between early exposure of the foetus to male hormones (or a similar exposure in early infancy) and alterations in the development and organization of brain circuits and changes in the behaviour (Hines et al. 2015). They caution against hasty attempts to implicate a linear relationship between early exposure to androgen and behaviour changes and recommend guidelines for future studies that would ensure replicability and avoid spurious findings. The article includes a list of measures to increase the replicability of results and avoid unreliable findings.

In the meanwhile, the science of psychoneuroendocrinology moves on, and, strengthened by the application of techniques of molecular genetics and genomics as part of its investigative toolkit, is poised to make decisive contributions in several areas where human intelligence and behaviour play important roles – child development, genetic counselling, education, law, gender disputes, forensic investigations, etc. (Newey 2019; Ward et al. 2018). The editorial in a recent edition of the journal *Comprehensive Psychoneuroendocrinology* proposes a psychoneuroendocrinological approach towards understanding and ameliorating the stress-related consequences of the Covid-19 pandemic. The editorial comments on the vast amount of knowledge accumulated over the past several years on the nature of stress and its management by the psychoneuroendocrinology scientific community. Special mention is made on how microbial infection by itself or in combination with other stress-raising events can affect brain functions and cause changes in mood and behaviour. The editorial raises the importance of encouraging the publication of research papers on the ill-effects of stress from the pandemic of Covid-19 and how they can affect patients, caregivers and the community (Dantzer et al. 2020).

Angela Saini's recent book *Inferior* presents a compelling narrative on the motivations behind the noisy gender disputes that raged over the last several centuries. Her observations are based on her visits to research labs and interviews with investigators involved in cutting edge research on the biological basis of gender identity (Saini 2017). Among the many engaging anecdotes in the book, the story of Helen Gardener is particularly notable. Helen Hamilton Gardener was the pen name taken legally by Alice Chenoweth Day (1853–1925), American writer, reformer and political activist for woman suffrage. Gardener was a steadfast opponent of the then widely held belief that women's brains were smaller and weighed less. She crossed swords with such high-profile men as William Hammond, former Surgeon General of the US Army who firmly believed in George Romanes' theory that female brains weighed less. The bitter arguments went on and Gardener finally decided to bequeath her brain to Cornell University for study and research where it still remains. Denise Duhamel, a contemporary American poet, includes a pantoum 'Helen Hamilton Gardener's Brain' in her book *Scald* (2017) from which the lines below are taken: (Duhamel 2017).

> When it came to poor blacks, scientists
> argued those populations, too, had smaller brains – boys' and
> girls' nervous systems could be ruined by math.
> Even Gardener herself fell into the trap (Denise Duhamel (2017) *Helen Hamilton Gardener's Brain*).

In a conversation with Cassandra Callaghan of the University of Michigan School of Dentistry and Thomas Fink, American poet and literary critic, Duhamel points out the staring incongruity in Gardener's mind on racial inequality, turning the nature-nurture discussion on its head again. "Helen Hamilton Gardener was out to prove that women were just as capable as men—but she meant, sad to say, white women were as capable as educated white women" (Callaghan and Fink 2018).

Helen Gardener's story continues to inspire historians, authors and academics. The most recent example is her biography *Free Thinker* (2020) authored by Kimberley Hamlin, Associate Professor of History at Miami University (Hamlin 2020).

Modern Neuroimaging The introduction of modern neuroimaging techniques like functional MRI (fMRI) and PET scans has advanced clinical diagnosis and research in cognitive and behavioural neuroscience significantly. In vivo visual delineation of the dynamics of the human brain by these modalities offsets methodological constraints associated with earlier clinicopathological and imaging methods. The introduction of Diffusion Weighted and Diffusion Tensor Imaging of the brain have further revolutionized the visualization of white-matter fibre connectivity of the brain (connectome) in health and disease. Neuroimaging science today has emerged as big data science; a truly multidisciplinary endeavour with the participation of engineers, computer and network scientists, radiologists and data scientists for disentangling and deciphering the myriad streaming neural signals. The recent report by Kelly Servick, staff writer at *Science* on attempts to introduce 'two-person MRI' equipment for simultaneous scanning of two people, sounds intriguing. This would enable the study of two brains placed adjacent to each other as they exchange information based on simple sensory feedback such as eye contact and touch. It is bound to push the operational capability of the neuroimaging module beyond the present limits, and at the same time test the endurance of the individuals housed in the gantry (Servick 2020). It would be interesting in this context to let our imagination take us to Sherrington's 'enchanted loom' we saw earlier with its countless sparkling shuttles taken over by two such 'looms.' Today's machines can of course scan not just how our brains *look* but also what and how they *feel*, *think* and *remember* – two of them at the same time! Even more remarkable is the recent report by a multidisciplinary team of investigators at the University of California, Los Angeles of a wearable equipment for deep brain stimulation and recording during free movement of humans (Topalovic et al. 2020). The equipment includes a platform for direct brain stimulation and recording of intracranial and scalp electroencephalogram (EEG). The functioning can be integrated and synchronized by connecting the equipment with Virtual Reality (VR) and Augmented Reality (AR) systems and wearables that would allow external measurement of various parameters like heart-rate, respiration, eye-tracking and scalp EEG. This facilitates cognitive and clinical research studies in freely moving humans compared to the earlier methods where the subject remained confined in a restricted lab space connected to a diagnostic equipment. The wearable equipment accommodated in a backpack opens the possibilities for the development of treatment modalities for neurologic and psychiatric disorders, the authors claim.

It is conceivable that the rapid progress in neuroimaging hardware and processing, as well as in image acquisition, representation, analysis, visualization and interpretation involving professionals with diverse sets of expertise could invite novel challenges and controversies. The use of deep learning algorithms for neural imaging and brain mapping that harnesses a wide variety of software tools in medical imaging technology, neurophysiology, engineering, cell biology, optogenetics, immunohistochemistry and nanotechnology hold several promising possibilities for the future. Not surprisingly, the establishment of fail-safe systems and processes for effective management of such endeavours with multidisciplinary participation is an indispensable imperative. The recent research article by John Borghi of the University of California Curation Center (UC3) and Ana Van Gulick of the Carnegie Mellon University highlights the urgency of establishing good Research Data Management (RDM) systems and practices in neuroimaging to ensure rigour and reproducibility (Borghi and Van Gulick 2018).

The paper by Madhura Ingalhalikar and colleagues may be cited as a case in point. The publication of their paper that investigated gender discrepancies in the structural connectome of the human brain and the disputes that followed touch on two issues: one was the gender difference in brain connectivity demonstrated by the authors and the other the rigour and reproducibility of the neuroimaging data generated in their diffusion tensor imaging studies. The authors studied network characteristics in a large number of youths and reported greater connectivity *within* the cerebral hemispheres in males and predominant connectivity *across* the hemispheres in females with greater 'cross-module participation' in the latter. They concluded that in the case of males, the structural features of the brain enable better coordination of perception with action whereas in the case of females, the priority appears to be to achieve better communication between two predominant processing modes: analytical and intuitive (Ingalhalikar et al. 2014). In a letter to the Editor in the same journal a month later, Daphna Joel and Ricardo Tarrasch of Tel-Aviv University challenged the image analysis methods employed in Ingalhalikar's work. Their own interpretation of Ingalhalikar's data suggested intra- and interhemispheric connections in both male and female brains (Joel and Tarrasch 2014). Several research papers appeared in the meanwhile arguing for and against sex difference in connectome architecture. In fact, around the same time Vivek Kulkarni, Post-doc research scholar in the University of California, Santa Barbara and colleagues carried out connectome analysis of 114 individuals of both sexes using decision support systems (simple decision tree and support vector machine). They presented their findings in the Brain and Health Informatics International Conference in Maebashi, Japan in 2013 outlining some of the differences in brain networks across the sexes (Kulkarni et al. 2013). In a more recent paper Jiang Xin and team reported connectome structure differences between men and women. They analysed the data of 1065 young healthy subjects from the open-access data of the Human Genome Project using a 3D Convolutional Neural Network (CNN) method and deep learning technique. They too were able to confirm the structure difference between male and female brains (Xin et al. 2019). The postulation by Molly Hyer and colleagues of Virginia Commonwealth University, Richmond that structural differences at connectome or synaptic levels observed in males and females may be the result of neuroplasticity influenced differently by sex hormones such as oestrogen and testosterone extends the discussion to the field of neuroendocrinology (Hyer et al. 2018).

The Future of Learning The role of physiological and environmental factors in altering cognition and behaviour by harnessing the plasticity of the brain may be described as nature's method of responding to nurture. 'Nurture' in the contemporary world also involves external devices to support or boost neural functions. The computer has been used as an educational tool from the 1980s to provide an environment enabling the learner to focus on a content field at a chosen time and place of her preference. Today, Computer Assisted Learning (CAL) has found wide application in fulfilling the learning needs in all spheres of education and in promoting self-directed and life-long learning. Successful use of E-learning methods and devices such as the internet, smartphone, i-pad and e-book reader relies on the correct choice of software resources and optimization of the learner's interactions in the process. Several educational institutions in India have adopted CAL in recent years. This is an ever-expanding field and a lot has happened in the last few years. At the same time, unfettered reliance on navigational tools as expeditors of learning has also attracted criticisms of educators and academicians in recent years.

Stephen Cowden and Gurnam Singh of Coventry University, UK are highly critical of the present scenario where higher education is commoditized as a 'service provision' with teachers being perceived as 'service providers' and students as 'consumers' who attend universities to secure a 'good job.' It should come as no surprise that students in a consumerist pedagogy prefer to step aside from taking the risk of any exploratory journey of the unfamiliar and elect to be straitjacketed into predictable educational tracks. Cowden and Singh have chosen the felicitous expression 'Sat-Nav' (Satellite Navigation) for this kind of education. Sat-Nav, like our present-day GPS, will take you from point A to point B on a pre-determined route. While recognizing the need for online learning to complement didactic instruction in technical education, they argue against any kind of abstracted or packaged forms of commercialized learning (Cowden and Singh 2013). The importance of the choice of navigational software in CAL and the critical role of the teacher as an informed facilitator cannot be overemphasized. The unprecedented push toward online learning created by the recent viral pandemic and lockdown has resulted in an equally extraordinary situation where learning at all levels have become more computer-*dependent* than computer-*assisted*. As pointed out by a team of investigators from Tampere University in Finland, the unprecedented push towards online learning as a readily available quick-fix solution during the Covid-19 lockdown and social distancing has opened a lucrative market for digital learning platform providers to sell their products and services (Teräs et al. 2020). They raise doubts about the intention of the service providers when it comes to developing better learning opportunities. And that begs the question: what, if any, are the special features of the ed-tech solutions that can nurture learning brains in the days of lockdown and physical distancing?

Virtual and augmented reality systems are the other methods that have entered the arena of teaching-learning and skills acquisition. Virtual Reality flight simulators and clinical skills labs are examples. The recently reported study by scientists from the Tel-Aviv University on the introduction of social robots as teaching assistants to facilitate the learning activity of students opens up an intriguing possibility. The study employed qualitative and quantitative measures to assess the effectiveness of robot instructors on promoting active learning skills and group learning activities of students in higher education. A variety of statistical tools were used in the study. Although the robot could not directly participate in verbal communications, the students took the robot's presence on a positive note and the learning environment itself was perceived as effective. An added feature reported was the relative advantage on time management and objectivity in the robot-supported group (Rosenberg-Kima et al. 2020).

The last two decades have also seen an unprecedented surge in efforts to augment or even create cerebral functions by non-biological means. This has resulted to a large extent from lessons learned from reverse-engineering the brain. Computer algorithms and Artificial Intelligence have been used to create neuronal network simulations with ever-increasing accuracy, unveiling umpteen possibilities for learning and functional achievements beyond the imagination of science fiction. Deep learning and machine learning algorithms with the ability to outperform humans are now employed with increasing frequency.

Neural implants to replace missing or dysfunctional cerebral areas have been in existence for over four decades. The neuro-prosthetic device known as cochlear implant to help people with defective hearing is a case in point. The term "cybernetic organism" or "cyborg" is used to describe a person with a technological device linked to his body parts in a "biomechatronic" combination. Michael Chorost, author, technology theorist and himself a recipient of cochlear implants envisages a future in which direct brain-to-brain electronic connectivity would become possible in future, creating a World Wide Mind (WWM) "For, if one can feel people's inner life electronically, it may be easier to reach out and connect with them in person" (Chorost 2011). A team from the University of Washington, Seattle, led by Rajesh Rao described the first direct brain-to-brain interface in humans and presented results from experiments in six subjects. Their non-invasive method used a combination of two types of equipment: Electroencephalography (EEG) to record signals emanating *from* the brain and transcranial magnetic stimulation (TMS) for sending information *to* the brain (Rao et al. 2014). The possibility of brain to brain direct communication challenges our very concept of learning where the knowledge/skills held by the teacher or available in a resource-base are transmitted or accessed by the learner by concerted effort. The equipment for the brain to brain direct communication reported by the Seattle team recently in *Nature* combines neuroimaging and neurostimulation to great advantage permitting learning content to be perceived and shared simultaneously by several people through a "social network of connected brains" (Jiang et al. 2019).

It goes without saying that the traditionally understood roles of the teacher and the taught, the concept of the facilitator and learner and indeed of even the roles of nature and nurture in the process of learning are getting blurred, if not obliterated. Apprehensions about the erosion of ethical boundaries in such a scenario are also not ill-founded. Illegitimate access to brain information and breach of privacy come to mind as immediate concerns. Elizabeth Hildt of the Illinois Institute of Technology, Chicago has reviewed the current opinion on the ethical issues in multi-person brain-to-brain interphases. She stresses on the need to protect individuals from divulging sensitive personal details in brain-to-brain communication. Direct brain to brain communication binds the participants (whether two or multiple) in a range of ethical issues. Safety, confidentiality and infringement of personal autonomy are foremost among them. The author mentions the participants' concept of the self and sense of identity as "complex implications." She advocates the establishment of interdisciplinary teams of investigators and formulation of policies and guidelines before considering widespread applications of brain to brain and direct brain communications on a wider scale (Hildt 2019).

Reflection It is conceivable that the broad range of instructional resources and platforms, some of them informal, may make it a daunting task for the novice to advance beyond the lowest rung of Ackoff's[6] DIKW pyramid (Data, Information, Knowledge, Wisdom) (Ackoff 1999). Burdened with a surfeit of data and information, he will find progress towards knowledge – not to mention wisdom – an implausible goal. The cognitive overload allows little time to reflect on why or how he has learnt what he has learnt. In J. Krishnamurti's words, "The brain, as it is now, is the slave of knowledge… When the brain frees itself from its conditioning, then the brain is infinite… Education then is freedom from conditioning, from the vast accumulated knowledge of tradition" (Krishnamurti 2011). A mindset of life-long learning, free of all shackles is reflected in *Aun aprendo* ('I am still learning' in

[6] Russel Ackoff (1919–2009) was a pioneer in the field of operations research, systems thinking and management science.

Spanish) that Besant Hill School of Happy Valley in Ojai, California has taken as its motto.[7]

Reflecting on what one has learned is a crucial step in the learning process. A practical step was recommended by Leonardo da Vinci more than four centuries ago.

> I have often found it of use to recollect the ideas of what I had considered in the day, after I was retir'd to Bed, and incompass'd[8] with the Silence and Obscurity of the Night. For by thus repeating the Contours, and other parts of Figures which require a close attention, their Images are strongly impressed on the Memory, and familiariz'd to the Mind (Leonardo da Vinci (1970a): *A Treatise of Painting*).

da Vinci advocated 'reflection' from another point of view also. He advised the novice painter to survey the reflection of his painting in a plain mirror to identify any faults. It has been recorded that da Vinci was fond of making his notes in mirror writing.

> When he is at Work, it may be of Service to have a plain Mirror by him; wherein he may frequently survey his piece, which will be there represented backwards, and will appear as if it were the Work of some other Hand; for by this Means he will be the better enabled to distinguish its Faults (Leonardo da Vinci (1970b): *A Treatise of Painting*).

Today one doesn't need a mirror for appraising one's work "represented backwards." The computer screen provides instant mirror images (Fig. 17.2).

The attributes of da Vinci, prodigious thinker and learner that he was, and considered the archetype of human proficiency are elaborated by Michael Gelb in his book *How to think like Leonardo da Vinci*. Gelb enumerates seven principles in da Vinci's exceptional life and career that reveal an uncanny resemblance to modern-day adult learning principles well-suited to be taken as a roadmap for the learning brain (Gelb 1998):

- **Curiosità**– Curiosità in Italian means curiosity and refers to developing an approach to a life filled with curiosity and a relentless search for continual learning.
- **Dimonstrazione** – Willingness to subject what has been learned for verification by practical experience and preparedness to learn from mistakes.
- **Sensazione**– Essentially means sensation. Here 'sensazione' signifies efforts to keep the intellect and perception constantly sharpened.
- **Sfumato** – The actual meaning of the word is 'gradient.' da Vinci often spoke of 'sfumato' when advising young artists on the need to avoid sharp margins in a

[7] Besant Hill School of Happy Valley was founded in 1946 by a group of educationists and philosophers: Annie Besant, Jiddu Krishnamurti, Aldous Huxley, Robert Logan, Dr. Guido Ferrando, Desikacharya and Rosalind Rajagopal and Louis Zalk. The original name 'Happy Valley School' was changed to the present 'Besant Hill School of Happy Valley' in 2007. *Aun aprendo* was taken from one of Goya's last drawings (made when he was 80 years old). The sketch shows an old man leaning on two walking sticks. Goya had inscribed *Aun aprendo* on the top left-hand corner of the drawing.

[8] 'incompass' is an archaic form of 'encompass'.

Fig. 17.2 Computer-generated mirror image. *Dancing Shiva*: Acrylic on canvass Rangaswami (2007)

painting by dampening the edges. Here it means an open mind that readily accepts ambiguity and uncertainty.

- **Arte/Scienza** – Simply put, this means 'whole-brain' thinking; in other words, achieving an integral and balanced approach towards art and science.
- **Corporalita** – The word refers to corporality. Gelb has interpreted it here to mean cultivation of physical strength, beauty and grace.
- **Connessione** –Implies connection. In modern usage, this can be interpreted as systems thinking; the ability to appreciate the interconnectedness of phenomena.

It is not difficult to see how these qualities would fit in eminently with the attributes that any modern educational institution would like to see in its graduates.

The need for reflection on one's thinking was highlighted by Chris Argyris, Emeritus Professor at Harvard's Graduate School of Education (Argyris 2011). Argyris calls it 'double-loop learning.' Unlike 'single-loop' learning where one tries to find out the cause of an error and applies corrective measures, 'double-loop' learning calls for reflection on one's cherished beliefs and assumptions and involves an internal dialogue where one reflects on the way one thinks and learns.

Leslie Hoffman and associates from the Indiana University School of Medicine have reported a perceptible correlation between the ability to reflect among medical students and their professionalism (Hoffman et al. 2016). The authors advocate inclusion of reflective activities in the curriculum so that the students do not remain unconnected from the overall educational experience. This is not limited to medical students of course. Grigori Guitchounts, neuroscientist working for his PhD in

Harvard University, has recently published an engaging account of his reflections on the incredibly challenging task of working with massive amounts of data in his pursuit of understanding brain architecture and function (Guitchounts 2020). He describes how he was plagued by doubts whether his understanding has kept pace with the volume of data amassed. He calls this an ‘existential crisis’ in neuroscience. Imagining the prospects of unravelling the complex network diagram of the human brain and comprehend its abstruseness vis a vis the small ability at hand made him frightened and unsettled.

Richard Frackowiak and Henry Markram working for the BlueBrain Project in Switzerland based on their reflection “over half a decade” have published a cogent roadmap for creating a unifying framework for neuroscience. They hope this would change the approach to neuroscience from a “hypothesis-lead, reductionist approach … to a “data-led, hypothesis-generating strategy.” They have described a predictive simulation modelling method to achieve this (Frackowiak and Markram 2015). They feel that the cerebral cartography described by them will lead to more accurate documentation of human brain structure and function “from genes to cognition.” The cogent and self-explanatory figure in their article representing the operational features of brain both on the spatial and temporal scales is particularly eye-catching.

“Big data and small comprehension”: Guitchounts’s narration of the existential crisis reminds one of a similar dilemma of incomprehension in a learner’s spiritual journey faced by Śvetaketu in Chandogya Upanishd (eighth-sixth centuries BCE). We are reminded of the need for introspection while exploring the highest dimensions of awareness and being. Śvetaketu’s father noticed the young man conceited, immodest and proud when he returned after 12 years of education and studying all the Vedas (‘big data’!). The question the father asks his son is most illuminating: “O Śvetaketu, now that you are conceited, immodest and proud of being a learned man, did you ask (your teacher) about that instruction through which the unheard of becomes heard, the unthought of becomes thought of, and the unknown becomes known?” (Chandogya Upanishad n.d.). If this is not a call for ‘double loop learning’ or ‘meta learning,’ what is?

What could be more uplifting for our prodigious legacy, our learning brain, than the urge to introspect and transcend its nature-nurture disconnect?

In the meanwhile, we hold our breath and wait for the arrival of the reverse-engineered, digitally reconstructed brain of *Homo digitalis*! (MacKenzie 2020).

17.2 Postscript

The write-up *Musings of a surreal brain* below was prompted by reading the piece *Lucy’s Reverie* in Christian de Duve’s book *Life Evolving*. de Duve’s views on the involvement of genes in the nature-nurture debate was discussed earlier.

In November1974, Donald Johanson American paleoanthropologist and his graduate student Tom Gray discovered the fossilized remains of the bones of an upright female walking hominin near a tributary of the Awash river in the Afar region in Ethiopia. This specimen belonging to the species *Australopithecus afarensis* was labelled AL 288-1 and subsequently named Lucy after the Beatles' song *Lucy in the Sky with Diamonds*. Johanson was fond of playing the song in the camp during their archaeological expedition. Scientists estimated that Lucy who lived approximately three million years ago had a cerebral cortical area of 700 Sq. cm; approximately one-third of that of modern man.

In *Lucy's Reverie*, Christian de Duve invites the reader to an imaginary daydream of the young Australopithecine during a slumber after a day's labour in the Ethiopian savannah. de Duve describes a few awesome scenes that a hominid could be expected to dream three million years ago. "Awe, fright and bewilderment alternate in the unformed recesses of her consciousness, giving place, in a brief moment, to a strange, evanescent sentiment of pure joy…Then, everything dissolves into sleep… The next morning, nothing but a vague memory remains…" de Duve points to the meagreness of material in Lucy's dream; given the scanty cortical area of her brain – nothing like the contents in a modern mind with three-times the area. Totally missing in it would be any thoughts on art, science, religion, social life or even a modest assortment of our rich panorama of emotional experiences.

Christian de Duve then poses the question: what would happen if the area of modern human cerebral cortex were to be increased three times over? It may not be difficult then, he says, for our children to grapple with relativity and for many of us to handle black holes, superstrings and genetic vocabulary as we would manage the alphabet. A few pages later in the book, he talks about the urgency of enhancing all our mental faculties – our intelligence, our sensitivity and our imagination – as a most desirable goal; an almost unavoidable imperative for humankind. But how? It is certainly not attainable in the foreseeable future by following the natural course of biological evolution. de Duve offers two solutions: one by eugenically enhancing our faculties (that brings to mind the recommendations of Victorian polymath Francis Galton) and the other by rationally combining genetic and cultural influences. "What, until now, was driven only by natural selection has to some extent become dissociated from it by our ability to affect the direction of evolution."

It is the latter that is reflected in the *Musings*; the image of a chimerical future human brain endowed with a cortical area of over 6000 Sq.cm as it ruminates over its all-pervading capabilities.

Research in simulation neuroscience is accelerating at an exponential pace with the participation of scientists from multiple disciplines with the support of cutting-edge technology. Reverse-engineering the brain involves understanding the algorithms that define the structural and functional characteristics of neural networking and communication and digitally recreating them. Efforts in this area are progressing at a furious pace in several research centres and neuroscience labs across the world. The BlueBrain Project is one such effort. It is a Swiss initiative under Écolepolytechnique fédéralede Lausanne – EPFL (Swiss Federal Institute of Technology Lausanne) and aims at creating biologically detailed digital reconstruction and simulation of the brain. The Project is well on its way to building a digitally reconstructed mouse brain. This, we are told, is to be followed by digitally reconstructed mammalian and eventually human brain. Henry Markram, Israeli neuroscientist, is the Director of the BlueBrain Project. Subtle references to some of the views expressed in the Project's reports can be recognized in the *Musings*.

Musings of a Surreal BrainWas it reverse-engineering or eugenics that brought me here? my cortical area nine times Lucy's brain and three times yours, ?The sulci and gyri in my *engineered loom*, the hippocampus, amygdala and corpus callosum, are digitally reconstructed and my genome edited with , my ready to hand editor of genes!Nature and nurture dwell in me in an unbroken course as in a Möbius strip.My was sculpted to perfection and molecular precision with special reference to algebraic topology. The all-important software was tested and ratified for assured execution and never-to-err operation.I'm connected with billions of brains and trillions of neurons: World-Wide-Mind is my omnipotent mission.I can create *Hamlet* at a moment's notice, with no need to call at the *Mermaid Tavern*; not to mention the *Iliad*, *Odyssey* and the *Mahabharata* too!Painting *Last Supper* and *Guernica* by the ready hand of mine – why, even *Crucifixion* on a – is never tiresome for me; catching the puzzled looks of da Vinci, Picasso and Dali at my unfailing flair keeps me forever immensely amused.The impeccable algorithm of my synaptic connectivity syncs with Newton and Einstein and countless other high-brows, well-known and not so well-known – men and women, past and present.Nutrients, hormones and physical workout? Don't even mention them to me. My network ingenuity makes them look archaic nothings. – dopamine, BDNF, anandamide – call them what you will, are woefully inapt to keep my shape or boost my strength.Synapses fire at my digital will and my connectome cares little for Darwin nor for his theory. Evolution no more is what it was; evolution for me is digitally hastened and never is it going to slip out of human hands.My cortical area, my volume and weight you strain so much to measure, come to nothing before my digital beauty and the of my awesome connectome. What counts is my singularity, my immaculate network dynamics.Yes, *Homo digitalis*, that's who I am!O, , give me a chance, and watch me wake up Lucy's pigmy brain, her australopithecine relic with a digital stroke and get her to mumble *Aun aprendo*!

References

Ackoff, R. (1999). *From data to wisdom in Ackoff, R. L. (1999) Ackoff's best* (pp 170–172). New York: Wiley. faculty.ung.edu › kmelton › Documents › DataWisdom.

Aminoff, M. J. (2017). The life and legacy of Brown-Se'quard. *Brain, 140*, 1525–1532. https://doi.org/10.1093/brain/awx071.

Argyris, C. (2011). Teaching smart people how to learn. In *On managing people*. Boston: Harvard Business School Publishing Corporation.

Arnold, R. (2015). Role of pilot lack of manual control proficiency in air transport aircraft accidents: 6th international conference on applied human factors and ergonomics (AHFE 2015) and the affiliated conferences, AHFE 2015. *Procedia Manufacturing, 3*(2015), 3142–3146. https://doi.org/10.1016/j.promfg.2015.07.862.

Bae, B.-I. I., Jayaraman, D., & Walsh, C. A. (2015, February 23). Genetic changes shaping the human brain. *Developmental Cell, 32*. https://doi.org/10.1016/j.devcel.2015.01.035.

Barlow, F. K. (2019). Nature vs. nurture is nonsense: On the necessity of an integrated genetic, social, developmental, and personality psychology. *Australian Journal of Psychology, 71*, 68–79. https://doi.org/10.1111/ajpy.12240.

Bassett, D. S., & Mattar, M. G. (2017, April). A network neuroscience of human learning: Potential to inform quantitative theories of brain and behavior. *Trends in Cognitive Sciences, 21*(4), 250–264. https://doi.org/10.1016/j.tics.2017.01.010.

Billington, T. (2017). Educational inclusion and critical neuroscience: Friends or foes? *International Journal of Inclusive Education, 21*(8), 866–880. https://doi.org/10.1080/13603116.2017.1283717.

Birch, C. (2019). "Are monads so much less than men?": Interspecies hierarchies and the female brain in may Kendall's evolutionary poetry. *Nineteenth-Century Gender Studies, 15*(3) pure.aber.ac.uk › portal › files › birch › are monads… ncgsjournal.com › issue153 › birch.

Borghi, J. A., & Van Gulick, A. E. (2018). Data management and sharing in neuroimaging: Practices and perceptions of MRI researchers. *PLoS One, 13*(7), e0200562. https://doi.org/10.1371/journal.pone.0200562.

Bouchard, T. J., Jr., Lykken, D. T., McGue, M., Segal, N. L., & Tellegen, A. (1990). Sources of human psychological differences: The Minnesota study of twins reared apart. *Science, 250*(1990), 223–228. https://doi.org/10.1126/science.2218526.

Brodmann, K. (1909). *Brodmann's localisation in the cerebral cortex: The principles of comparative localisation in the cerebral cortex based on cytoarchitectonics (*L. J. Garey, Trans.). Springer. www.appliedneuroscience.com › PDFs › Brodmann.

Brown-Séquard. (1889, July 20). The effects produced on man by subcutaneous injections of a liquid obtained from the testicles of animals. *The Lancet*. www.usrf.org › news › TRT.

Callaghan, C., & Fink, T. (2018, January 18). Exchange with Denise Duhamel on *Scald* posted in *Dichtung Yammer*. dichtungyammer.wordpress.com › 2018/01/18 › exchange.

Capra, F. (2007). *The science of Leonardo*. New York: Anchor Books.

Captain Sully's Minute-by-Minute Description of The Miracle On The Hudson | Inc. (n.d.). www.youtube.com › capt. sully › watch.

Chandogya Upanishad. (n.d.). *Chandogya Upanishad: With the Commentary of Sankaracharya and Translated by Swami Gambhirananda. Chapter VI, Section 1 verses 2 & 3 Published by Advaita Ashrama (Second Edition 1992, pp. 406–409).*

Chorost, M. (2011). *World wide mind: The coming integration of humanity, machines, and the internet* (p. 167). Free Press (Simon & Schuster Inc.).

Cotman, C. W., & Berchtold, N. C. (2002, July). Exercise: A behavioral intervention to enhance brain health and plasticity. *Trends in Neurosciences, 25*(6), 295–301. https://doi.org/10.1016/S0166-2236(02)02143-4.

Cowden, S., & Singh, G. (2013). Sat-Nav education: A means to an end or an end to meaning? In S. Cowden & G. Singh (Eds.), *Acts of knowing: Critical pedagogy in, against and beyond the university*. London: Bloomsbury, 2013.

Crick, F. H. C. (1995). *The astonishing hypothesis: The scientific search for the soul* (p. 11). London: A Touchstone Book. Published by Simon & Schuster.

Dantzer, R., Heuser, I., & Lupien, S. (2020, February–May). Editorial Covid-19: An urgent need for a psychoneuroendocrine perspective*., Comprehensive Psychoneuroendocrinology, 1–2*, 100003. https://doi.org/10.1016/j.cpnec.2020.100003.

de Amorim, G. O., Albuquerque, L. C. A., de Araujo, P. L., Balata, P. M. M., Luckwü-Lucena, B. T., & da Silva, H. J. (2017). Contributions of neuroimaging in singing voice studies: A systematic review. *Revista. CEFAC, 19*(4), 556–564. https://doi.org/10.1590/1982-021620171942317.
de Duve, C. (2002). *Life evolving: Molecules, mind and meaning* (p. 264). New York: Oxford University Press.
Di Liegro, C. M., Schiera, G., Proia, P., & Di Liegro, I. (2019, September). Physical activity and brain health. *Genes, 10*(9). https://doi.org/10.3390/genes10090720.
Duhamel, D. (2017). Helen Hamilton Gardener's Brain in *Scald*. University of Pittsburgh Press. ISBN 10: 0822964503.
Eccles, J. C., & Gibson, W. C. (1979). *Sherrington his life and thought*. Berlin/Heidelberg: Springer.
Finc, K., Bonna, K., He, X., Lydon-Staley, D. M., Kühn, S., Duch, W., & Bassett, D. S. (2020). Dynamic reconfiguration of functional brain networks during working memory training. *Nature Communications, 11*(2020), Article number: 2435. https://doi.org/10.1038/s41467-020-15631-z.
Fischer, K. W., Goswami, U., & Geake, J. (2010). The future of educational neuroscience. *Mind Brain and Education, 4*(2), 68–80. https://doi.org/10.1111/j.1751-228X.2010.01086.x.
Frackowiak, R., & Markram, H. (2015). The future of human cerebral cartography: A novel approach. *Philosophical Transactions of the Royal Society B, 370*, 20140171. https://doi.org/10.1098/rstb.2014.0171.
Fuchs, E., & Flügge, G. (2014). Adult neuroplasticity: More than 40 years of research. *Neural Plasticity*, 1–10. https://doi.org/10.1155/2014/541870.
Gao, J., Leung, H. K., Wu, B. W. Y., Skouras, S., & Sik, H. H. (2019, March 12). The neurophysiological correlates of religious chanting. *Nature Scientific Reports, 9*(1), 4262. https://doi.org/10.1038/s41598-019-40200-w.
Gawron, V. (2019). *Automation in aviation–accident analysis – MTR 190013 MITRE* (Technical report, 2019). www.mitre.org › pr-16-3426-lessons-lost-accident-analysis.
Gelb, M. J. (1998). *How to think like Leonardo da Vinci: Seven steps to genius every day*. Bantam: Doubleday Dell Publishing Group Inc.
Gerstner, W. (2016). Hebbian learning and plasticity. In M. A. Arbib & J. J. Bonaiuto (Eds.), *From neuron to cognition via computational neuroscience* (p. 2016). MIT Press. ISBN 978-0-262-03496-8.
Glasser, M., Smith, S., Marcus, D., et al. (2016). The human connectome project's neuroimaging approach. *Nature Neuroscience, 19*, 1175–1187. https://doi.org/10.1038/nn.4361.
Gómez-Pinilla, F. (2008, July). Brain foods: The effects of nutrients on brain function. *Nature Reviews Neuroscience*, (9/7), 568–578. https://doi.org/10.1038/nrn2421. https://www.ncbi.nlm.nih.gov › pmc › articles › PMC2805706.
Gould, S. J. (1981). *The mismeasure of man*. London: W. W. Norton & Company.
Guitchounts, G. (2020, January 23). An existential crisis in neuroscience Issue 81: *Maps – Nautilus*. nautil.us › issue › maps › an-existential-crisis-in-neuroscience.
Hamlin, K. A. (2020). *Free thinker – Sex, suffrage, and the extraordinary life of Helen Hamilton Gardener*. W. W. Norton & Company. ISBN -10 1324004975.
Hartzell, J. F., Davis, B., Melcher, D., Miceli, G., Jovicich, J., Nath, T., Singh, N. C., & Hasson, U. (2016, May). Brains of verbal memory specialists show anatomical differences in language, memory and visual systems. *NeuroImage*, *131*(1), 181–192. https://doi.org/10.1016/j.neuroimage.2015.07.027. Epub 2015 July 15.
Hebb, D. O. (1949). *The organization of behavior: A neurophysiological theory*. Wiley. s-f-walker.org.uks-f-walker.org.uk › pubsebooks › pdfs › The_Organization of Behavior.
Hildt, E. (2019). Multi-person brain-to-brain interfaces: Ethical issues. *Frontiers in Neuroscience, 13*, 1177. https://doi.org/10.3389/fnins.2019.01177.
Hines, M., Constantinescu, M., & Spencer, D. (2015). Early androgen exposure and human gender development. *Biology of Sex Differences, 6*(3). https://doi.org/10.1186/s13293-015-0022-1.

Hoffman, L. A., Shew, R. L., Vu, T. R., Brokaw, J. J., & Frankel, R. M. (2016, June). Is reflective ability associated with professionalism lapses during medical school? *Academic Medicine, 91*(6), 853–857. https://doi.org/10.1097/ACM.0000000000001094.

Hyer, M. M., Phillips, L. L., & Neigh, G. N. (2018). Sex differences in synaptic plasticity: Hormones and beyond. *Frontiers in Molecular Neuroscience, 11*, 266. Published online 2018 Jul 31. https://doi.org/10.3389/fnmol.2018.00266.

Ingalhalikar, M., Smith, A., Parker, D., Satterthwaite, T. D., Elliott, M. A., Ruparel, K., Hakonarson, H., Gur, R. E., Gur, R. C., & Verma, R. (2014, January 14). Sex differences in the structural connectome of the human brain. *PNAS, 111*(2), 823–828. https://doi.org/10.1073/pnas.1316909110.

Jiang, L., Stocco, A., Losey, D. M., Abernethy, J. A., Chantel, S. Prat, C. S., & Rao, R. P. N. (2019). BrainNet: A multi-person brain-to-brain interface for direct collaboration between brains: *Scientific Reports* (Nature Research) www.nature.com › scientific reports › articles. https://doi.org/10.1038/s41598-019-41895-7.

Joel, D., & Tarrasch, R. (2014, February 11). On the mis-presentation and misinterpretation of gender- related data: The case of Ingalhalikar's human connectome study. *PNAS, 111*(6) E637 Published online 2014 Jan 29 |. https://doi.org/10.1073/pnas.1323319111.

Kalamangalam, G. P., & Ellmore, T. M. (2014, October). Focal cortical thickness correlates of exceptional memory training in Vedic priests. *Frontiers in Human Neuroscience*, *8*, Article 833, 1–7. https://doi.org/10.3389/fnhum.2014.00833. https://www.frontiersin.org › articles › fnhum.2014.00833 › full Accessed on 11 Dec 2019.

Kimura, T., Kaneko, F., Iwamoto, E., Saitoh, S., & Yamada, T. (2019). Neuromuscular electrical stimulation increases serum brain-derived neurotrophic factor in humans experimental. *Brain Research, 237*(1), 47–56. E-pub 2018 Oct 10. https://doi.org/10.1007/s00221-018-5396-y.

Krishnamurti, J. (2011 Reprint 2017). Is life a movement of pain with occasional happiness? In The whole movement of life is learning: J Krishnamurti's Letters to His Schools: (42, p. 150) Krishnamurti Learning Foundation Trust Ltd. Also accessible at infed.org › mobi › jiddu-krishnamurti-and-his-insights-into-education.

Kulkarni, V., Pudipeddi, J. S., Akoglu, L., Vogelstein, J. T., Vogelstein, J., Vogelstein, R., Ryman, S., & Jung, R. E. (2013, October 29–31). Sex differences in the human connectome conference paper *in Brain and health informatics international conference*, BHI 2013, Maebashi, Japan, Proceedings. https://doi.org/10.1007/978-3-319-02753-1_9.

Leonardo da Vinci. (1970a). *A treatise of painting* (Translated from The Original Italian 1721) (pp. 34–35). https://openlibrary.org/books/OL23349833M/A_treatise_of_painting Accessed on 24 Jan 2020.

Leonardo da Vinci. (1970b). *A treatise of painting* (Translated from The Original Italian 1721) (pp. 138–139). https://openlibrary.org/books/OL23349833M/A_treatise_of_painting. Accessed on 24 Jan 2020.

Lindell, A. K., Kidd, E., & Why Right-Brain Teaching is Half-Witted. (2011). A critique of the misapplication of neuroscience to education. *Mind, Brain, and Education, 5*(3), 121–1270. https://doi.org/10.1111/j.1751-228X.2011.01120.x.

MacKenzie, R. J. (2020). The Markram interviews part three: The blue brain project July 28, 2020. www.technologynetworks.com › neuroscience › articles › markram interview.

Maguire EA, Woollett K, Spiers HJ (2006) London taxi drivers and bus drivers a structural MRI and neuropsychological analysis. Hippocampus. 16(12):1091–1101. https://www.fil.ion.ucl.ac.uk › Maguire › Maguire2006. https://doi.org/10.1002/hipo.20233.

McEwen, B. S. (1988). Steroid hormones and the brain: Linking "nature" and "nurture". *Neurochemical Research, 13*(7), 663–669. https://doi.org/10.1007/BF00973285.

Medawar, E., Huhn, S., Villringer, A., & Witte, A. V. (2019). The effects of plant-based diets on the body and the brain: A systematic review. *Translational Psychiatry, 9*, 226. https://doi.org/10.1038/s41398-019-0552-0.

Meshberger, F. L. (1990). An interpretation of Michelangelo's creation of Adam based on neuroanatomy. *Journal of the American Medical Association, 264*(14), 1837–1841.

Moldakarimov, S. B., & Sejnowski, T. J. (n.d.). *Neural computation theories of learning*. papers.cnl.salk.edu › PDFs › Neural Computation Theories of Learning.

Mongillo, G. (2012). *Hebbian learning in the encyclopedia of the sciences of learning* (N. M. Seel, Ed.). https://doi.org/10.1007/978-1-4419-1428-6_1898.

Nemani, A., Yücel, M. A., Kruger, U., Gee, D. W., Cooper, C., Schwaitzberg, S. D., De, S., & Intes, X. (2018, October 3). Assessing bimanual motor skills with optical neuroimaging. *Science Advances, 4*(10), eaat3807. https://doi.org/10.1126/sciadv.aat3807.

Newey, P. J. (2019, November). Clinical genetic testing in endocrinology: Current concepts and contemporary challenges. *Clinical Endocrinology, 91*(5). https://doi.org/10.1111/cen.14053.

Newman, E. A., Araque, A. & Dubinsky, J. M. (Eds.). (2017). Book review of *The beautiful brain: The drawings of Santiago Ramón y Cajal*. New York: Harry N. Abrams. Reviewed by Ariane Dröscher, University of Trento: *Nuncius*, *33*(2018) 137–170.

Nicholls, D., Sweet, L., & Hyett, J. (2014). Psychomotor skills in medical ultrasound imaging: An analysis of the core skill set. *Journal of Ultrasound in Medicine, 33*(8), 1349–1352. https://doi.org/10.7863/ultra.33.8.1349.

Noble, D. (2015). Conrad Waddington and the origin of epigenetics. *The Journal of Experimental Biology, 218*, 816–818. https://doi.org/10.1242/jeb.120071.

Passey, G. E. & Mc Laurin, W. A. (1966). *Perceptual-Psychomotor tests in aircrew selection: Historical review and advanced concepts'* US Air Force Systems Command. apps.dtic.mil › dtic › perceptual-psychomotor tests … › fulltext.

Penfield, W. (1961). *Activation of the record of human experience: Summary of the lister oration delivered at the Royal College of Surgeons of England on 27th April 1961*. www.ncbi.nlm.nih.gov › pmc › articles › PMC2414108 › lister › oration.

Penfield, W., & Boldrey, E. (1937, December). Somatic motor and sensory representation in the cerebral cortex of man as studied by electrical stimulation. *Brain, 60*(4), 389–443. https://doi.org/10.1093/brain/60.4.389.

Penfield, W., & Rasmussen, T. (1950). *The cerebral cortex of man: A clinical study of localization of function*. New York: Macmillan.

Pevsner, J. (2019, April 6). Leonardo da Vinci's studies of the brain. *The Lancet, 393*(10179), 1465–1472. https://doi.org/10.1016/S0140-6736(19)30302-2.

Phillips, C. (2017, June). Lifestyle modulators of neuroplasticity: How physical activity, mental engagement, and diet promote cognitive health during aging. *Neural Plasticity*. https://doi.org/10.1155/2017/3589271.

Portera-Sánchez, A. (2001a). Who was Cajal? In P. C. Marijuán (Ed.), *Cajal and consciousness* (Annals of the New York Academy of Sciences, Vol. 929, p. 257).

Portera-Sánchez, A. (2001b). Who was Cajal? In P. C. Marijuán (Ed.), *Cajal and consciousness* (Annals of the New York Academy of Sciences, Vol. 929, Quote from Recollections of my life: Autobiography of Cajal, p. 257).

Quaglio, G., Corbetta, M., Karapiperis, T., Amunts, K., Koroshetz, W., Yamamori, T., & Draghia-Akli, R. (2017, March). Understanding the brain through large, multidisciplinary research initiatives. *The Lancet Neurology, 16*(3), 183–184. https://doi.org/10.1016/S1474-4422(17)30020-0.

Raichlen, D. A., & Polk, J. D. (2013, January 7). Linking brains and brawn: Exercise and the evolution of human neurobiology. *Proceedings of the Royal Society Biological Sciences, 280*(1750). https://doi.org/10.1098/rspb.2012.2250.

Ramachandran, V. S. (2004). The astonishing Francis Crick (Guest editorial). *Perception, 33*, 1151–1154. https://doi.org/10.1068/p3310ed.

Rao, R. P. N., Stocco, A., Bryan, M., Sarma, D., Youngquist, T. M., Wu, J., & Prat, C. S. (2014). A direct brain-to-brain Interface in humans. *PLoS One, 9*(11). https://doi.org/10.1371/journal.pone.0111332.

Reichelt, A. C., Westbrook, R. F., & Morris, M. J. (2017). Editorial: Impact of diet on learning, memory and cognition. *Frontiers in Behavioral Neuroscience, 11*, 96. https://doi.org/10.3389/fnbeh.2017.00096.

Romanes, G. J. (1887). Mental differences between men and women in George Romanes – *Deviance, disorder and the self: Sexuality* (p. 666). www.bbk.ac.uk › sexuality › romanes › 17-5-0 romanes.

Rosenberg-Kima, R. B., Koren, Y., & Gordon, G. (2020, January 13). Robot-supported collaborative learning (RSCL): Social robots as teaching assistants for higher education small group facilitation. *Frontiers in Robotics and AI, 6*, Article 148. https://doi.org/10.3389/frobt.2019.00148.

Saini, A. (2017). *Inferior: How science got women wrong – And the new research that's rewriting the story*. London: 4th Estate – Harper Collins.

Schmidt, M., Egger, F., Benzing, V., Jäger, K., Conzelmann, A., Roebers, C. M., & Pesce, C. (2017, August 17). Disentangling the relationship between children's motor ability, executive function and academic achievement. *PLoS One*. https://doi.org/10.1371/journal.pone.0182845.

Servick, K. (2020). In two-person MRI, brains socialize at close range. *Science, 367*(6474), 133. https://doi.org/10.1126/science.367.6474.133, also at https://doi.org/10.1126/science.aba8276

Shaffer, J. (2016, July). Neuroplasticity and clinical practice: Building brain power for health. *Frontiers in Psychology, 7*, 1–12. https://doi.org/10.3389/fpsyg.2016.01118.

Sherrington, S. C. (1906). *The integrative action of the nervous system internet archive* 2008. http://www.archive.org/details/integrativeactio00sheruoft

Sherrington, S. C. (1940). *Man on his nature* (pp. 177–178). Cambridge University Press (1953).

Simpson, E. (1972). *The classification of educational objectives in the psychomotor domain: The psychomotor domain* (Vol. 3). Washington, DC: Gryphon House. detonline.org › module5 › Psychomotor Objectives.

Snyder, P. J., & Whitaker, H. A. (2013). Neurologic heuristics and artistic whimsy: The cerebral cartography of Wilder Penfield. *Journal of the History of the Neurosciences, 22*, 277–291, Taylor & Francis Group, LLC. https://doi.org/10.1080/0964704X.2012.757965.

Sotiropoulos, S. N., & Zalesky, A. (2017). Building connectomes using diffusion MRI: Why, how and but. *NMR in Biomedicine*. 2019*, 32*, e3752. https://doi.org/10.1002/nbm.3752.

Sperry, R. (1982). Some effects of disconnecting the cerebral hemispheres Nobel lecture December 8, 1981. Bioscience Reports 2, 265–276. https://www.nobelprize.org/www.nobelprize.org › prizes › medicine › 1981 › sperry › lecture.

Sri Aurobindo. (1939). *A dream of surreal science*. Sri Aurobindo Birth Centenary Library 1972 (Vol. 5, Collected poems. p. 145). Sri Aurobindo Ashram Pondicherry. www.aurobindo.ru › workings.

Sri Aurobindo. (n.d.). *Life Divine* (Book I) Sri Aurobindo Birth Centenary Library 1972 (Vol. 18, p. 299). Sri Aurobindo Ashram Pondicherry www.aurobindo.ru › workings.

Starling, E. (1905). The Croonian lectures on the chemical correlation of the functions of the body: Delivered before the Royal College of Physicians of London on June 20th, 22nd, 27th & 29th (p. 6). *Internet Archives* ark:/13960/t76t4b555.

Stiles, J. (2011, December). Brain development and the nature versus nurture debate. *Progress in Brain Research.* https://doi.org/10.1016/B978-0-444-53884-0.00015-4.

Sushruta Samhita English Translation. (Ed.), Kaviraj Kunjalal Bhishagratna (Vol. II). *Chikitsa Sthanam* (Chapter XXIV, p. 491) (Internet Archive 2008). http://www.arcliive.org/details/englislitranslatiOOsusruoft

Tengeler, A. C., Kozicz, T., & Kiliaan, A. J. (2018, August 1). Relationship between diet, the gut microbiota, and brain function. *Nutrition Reviews, 76*(8), 603–617. https://doi.org/10.1093/nutrit/nuy016.

Teräs, M., Suoranta, J., Teräs, H. & Curcher, M., (2020). Post-Covid-19 education and education technology 'solutionism': A Seller's market. *Postdigital Science and Education* (Published Online 13 July 2020). https://doi.org/10.1007/s42438-020-00164-x.

Thomas, M. S. C., Ansari, D., & Knowland, V. C. P. (2018). Annual research review: Educational neuroscience: Progress and prospects. *The Journal of Child Psychology and Psychiatry*. https://doi.org/10.1111/jcpp.12973.

Tipton, C. M. (2008). Susruta of India, an unrecognized contributor to the history of exercise physiology. *Journal of Applied Physiology, 104*, 1553–1556. https://doi.org/10.1152/japplphysiol.00925.2007.

Topalovic, U., Aghajan, Z. M., Villaroman, D., Hiller, S., Christov-Moore, L., Wishard, T. J., Stangl, M., Hasulak, N. R., Inman, C. S., Fields, T. A., Rao, V. R., Eliashiv, D., Fried, I., & Suthana, N. (2020). Wireless programmable recording and stimulation of deep brain activity in freely moving humans. *Neuron*(IF 14.415). https://doi.org/10.1016/j.neuron.2020.08.021.

Voss, P., Thomas, M. E., Cisneros-Franco, J. M., & de Villers-Sidani, É. (2017, October 04). Dynamic brains and the changing rules of neuroplasticity: Implications for learning and recovery. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2017.01657.

Wallas, G. (1926). *The art of thought.* Butler & Tanner Ltd. Internet Archive (p. 78). https://archive.org › details › theart of thought.

Ward, T., Wilshire, C., & Jackson, L. (2018). The contribution of neuroscience to forensic explanation. *Psychology Crime & Law, 24*(3). https://doi.org/10.1080/1068316X.2018.1427746.

White, C., Rodger, M., & Tang, T. (2016). Current understanding of learning psychomotor skills and the impact on teaching laparoscopic surgical skills. *The Obstetrician and Gynaecologist, 18*(1), 53–63. https://doi.org/10.1111/tog.12255.

Woollett, K., & Maguire, E. A. (2011, December 20). Acquiring "the knowledge" of London's layout drives structural brain changes. *Current Biology, 21*(24–2), 2109–2114. https://doi.org/10.1016/j.cub.2011.11.018.

Woollett, K., Hugo, J., Spiers, H. J., & Maguire, E. A. (2009). Talent in the taxi: A model system for exploring expertise. *Philosophical Transactions of the Royal Society B, 364*, 1407–1416. https://doi.org/10.1098/rstb.2008.0288.

Xin, J., Zhang, Y., Tang, Y., & Yang, Y. (2019, March 8). Brain differences between men and women: Evidence from deep learning. *Frontiers in Neuroscience*. https://doi.org/10.3389/fnins.2019.00185.

Zhang, J., Chen, K., Wang, D., Gao, F., Zheng, Y., & Yang, M. (2020, April 8). Advances of neuroimaging and data analysis: Editorial in *Frontiers in Neurology*. https://doi.org/10.3389/fneur.2020.00257.

Part III
Learning and Technology

Chapter 18
Merging Education Systems with Humanware

Michael L. Mathews

18.1 Introduction

People are fascinated with new technological advances in the medical, science, and education disciplines. There are thousands of breakthroughs in each discipline in combination with technology. The famous Moore's law of technology; that technology advances at a given rate is verified and proved over the past 48-years. This animation can be viewed at Visualizing Moore's Law in Action[1].

All advancements have only proven we can develop better systems, while cancer, addictions, suicide, depression, and anxiety loom over society at increasing rates. The reason is simple; we have separated the human heart and being from the advancements. Humanware takes a holistic approach to technological advances and brings the two together for a greater outcome. An article describing the holistic approach can be viewed at https://www.cccu.org/magazine/reflections-that-transform/.

By taking an even high approach, we can see how humans are connected to the world in a rhythmic fashion.

[1] Visualizing Moore's Law in Action (1971–2019) – https://www.visualcapitalist.com/visualizing-moores-law-in-action-1971-2019/?fbclid=IwAR3BokAmQjdhdBkKjHmLducV3x9Et11i8g05cCJc27mP_lWC4sCtFdt7JIQ

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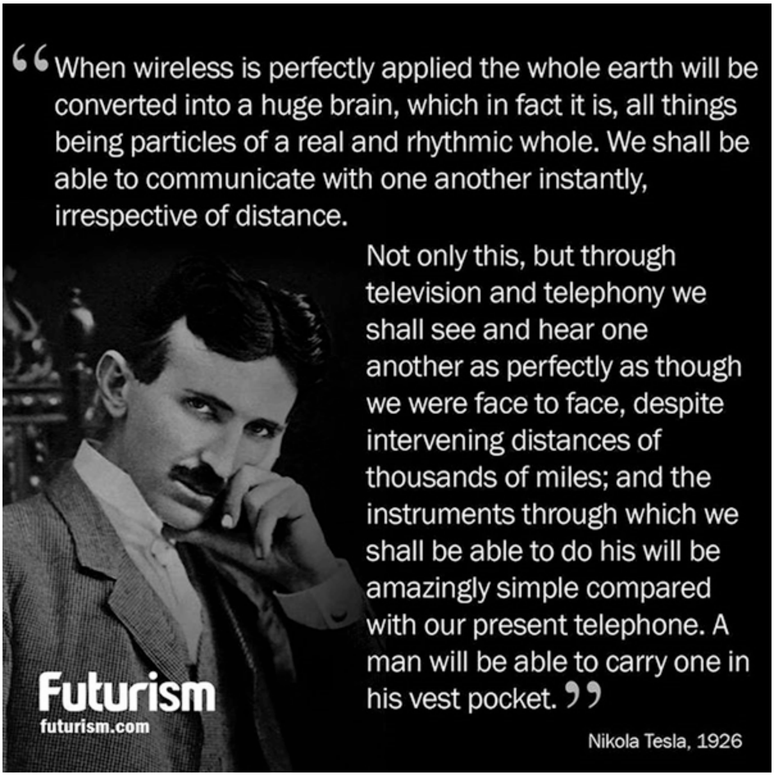
18.2 The Rhythmic Filling of the Entire Earth with Knowledge

I recently shared the power of digital electrons floating through space to a group of students and leading professors. Even though the audience were all users of smartphones and modern-day wireless connections at their favorite coffee shops, they did not realize the power of *all things* digital and circular throughout the earth. I shared the following aspects of electrons with the audience who have toured Oral Roberts University's new Global Learning Center.

1. An electron is the size of 1-billioneth of the smallest atom.
2. A digital electron can transfer through the earth's air at the speed of 124,000 to 186,000 miles per second.
3. An electron can hit every square mile of the earth in less than 18 s.
4. A string of electrons can carry a text message between two containers of liquid without any power connected to those two containers.
5. The digital electrons carrying educational information can be delivered anywhere in the world, who has Oral Roberts University digital signal to receive it on any device capable of connecting to the web.
6. The digital electrons leaving ORU's Global Learning Center can transmit the equivalent of 36 million 300-page books every day.

The abovementioned aspects are made possible as the air we breathe operates in a digital transmitting cosmos. This means that electrons can move across the air and be "attenuated" with wireless antennas to move at rates close to the speed of light. Combining the digital transmission rates with technologies such as augmented and virtual reality allows us to transfer knowledge and intelligence in a non-ending circular fashion around the world. With the state-of-the-art capabilities of the Global Learning Center, we have demonstrated the instantaneous teleportation between people from other parts of the world – who are simply connecting through our digital transmission. Without appearing as "mystical," we have beamed in people from multiple rooms and from multiple devices at the exact same time. In addition, we have demonstrated augmented reality much like Pokémon Go from an academic perspective, which can be accessed anywhere in the world by EON Reality. Oral Roberts University and EON Reality's academic and enterprise edition of augmented and virtual reality (AVR) allows digital electrons to be placed on a piece of paper or within an email and sent anywhere in the world. The electrons being sent in and out are able to wirelessly decode over 7000 academic learning objects. This video attempts to show this capability.

After 12 years of working at Cray Research and 12 years at SunGard Data Systems, people naturally assume that I am some sort of data genius. After basking in the few short moments of people thinking I am a genius, I share the reality of what may have been known for years. After reviewing the quotation below by inventor Nikola Tesla in 1926, you may conclude that his vision of geo-related technology, including wireless, would surely classify him as heretic even in the year 2017.



It may not seem possible; however, Nikola Tesla envisioned the Internet of Things (IoT) before the first World Wide Web connection was even referred to as the Internet. He completely wrapped his visual mind on the scientific discoveries that just allowed me to demonstrate the phenomenal breakthrough aspects of Oral Roberts University's Global Learning Center.

Until recently, current discoveries with technological advances could not allow most humans to understand the things envisioned in 1926, let alone the things mentioned thousands of years ago. People could not believe as they could not visualize them, touch them, or see them in action. However, the words chosen by Tesla "When wireless is perfectly applied the whole earth will be converted into a huge brain, which in fact it is, all things being particles of a real and rhythmic whole" actually describe the Internet of Things. It is important to note that one of Tesla's other statements which allow us to see where his thinking was at was "If you wish to understand the universe, think of energy, frequency, and vibration." The full aspects of wireless broadcast technology, the Internet, and digital electrons all relate to energy, frequency, and electrical vibrations in the cosmos.

Summary It is exciting to realize that the world is ready to experience new discoveries, as well as reveal discoveries known thousands of years ago that relate to the energy, frequency, and vibrations of the earth's cosmos which Tesla mentioned.

These revelations and discoveries of global connectedness have ignited the innovative efforts at Oral Roberts University. We have defined and now trademarked two new concepts related to reaching all the world with new paradigms in technology advancements. The two words being trademarked by Oral Roberts University along with their definitions are:

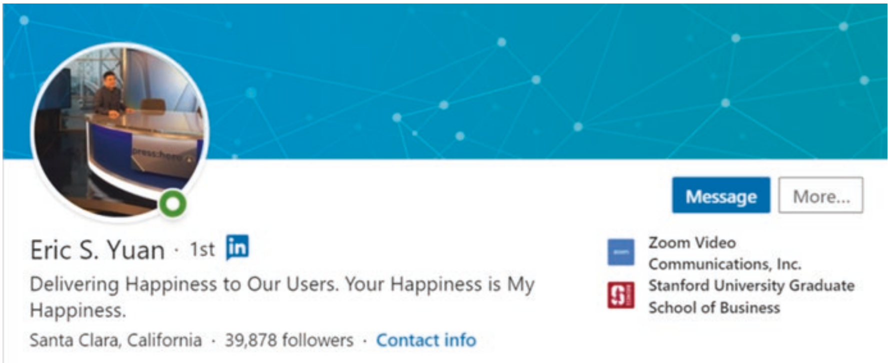
1. ORU Geovision Technologies – Global educational services using a geospatial data structure to deliver digital bytes of information and data to students via smartphones, tablets, other smart devices, virtual reality glasses, or other wireless, wearable, virtual learning, virtual reality, or telepresence objects or devices carried or worn by the students
2. ORU Geonetics – The study and analysis of digital phenomena that aligns and connects people via geospatial and global information systems on a global scale to improve the education and well-being of humanity

The latest geospatial intelligence, the Internet of Things, alongside augmented reality, virtual reality, and artificial intelligence morphing into "mixed reality" will literally transform the methods in which society can access education, knowledge, and intelligence (Mathews and Krigsman 2017; Mathews 2018, 2019a, 2019b, 2019c). The whole of the earth being rhythmically connected is Tesla's vision come to pass, in due season. However, if we look back thousands of years ago, the same concept of energy, frequencies, and vibrations is described in ancient Bible writings by King David when he stated "Heavens declare the glory of God; the skies proclaim the work of his hands. Day after day they pour forth speech; night after night they reveal knowledge. They have no speech, they use no words; no sound is heard from them. Yet their voice goes out into all the earth, their words to the ends of the world… It rises at one end of the heavens and makes its circuit to the other; nothing is deprived of its warmth."

The word *circuit* that was used thousands of years ago allows us to see the connectedness of all the technologies that would eventually be discovered and revealed. We are truly living, working, and discovering in the greatest of time. This connectedness through geo-technologies will truly provide a rhythmic brain that sheds new knowledge and intelligence at the speed of light. Another way to say the same thing is "there is an increasing rhythmic filling of the entire earth with knowledge and intelligence, made possible with geo-technologies."

18.3 Accelerating Beyond "Happy" with Advancements in Technology

Last week I saw three corporate slogans for Zoom that echo the words "We Deliver Happiness." One of these was directly on the LinkedIn Profile of Eric S. Yuan, Zoom's Founder and CEO. The next day I saw the below eye-catching banner at an airport. I recall thinking to myself that this is one of the most creative marketing ideas I have ever seen. To tie the word "happy" to the everyday web-conferencing activities that we are all engaged with is a creative way to make the feeling of Zoom fatigue more appealing.



Reflecting on using "happy" alongside technology solutions reminded me that happiness is a great feeling. However, happy is also very temporal and elusive. My mind quickly traveled over the past 10 years on the many uses of technology. In this quick mind travel, I was amazed at how much good has come from advancements in technology. These technological advancements have sped up language translations, helped blind people see, helped disabled individuals walk, cured numerous diseases, eradicated polio, and most recently helped a 17-year-old student-intern at NASA discover a new planet. Cray Research also announced the deployment of the first Exascale supercomputer, which will be delivered to Oak Ridge National Laboratory and outperform the combined calculating speed of the current fastest 160 supercomputers.

The list of advancements and discoveries could go on and on. The potential for this much computing power, invention, and innovation is simply indescribable. However, the intentional persuasion to be "happy" about all these advancements may be just as elusive as the term "happy" itself. I believe we must be more intentional with the technologies entrusted to civilization, lest we are misled with the next generation of technological feats and accomplishments.

The slogan by Zoom of creating "happy" is an impressive statement, yet is only scratching the surface of the real breakthroughs the technology can bring forth. There is indeed a renaissance with people who grasp the profound challenges humanity faces and how technology creates a different world than we know today.

The concept of creating a happy environment, service, or even world populace is in vogue. In 2019, former Google executive Mo Gawdat created an organization called One Billion Happy.

The premise behind this initiative of creating one billion happy people has to do with the emergence of artificial intelligence. The foundation of this organization has tremendous potential to help force a happy environment or society. Unfortunately, the objective of creating happy people is still elusive and unmeasurable. As the old saying goes, "Many people climb a ladder only to get to the top and find out that the ladder has been leaning against the wrong building." The premise for trying to create one billion happy people makes sense when you consider that artificial intelligence can only replicate the behavior of people, things, or machinery. The intent to create happiness is so that artificial intelligence will not replicate the perceived current behavior of people. This perceived current behavior includes hatred, selfishness, bigotry, prejudice, racism, anger, and political bias. If artificial intelligence lives up to its true systemic nature, it will learn the current behavior of modern-day humanity. I give Mo Gawdat a lot of credit for this endeavor of attempting to switch the behavior toward happiness, as it is better than the current state. However, there may be a few different attributes other than happiness hidden within humanity that can be measured and create an even more systemic change in our society. These may include joy, peace, love, hope, and faith.

Artificial intelligence can watch, observe, record, and replicate the patterns that our human society is performing and behaving like. The ability to videotape, record, and archive human behaviors through artificial intelligence is a breakthrough. The breakthrough occurs as our civilization can hear, see, observe, and analyze what we truly look and sound like. The most significant forms of self-change are when people finally see what they sound, look, and behave like. I realize that we do not need technology to step back and see, hear, observe, and analyze what we have become. This analysis is truly what faith, hope, and love are all about. Unfortunately, many people have become delusional and unaware of the simplicity of joy – which develops unity, peace, faith, hope, and love.

If I wake up each morning feeling happy, it is a completely different feeling than waking up full of joy. Happiness may be defined for each one very differently, such as do I have enough cars, money, homes, friends, knowledge, college degrees, etc. Joy, on the other hand, is easy to see and easy to measure as it is a state of heart and mind that learns to be content no matter what things I possess or don't possess. Discovering the joy of being content with any circumstance allows me to express peace, faith, hope, and love. In essence, joy becomes my inner strength. May I suggest we will get far more inner change and societal change with human joy than just happiness.

My premise for this article is to make a statement that technology is nothing more than a modern way to eventually manifest how people think, act, and behave. If the outcome of technology is merely happiness, we may be very disappointed. One of the most recognize songs in American history is the 1971 song "I'd like to teach the world to sing." The song was written on behalf of Coca-Cola to align the message of "perfect harmony" with their sugar water, called Coca-Cola. In 2020, Zoom and One Billion Happy are aligning "happiness" with the use of technology. In both cases, the marketing is clever and works for a few years, yet the pain within our society has never been greater. Technology needs to aid in attributes that accelerate way beyond happiness.

May I call upon every technologist, visionary, and technology company to look well beyond the vision of making people happy. We have the ability with data science, the Internet of Things, 5G, and the fastest supercomputers in the world, to help people see that there are far greater attributes than just being "happy."

I am pleased to report that two organizations have accelerated well beyond "happy." UNITE714 has organized a movement that brings "unity" across the globe to have people pray for the world in ways that far exceed happiness. They are now bumping up against the first billion people to gather and assemble for a more significant cause than "happy." They have united 889 million individuals around the world as they leverage the latest technologies. Shekhar Kallianpur, a visionary in Mumbai, India, started a movement called the 4AM Challenge (Billion Home Altars) well before COVID-19. Ironically, this vision allowed hundreds of millions in India to be prepared for a season of quarantine.

Whether it is One Billion Happy, UNITE714, or Billion Home Altars, it is clear that there are a growing number of organizations stretching the use of technology to virtually reach billions of people with technologies like Zoom. It behooves all of us to think through how each organization will define and impact how people are stretching humanity to accelerate past "happy" into life-changing attributes such as peace, unity, love, hope, and faith.

18.4 Leveraging Disruptions vs. Creating Disruptions

Years ago, I worked for Dan McLaughlin, a phenomenal leader at Cray Research Inc. Dan would challenge me every time I had an innovative idea. He would say, "Mike, I like your idea, but you will need to say the same thing, but use different words to convey your idea." It was his way of letting me know that innovative ideas are difficult to convey and more people will embrace the change. His wisdom forced me to use many different visuals and words to help the myriad of people that I wanted to embrace my ideas. Dan's advice helped me shorten the innovation adoption cycle and allowed me to challenge others to use the appropriate phrase(s) to convey their own innovative ideas.

18.4.1 Disruptive Technology Is Not the Same as Disruptive Innovation

In the mid-1990s, Dr. Clayton Christensen[2] came up with the term *disruptive innovation* as the metaphor for suggesting changes to business processes, industry, and society. Technology vendors loved this concept, but they changed the phrase to *disruptive technology*, which made a self-serving assumption that technology made the innovation a reality. Most companies did this to sell their technology devices and solutions as the silver bullet to change business processes, industries, or areas of society. In many ways, technology can change certain aspects of business and society. However, there is little evidence that things are changing in the right direction,

[2] https://claytonchristensen.com/

except that technology companies are starting to become the new Fortune 500 leaders.

The in vogue and flawed phrase *disruptive technology* allowed technology companies to see their revenue skyrocket. The burden of the disruption was on the back of the users of the technology. Clayton Christensen's proper phrase (theory) "disruptive innovation" leverages process improvement and a balance in technology, but doesn't let technology drive the disruption. The improper phrase "disruptive technology" forces itself upon industry or society due to its glamour, while seldom changes things for the better. When the later use is applied, the technology will generally create more work and confusion among people.

After 20 years of creating a lot of "perceived" changes with disruptive technology, people have become overwhelmed and bewildered with all the disruption. Some of the widespread depression and anxiety related to work and family is the result of two to three generations of fashionable technology that never really improved things. It is merely wishful thinking under the guise that "disrupting" people, business, industry, and society with technology is always positive. Instead, a belief that technology with a sole purpose to cause disruption has put people on the proverbial gerbil wheel. Clayton Christensen's original theory of "disruptive innovative" was reasonable, but changing the phrase and intent was a colossal mistake.

About 5 years ago, while witnessing all the false promises of technology being caused by "disruptive technology," I changed my own personal mission statement as a Chief Information Officer (CIO) to read "Help people survive and thrive in the global and digital age in which we find ourselves." The number of people feeling overwhelmed made me realize that the more disruption was being fabricated, the less likely people were embracing it. The statement of the Cray Research Inc. leader rang in my ears, "Mike say the same thing, but use different words." I started to publicly speak out that I was opposed to disruptive technology, but was completely supportive of leveraging technology to solve world problems. In essence, I changed the phrase "disruptive technology" to "transformative technology." This personal shift has created a 50X improvement in reaching people worldwide, alongside a full list of digital transformation measurements for higher education.[3]

18.4.2 Aligning Real Disruption with Technology

COVID-19 has proven to illuminate Clayton's theory, opposed to purposefully fabricating disruption to sell technology. We are all currently witnessing a real disruption across the globe that allows technology to be leveraged to transform the issues we now encounter. While most of the world was slowed down by the global

[3] https://hubspot.cioreview.com/cioviewpoint/the-cios-best-friend-a-digital-transformation-index-nid-24393-cid-236.html

pandemic, I could sense the reality that this may be the first real global disruption we have seen in generations. It was also clear that people could quickly embrace the innovative ideas in the making for years. The innovations that were in the shadows for years no longer needed "different words" to explain them, as they were required to address health, education, finance, communications, and regulatory challenges. Within 4 months of COVID-19, the disruptive innovation of Zoom grew from 20 million users to 350 million users, while people realized they could do business and education and have collaboration and relationships in a limited, but surely, innovative manner.

I witnessed things that took me 20 years to explain quickly become embraced. I heard leaders say, "I finally understand what you have been talking about." In a very humble way, I realized that a real disruption was needed to allow many innovations in technology to be embraced. Dan's words still echo in my ear, as I realized we are all saying the same thing, but using different words such as COVID-19, global pandemic, shelter in place, lockdown, limited air transportation, borders closed, 14-day quarantine periods, etc.

I invested 24 years of my career in seeing professors embrace the value of technology to do more virtual, distance, remote, and online learning. With just a few word changes, they flipped the switch and saw the innovations waiting in the shadows. Ironically, Dr. Clayton Christensen passed away just before the COVID-19 pandemic: January 23, 2020. I am reasonably sure that he is on the other side, grinning that his theory has held true. However, he also sees that you can't fabricate disruptions for the benefit of technology; but you can leverage technology when a true disruption occurs.

One of the best examples illustrating disruptive innovation occurred with a very simplistic and wholesome global movement called UNITE714[4], which started in March 2020. This movement can easily be named the largest virtual ongoing viewing by people in human history. This unified front or coalition of relationships has resulted in over 889 million people viewing or participating in this "virtual cosmos of humanity" for one purpose. Until April 2020, the largest virtual or online gathering was the April 2020 Fortnite concert[5] with slightly over 12.5 million people. What we are seeing is a new disruptive innovation that allows virtual gatherings like UNITE714 to be in perpetual motion. This continuous motion with UNITE714 is being described as a "virtual cosmos" or "virtual ecosystem." Granted, a Fortnite concert is a decent call to action, but the call for anyone to pray twice a day across the virtual cosmos since March 2020 is unprecedented. Keep in mind; this has happened during the very time that many churches around the world have not been able to meet. Many people would call this a Black Swan[6] event.

[4] https://www.unite714.com/

[5] https://www.theverge.com/2020/4/23/21233946/travis-scott-fortnite-concert-astronomical-record-breaking-player-count

[6] https://en.wikipedia.org/wiki/Black_swan_theory

Prior to the disruption of COVID-19, a clergy member or movement would have a difficult time getting 800 people to pray in a unified fashion, let alone across all religious groups around the world. I know many of my colleagues and friends who have tried for years to get religious groups to leverage technology. It took a global disruption to leverage the innovative technologies that have been waiting in the shadows.

For years, clergy have minimized technology by using it to make themselves look and sound better. With one global disruption, they are reaching out around the world with no pretense, other than praying, caring, and sharing across the cosmos – everywhere digital signals are found across the Internet (social media, email, newsletters, YouTube, Vimeo) and cable TV platforms.

One final example is the Children's Guild Alliance[7], which immediately switched their October 2020 Kid's First Conference[8] from a national conference to a global conference for K12 teachers across the world. This shift was a quick "re-tooling" to step up their mission to help 100% of the world versus just the 3% of the world living in America. Based on this shift, the entire line-up of keynote speakers has shifted to include worldwide leaders like John Baker from the global learning management system company, D2L.[9]

A true disruption produces true results, as it leverages the very innovations that have been talked about for years!

18.5 Accelerating Innovation to Deliver the Impossible in Education

18.5.1 COVID-19: Making History in Education

In 2007, I was privileged to sit next to Admiral John Ryan, former Chancellor for the State University of New York. Dr. Ryan waited for everyone to get up from the

[7] https://childrensguild.org/

[8] https://kidsfirstconference.org/

[9] Desire to Learn; https://www.d2L.com

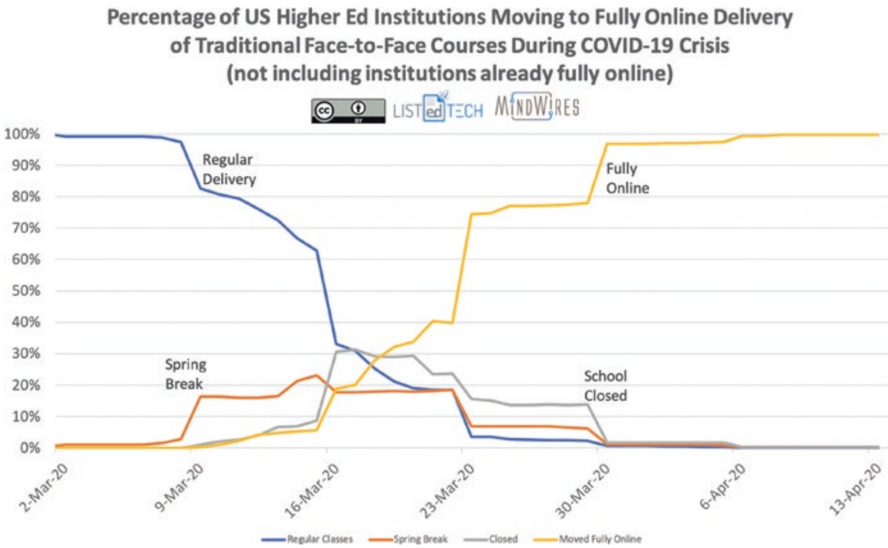
conference table and glanced at me and personalized these words “Mike, do you know you can do the impossible, however in order to do the impossible you have to know the right timing.”

Coming from a Chancellor who oversaw 64 universities with 80,000 faculty and 425,000 students, this was a profound statement. As I thought about his statement, I could only image how desperately he wanted to influence higher education and do the impossible. Fortunately, Admiral Ryan was wise enough not to try the impossible during the wrong season of time.

As the years have passed, I would often reflect on these words by the former chancellor. Like thousands of others, I have also had many glimmers of hope that the 60 million students engaged in K12 and higher education would eventually see a transformation.

18.5.2 The Day of the Impossible Arrived

During March 2020, the season of change for education arrived through COVID-19. It was now time to test the impossible that John Ryan referenced. By the end of March 2020, 90% of all education was switched to virtually and/or online. The timing was finally right to see the impossible occur. The chart below illustrates the impossible switch that education accomplished over a 4-week period of time.



To put this in perspective, Zoom™ grew their customer base from 20 million to 300 million during a 90-day window of time. To put this in perspective, imagine any other utility such as cable, electricity, or sewer/water handling that kind of customer increase without failing. Zoom, along with thousands of education organizations, accomplished this transformation live, with minimal interruptions.

This impossible moment in time reminded me of the 15-year-old book by Nicholas Carr – *Does IT Matter?* (http://www.nicholascarr.com/?page_id=23). Carr's premise was IT should be a utility and run behind the scenes. May I suggest that the changes during COVID-19 proved that IT in education has become better than a utility. To switch the tracks in this short window of time, while keeping the trains moving with minimal downtime, is doing what John Ryan mentioned "the impossible, in the right season of time."

The same type of miracle that happened in 1954 when Roger Bannister broke the 4-minute mile just occurred in education during COVID-19. Since that initial miracle performed by Roger Bannister, over 1400 other runners have broken the same barrier of running a sub-4 minute mile. The miracle of transitioning curriculum and classes online into the virtual world via cloud services like Zoom™ has allowed educators to think differently: outside of the classroom box. Never before have faculty, administration, staff, and students imagined what can occur in less than 30 days.

At Oral Roberts University, the world-renown Global Learning Center, built in 2017, allowed the transition to a fully virtual environment to happen in less than 2 days. The Global Learning Center technology had been prepared and ready for a few years – but the impossible could not happen until the timing was right. COVID-19 opened the flood gate for the impossible to occur.

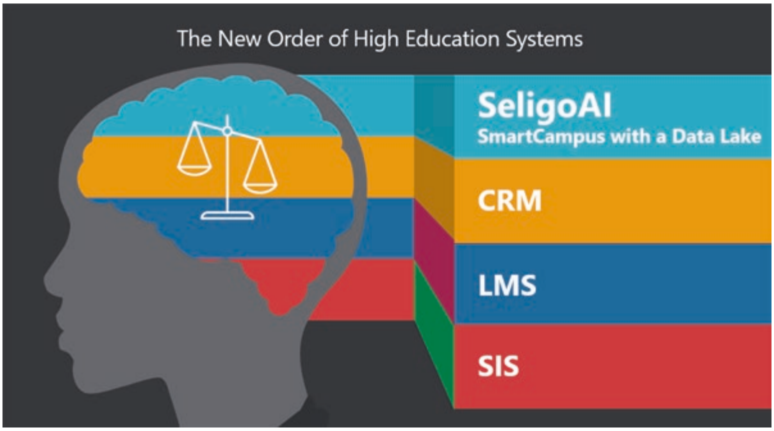
18.5.3 Moving Forward in the Season of the Impossible

This unique moment in the history of education has reminded all vested parties that education is more resilient, more nimble, and more open-minded to ideas to adjust to unforeseen circumstances. Many of these ideas have been waiting for a season of "inflicted change" caused by COVID-19. During the past few years, Oral Roberts University has delved into many new innovations to address the needs of students, the economy, and society. We can now see these innovations ready to be used on a mass scale, thanks to the new line of thinking created by COVID-19. Below are two of the many innovative ideas that were birthed for a time such as COVID-19.

An AI Lifesize Digital Assistant With depression and anxiety becoming one of education's greatest distractions among students, ORU has developed an artificial intelligent mirror that can nudge students into the proper direction at any given moment in time. Rather than being distracted by a smartphone, worries, concerns, and anxieties, students can speak into any Alexa-based product or the physical mirror and ask how they are doing in school, be prompted to take action on their course work, and have their entire class scheduled echoed back to them. The students can even take the national self-depression test known as PHQ-9.

SeligoAI Smart Campus Platform It has been 25–35 years since the first education systems known as Student Information Systems (SIS), Learning Management Systems (LMS), and Customer Relationship Management (CRM) platforms have been invented. These same systems operate with the same decades old design with an over-simplified student life cycle. This works great for each individual school or campus, but does not allow student records to be unified and transferable between education entities, let alone the multiple systems on any one campus. SeligoAI is the first system that leverages AI/ML with Amazon-enabled services.

This smart-campus environment co-designed at ORU in cooperation with a former college president, Dr. Gregory Jordan, changes the entire campus data systems to an intelligent platform run from an Amazon architecture and a data lake. This has been the breakthrough every educational leader has been waiting for.



Bibliography

Mathews, M. L. (2018). Faculty leading the way in innovation: The dawning of a new era. *The Center for Digital Education's CONVEGE*. Available at: http://works.bepress.com/michael-mathews/48/

Mathews, M. L. (2019a). Transforming the learning experience. *Industry Era.* Available at: http://works.bepress.com/michael-mathews/68/

Mathews, M. L. (2019b). AI-enabled mirrored intelligence application: A personal and life sized digital assistant. *CIO Applications*. Available at: http://works.bepress.com/michael-mathews/65/

Mathews, M. L. (2019c). Mirror – Mirror on the wall. *CIO Techie*. Available at: http://works.bepress.com/michael-mathews/64/

Mathews, M. L.., & Krigsman, M. (2017). *Virtual reality: Innovation in Higher Education*. Available at: http://works.bepress.com/michael-mathews/3/

Chapter 19
How the Stress Mess Impacts Learning

Martha Kaufeldt

19.1 Introduction

According to the International Stress Management Association (ISMA, https://isma.org.uk/), stress is the body's response to excessive pressures, confusion, and trauma. As one experiences real danger, perceived threats, or chaos, the fight or flight or "reflex response" kicks into gear. Since the beginning of the twenty-first century, workplace leaders, educators, parents, and students are reporting levels of excess stress and anxiety at near unbearable levels. School and job success, relationships, health, and general well-being have begun to suffer, and according to the World Health Organization (WHO), stress may very well be the greatest health epidemic of the twenty-first century (Fink 2016).

For many, being "stressed" is the new normal state of being. Our daily lives, although full of opportunity, often leave many of us anxious, stressed, exhausted, and depleted. Many adults may be at the point of being in a perpetual state of stress about work, economic situations, relationships, families, and politics, not to mention a global pandemic and the critical state of our planet! The "Stress in America" annual survey conducted by the American Psychological Association found that as many as 64% of Americans reported they are stressed about the future of the nation, employment, money, the political climate, violence, and crime (American Psychological Association 2018).

Has Stress Really Gotten Worse in the Twenty-First Century? Many research studies and articles in the last decade have indicated that increasing stress levels is a huge global problem. Headlines read, "The Kid's Aren't All Right," "The Stress in

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America Study," "Cortisol: Why the Stress Hormone is Public Enemy Number One," and "Stress, the "health epidemic of the 21st century." World Health Organization Director-General, Dr. Tedros Adhanom Ghebreyesus, declares that mental health is positioned high on WHO's development and humanitarian agenda (WHO 2019). Stress and anxiety are mental health conditions that can contribute to poor health, early death, human rights violations, and economic losses. Cognitive deficits and reduced academic achievements are believed to be a direct result from these mental health conditions. The vision of the WHO Special Initiative for Mental Health is that all people achieve the highest standard of mental health and well-being (WHO 2019).

Stress Is Not Just a Western Civilization Issue The 2019 Gallup Global Emotions Report states that over a third of the 150,000 people who were surveyed from over 140 countries reported they had suffered some degree of stress on the day prior to the survey. At least one in five reported experiencing sadness or anger. The international poll reported that the levels of worry, sadness, and stress were at an all-time high. In the USA 55% of adults said they felt stressed. Greece reported the most stressed population in the world with 59% of those surveyed saying they experienced stress on the day before the poll. The country with the most positive responses was Paraguay. The USA was the 39th most positive country, the UK was 46th, and India ranked 93rd (Gallup Global Emotions Report 2019).

Modernization and increasing technological and economic progress have made our daily lives easier and more efficient and have increased life expectancy. But there is a drawback of this progress; it appears to have a detrimental effect on our health and well-being. Technology and economic progress are attributed to promoting the rise of unhealthy lifestyles and increased stress levels, particularly among the youth. The general level of worry and unhappiness in the world is creating a global epidemic of stress. Chronic stress is becoming part of the "new normal" for people of all ages and may be causing a decrease in productivity and an increase in a variety of health problems. A strong indicator of the rising stress levels is the increase in stress-related physical and mental health issues: depression, anxiety, obesity, cardiovascular disease, and insomnia.

> The stress hormone, cortisol, is public health enemy number one. Scientists have known for years that elevated cortisol levels: interfere with learning and memory, lower immune function and bone density, increase weight gain, blood pressure, cholesterol, heart disease… The list goes on and on. Chronic stress and elevated cortisol levels also increase risk for depression, mental illness, and lower life expectancy. (Bergland 2013)

Children and teens have their own set of worries and stressors to deal with in and out of school. We know that when parents and families are experiencing daily stress, the children may be exposed to a stressful living environment, perhaps even toxic. Adolescents are of particular concern regarding a possible "rise of despair," with huge increases in social media use, anxiety, depression, and self-inflicted injuries.

> We live in a stressful world and troubled times, and that is not supposed to be the way for children to grow up. Schools can be the safe haven where academic practices and classroom

strategies provide children with emotional comfort and pleasure as well as knowledge. (Willis 2014)

19.2 Why Stressed Brains Fail to Learn Properly

Perceived threats in the environment, true danger, and everyday struggles have a huge impact on a student's ability to thrive at school and be happy. To understand the problem and how stress interferes with learning and memory, we will investigate five areas specific to educational settings:

- The neurobiology of the *stress response* system and how stress and trauma can impact learning and memory
- Three types of stress and three types of responses
- The likely psychological, environmental, and situational sources of stress in educational settings
- Possible prevention strategies to avoid triggering stress
- Strategies to help students manage stress

19.3 The Biology of the Reflex Response

The brain's survival mechanism is triggered when confronted with danger or the perception of a possible threat. These threats can occur within the environment and be related to immediate survival issues or from emotional and/or psychological events. When we experience true danger, excessive pressure, or a highly stressful situation, our brains trigger the FIGHT-FLIGHT-FREEZE response designed for emergencies (Kaufeldt, 2010). When this reflex is triggered, the brain may first react defensively ready to *fight* and fend off the danger. Or it may have an urge to flee (*flight*) and avoid the stressor. In some instances the reaction may be to *freeze*, rendering the person quite paralyzed with fear and unable to fight or flee.

The challenge is that when we experience this *reflex response*, virtually *all complex cognitive processes are temporarily suspended*. Stress can impair one's executive functions, such as the ability to pay attention, regulate emotions, and think flexibly. During stressful events or when one perceives a threat, little new learning can take place. Our ability to remember prior knowledge is impaired and it is difficult to store new incoming information.

Several areas in the midbrain work in tandem when reacting to stressful situations. The ***reticular activating system (RAS)*** located at the top of the spinal cord and extending to the midbrain vigilantly scans the environment and directs our attention to possible threats, resources, or opportunities for pleasure. The RAS is a complex bundle of neurons that serve as a sensory filtering system with input coming from the sensory organs. A screening process known as ***sensory gating*** occurs within the RAS. Strong feelings relating to danger or the perception of threat are permitted to pass and be processed; however, information coming from the other sense organs may be temporarily blocked. When the danger and threatening conditions have receded, the RAS then directs focus to any stimuli that arouses our curiosity, seems fun, and might bring pleasure.

Our ***amygdala*** (**amygdalae – plural**) is one of two almond-shaped neuron bundles embedded behind the temporal lobes and deep within the limbic (midbrain) area. The ***reticular activating system (RAS)*** sends the filtered data to the amygdalae. The amygdalae scan the surroundings to identify the source of the threat and then direct all attention to the possible danger. This automatic response takes command and triggers the brain and body to react with the FLIGHT-FLIGHT-FREEZE response. This starts the immediate release of our stress hormones, adrenaline (also known as epinephrine) and cortisol.

The amygdalae act as gatekeepers to other brain structures in the midbrain. The ***hippocampus*** (plural hippocampi) acts like “Grand Central Station” and is a conduit to the cerebral cortex. The hippocampus is responsible for the retrieval and then the storage of long-term memories. When new information arrives, the hippocampus quickly analyzes what is perceived and compares it to prior stored memories. If the new incoming information is unknown, generates a negative memory, or isn’t similar to any prior stored experiences, the brain triggers our *reflexive* emergency response system. This “distress” is related to the source of the stress, but also involves the degree to which one then *feels a lack of ability to influence* or control the stressor. When one is experiencing stress, emotional upsets, or perceived threats, the reflex response takes over and ***any new learning may be minimized*** (Hobson 2018).

A stress response is an important biological reaction to any potentially dangerous situation or perceived threats. In most cases, the body should begin to relax and return to homeostasis immediately after the reflex response has been triggered. (***Homeostasis*** is the body’s ability to maintain a stable internal state despite various changes.) This reflexive response prepares one’s body to react quickly and protect you in an emergency. However, when one experiences stress and this system is activated day after day, it can eventually put one’s physical and mental health at serious risk. Long-term (chronic) stress is known to lead to various physical ailments, such as high blood pressure, cardiovascular disease, headaches, sleep difficulties, a weakened immune system, and even chronic pain. Chronic stress can also affect one’s mood, thoughts, motivation, self-esteem, and energy. Over time, repeated stressors actually have a detrimental effect on the brain’s learning abilities.

19.4 Three Types of Stress and Three Types of Responses

As we explore the stress response, it is helpful to distinguish among the three basic **types of *stress*** as described by the American Psychological Association (APA): acute, episodic acute, and chronic stress. Each has its own specific characteristics and symptoms. There are also three types of ***responses*** to stress: positive, tolerable, and toxic (Ehrenfeld 2018).

Acute (a situation or phenomenon experienced to a severe or intense degree)

Acute stress is the most common stress. It may result from excessive demands or pressure. It can be anticipatory anxiety as you worry about an upcoming event. Acute stress can be thrilling and exciting in small doses, but too much is exhausting. It doesn't cause any real long-term damage because it is so short-lived.

Temporary symptoms associated with acute stress:

- Emotional reactions such as anger and irritability
- Depression and/or sadness
- Anxiety, overexcitedness, and/or nervousness
- Muscular tension in the neck, shoulders, and back
- Tension headaches
- Stomach upsets and intestinal problems
- Rapid heart hate and high blood pressure

Acute stress can happen at any time and the body should be able to return to homeostasis fairly quickly. It can be a very scary or an extremely exciting event, but it is *manageable*.

Episodic Acute Stress When acute stress events are suffered too frequently, it is called episodic acute stress. This type of stress is also relatively self-inflicted. It is brought on by busy schedules and often unrealistic goals and demands. For people who experience episodic acute stress, their daily lives are often in chaos and in some kind of crisis. They seem to always have something going wrong. For some, they are a type A personality. They take on and try to manage a slew of demands and pressures on themselves. They seem perpetually in the clutches of acute stress, always in a rush, but always late or missing a deadline. Healthy relationships with others may be difficult to maintain.

Symptoms of episodic acute stress in a person with "nervous energy" (type A):

- Frequently overly excited
- Short-tempered, irritable, anxious, and/or tense
- Strong competitive drive and/or aggressiveness
- Impatient with others
- Attempting to multitask

Symptoms of episodic acute stress in a "worry-wart" person:

- Pessimistic – See disaster around every corner
- See the world as a dangerous place and worry about what will happen
- Get overaroused from a stressful event and are more tense and anxious

With episodic acute stress, the reflex response occurs frequently but is not chronic (constant). It makes more excessive physical demands on the brain and body, but there are periods when the stress recedes. Persistent stress headaches, ulcers, hypertension, and even heart disease may begin to manifest. Eventually episodic acute stress will probably demand some outside professional medical treatment and psychological help.

Chronic Stress While we know that acute stress can even be exhilarating at times, chronic stress is not. It is dangerous and unhealthy (Innes and Selfe 2014). Chronic stress comes when a person doesn't see a way out of a miserable situation. They have little or no control of their circumstances. It is a grinding stress that wears people down, destroying brains, bodies, relationships, and lives. This type of stress is from long-term exposure to a variety of stressors. These long-term stressful situations such as unhappy relationships, poverty, illnesses, or family conflicts may appear to be unending, and the accumulated stress that results from exposure to them can be life-threatening (Sincero 2012).

Symptoms of chronic stress include:

- Dry mouth
- Difficulty in breathing
- Pounding heart
- Stomach ache
- Headache
- Frequent urination
- Irritability
- Inability to concentrate
- Difficulty in sleeping
- Frequent fatigue

Serious illnesses such as stroke, heart attack, cancer, and mental disorders – clinical depression and post-traumatic disorder – can originate from chronic stress. Chronic stress may be a result of traumatic, adverse childhood experiences that become internalized and remain forever painful and present. People dealing with chronic stress begin to get used to it. They forget it's there. In fact, your brain "resets" your baseline for homeostasis. You begin to cope and tolerate even higher stress levels. You are instantly aware of acute stress because it is new, but you might ignore chronic stress because it is familiar, unrelentless, and how you deal with your daily life.

Three Responses to Stress These three terms generally refer to how the reflex response affects the brain and body in relationship to the frequency or severity of the stress.

- **POSITIVE – This type of stress response** is a normal experience and an essential part of our healthy development. This was also described as "eustress" (good+ stress) by endocrinologist Hans Selye (Selye 1974). This type of stress response might feel uncomfortable or a little frightening but is experienced as a positive challenge. Some situations that might trigger a positive stress response are the first day at a new school, getting ready to ride a roller coaster, or getting prepared for a job interview. The classic symptoms of positive stress are:

– Brief increase in heart rate and blood pressure
– Rapid, shallow breathing
– Mild elevations in pleasure hormone levels (endorphins)
– A feeling of hope and excitement
– A feeling of challenge and motivation

- **TOLERABLE – This type of stress response** really activates the body's reflex response. It is triggered as a result of more severe stressors that are not particularly fleeting and may last a little longer. These types of experiences might include a frightening injury, losing a loved one, or being in a natural disaster. Reacting to this type of stress can be tolerable if the event is not too prolonged and if there is intervention or help from others. Then the brain and body begin to recover without lasting damaging effects.
- **TOXIC – This stress response** occurs when one experiences severe, frequent, and/or prolonged adversity. This might include:

– Physical or emotional abuse
– Frequent neglect or hunger
– Living with someone who has a mental illness or is abusing substances
– Experiencing violence at home or in the neighborhood
– Lack of adequate adult care and support

This kind of regular activation of the stress response system can actually disrupt cognitive development and affect one's general health. Chronic stress can increase one's risk for stress-related diseases and can have a cumulative toll on an individual's physical and mental health – throughout one's lifetime. But research also indicates that when children are surrounded by caring adults, it is possible to prevent or reverse the damaging effects of the toxic stress response.

A student's emotional state can make the difference in learning. Positive emotions facilitate one's ability to pay attention, focus, and learn, rather than worrying about being humiliated, anticipating failure, or not feeling included. Learning is minimized when we perceive threat or encounter unrealistic expectations. On the other hand, a healthy level of stress energizes our brain for engagement. Our brains respond positively to appropriate challenges (within our reach), novelty, and things that pique our interest. "Tolerable" stress and pressure (with appropriate support and feedback) can enhance learning and improve memory (Fig. 19.1).

Some common features of *stress triggers* include:

- Experiencing something new or unexpected, especially if one feels unprepared
- Any kind of change: such as altered routines, new people, or unfamiliar situations
- Encountering something that threatens one's sense of self and safety
- Feeling one has little control over a situation

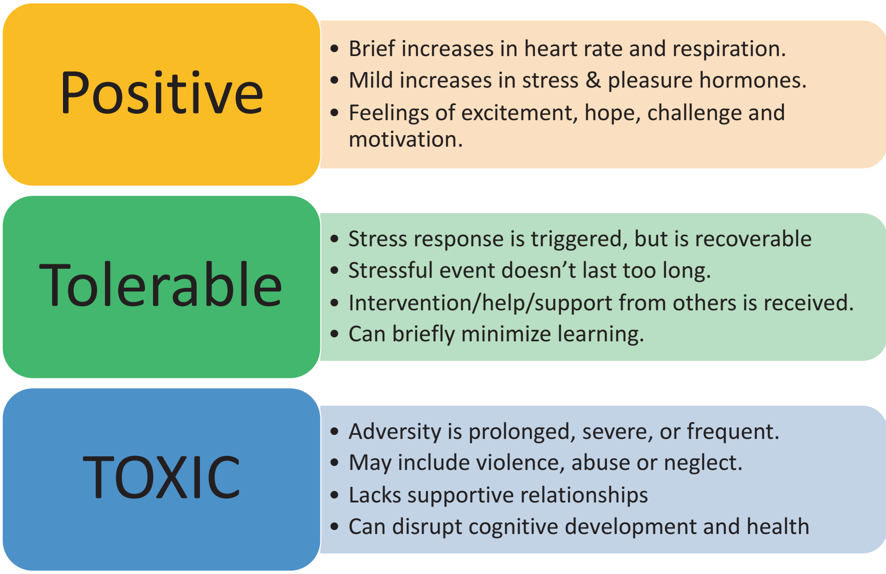

Fig. 19.1 Positive, tolerable, and toxic stress

19.5 Sources of Childhood Stress

Student stress can occur at all levels of the socioeconomic pyramid. Children in poverty are frequently exposed to more intense and longer-lasting stressors in their home environments. Their responses to chronic family stressors such as homelessness, poverty, joblessness, and poor nutrition will be carried with them to school. Additionally, research on the long-term effects of adverse childhood trauma, such as abuse, neglect, family instability, and dysfunction, has significant impact on school performance.

Many students from more affluent communities are often under tremendous pressure to perform academically, excel in a sport, or develop a talent. This intense pressure (often coming from parents) may lead to students feeling overwhelmed. Their days may be quite "overscheduled" and have little down time to recharge. In any case, students who arrive at school already experiencing a high level of stress from home will be more likely triggered into a FIGHT-FLIGHT-FREEZE reflexive response in the classroom.

Allostasis and Allostatic Load Homeostasis is the body's need to maintain an internal constant state, remaining stable by staying the same. Homeostasis includes the ability to maintain all body systems within a "normal" range such as temperature, oxygenation, glucose levels, and a Ph/acid balance. Thankfully there is a wide range of variability. There are many factors in our environment that change throughout the day and the body must be vigilant and adaptable. Our powerful stress response system is designed to protect us during temporary acute events and then return our brains and bodies back to baseline – homeostasis – within a fairly short amount of time. When the system is activated repeatedly, and the body rarely has a chance to recoup, it can cause damage: physically and mentally.

Coined in the early 1980s, *allostasis* is the scientific term for fight-flight-freeze, when we must get a maximum energy response to the parts of the body that need it the most. Allostasis is when our brain communicates swiftly with the body's endocrine system (primarily the adrenal glands) and initiates efficient responses for dealing with real or perceived danger. Allostasis is happening throughout the day, always helping us adjust to changes and challenges – not just life-threatening events. When we experience an acute stress event, it is allostasis that helps our body cope, maintain internal equilibrium, calm down, and return to homeostasis.

When experiencing episodic acute stress, chronic stress, or events that have no resolution or foreseeable end, our body becomes "stressed out." This is referred to as *allostatic load.*

> **Allostatic load** refers to the cumulative effects of chronic and acute stress on the body. It is the process and the product of 'wear-and-tear' on the body and brain. This results from chronic over-activity or inactivity (called dysregulation) of physiological systems that are normally involved in adaption to environmental challenges. (McEwen and Gianaros 2010)

Allostatic load doesn't just appear when we experience stressors from the environment or situation, but we can bring it on ourselves! There are several ways that we can initiate allostatic load by living in a way that keeps us out of balance.

- Overeating or regularly consuming too rich of a diet
- Missing important sleep
- Avoiding regular exercise
- Worrying about things that *might* happen – anticipatory anxiety
- Staying in an unhealthy relationship
- Overscheduling, multitasking, and working at an unrelenting pace
- Maintaining a constant state of alert using technology/screen time

So allostasis is normal and has benefits, whereas the long-term effects of allostatic load can be quite unhealthy. For instance:

- During an acute event the additional adrenaline and cortisol that is released can actually promote and improve one's memory (you want to be able to remember and recall the stressor to avoid it in the future). However, when the stress is unending, the allostatic overload can actually *inhibit* new memory formation. Research has also discovered that chronic/toxic stress can trigger cell death in the hippocampus – the seat of memory!
- During an acute event the immune system is stimulated to move important cells to places in the body where they are needed to fight injuries or diseases. However, when there is an allostatic load, it may trigger the suppression of the immune system.
- Positive and tolerable stress prompts the cardiovascular system to temporarily increase blood pressure. During the day allostasis raises and decreases blood

pressure and directs blood flow as needed to do tasks. Repeated elevation of blood pressure can eventually promote plaque buildup in the arteries and even cause a stroke.
- During allostasis the body's metabolism converts proteins to carbohydrates to replenish energy reserves after exercise or any physical exertion. Our bodies need fuel. However, when experiencing allostatic load due to physical exhaustion, lack of sleep, or psychological stress, the body becomes "food-seeking" and may cause you to eat more than you really need and to grab some junk food. Under chronic/toxic stress, bodies can become insulin resistant and produce an increased risk of cardiovascular disease and obesity.

The twenty-first century has come with a variety of new stressors. Life is much more complex, and our daily interactions are often stress-producing. Some of the stressors adults and children may encounter include:

- **Economic Stress and Employment.** In Denver, Colorado, more than 75% of residents said that work and money are their most significant sources of stress. Even children age 8–17 across the USA said they worry about getting good grades, doing well in school, and their family's financial situation (Munsey, 2010).
- **Relationships/Divorce.** In the USA, almost 50% of all marriages end in divorce or separation – that doesn't even include non-marriage relationships. Many children now have multiple sets of parents and grandparents. Some arrangements might be cordial – but many are volatile, putting children in the middle.
- **School/Public Shootings/Terrorist Attacks.** Although globally terrorist attacks have reduced by approximately 40%, the USA has seen a recent surge in terror-related violence over the past 10 years, with 65 attacks in the USA in 2018, up from six in 2006 (Romero 2018). Many students report fear of school shootings.
- **Homelessness.** The housing crisis in many of our most populous states puts many families without a stable home life. Security of a roof overhead is only guaranteed from paycheck to paycheck.
- **Alcoholism and Drug Addiction.** While alcoholism has been around for centuries, it wreaks havoc among all socioeconomic levels and ethnic groups. The easy availability of new designer street drugs has created an epidemic.
- **Political Divisiveness.** The constant fighting, mistrust, name-calling, and general unrest are played out before our eyes in real time. The media fans the flame and we are bombarded with chaos and bipartisan politics.

Information Overload? It may also be possible that this generation is now suffering from *information overload.* With excessive technology usage providing multiple connections to academic, social, and recreational events, many researchers believe that stress levels are being exacerbated. Incessant interruptions and distractions make it hard for the brain to concentrate. The sheer volume and complexity of information that one is expected to take in and process continues to increase and can be overwhelming. It is estimated that those with smart phones are interrupted with a text, announcement, or call every 1–3 min throughout the day. There are also other psychological components that develop. "FOMO," the Fear of Missing Out, prompts one to check frequently for more information. Our desire and possible addiction to know more has been referred to as "Infomania."

- When using devices for work or communication, there is constant brain "switching" which can be exhausting and lead to stress. The belief that one is able to *multitask* is a myth. The brain can really only focus on one conscious event at a time. Therefore, we begin to function with only *continuous partial attention*, which is neither efficient nor productive. In fact, some researchers are suggesting that many have developed "Acquired Attention Deficit Trait." When the brain has a multitude of simultaneous demands, it can create a feeling of inadequacy. One begins to feel guilt, shame, and distress about our inabilities to be successful and get things done.

  Common stress triggers at school or university may include:

- Overwhelming amounts of assignments, homework, and projects – perhaps all due at that same time.
- Extremely high anxiety about doing well on upcoming exams. Feeling unprepared.
- High level of self-judgment and self-doubt about one's capabilities. Unsure of expectations.
- Experiencing a high degree of peer pressure in academics or athletics.
- Feeling different from others: ethnicity, religion, race, language, and gender identity. This may in fact contribute to some bullying behaviors from other students leading to further social isolation, humiliation, and poor self-image.
- A student's anxiety about future college and/or career selections and expectations.

19.6 Stress Prevention: Maintaining a Safe and Secure Climate and Environment for Learning

Consciously and unconsciously the brain pays attention to everything in the environment. Using multiple senses, it picks up subtle and overt feedback. The physical environment can have positive or negative effects on the learning process. There are potential psychological, environmental, and situational sources of stress in every educational setting. Classrooms, schools, and universities would do well to examine everyday instructional practices, student groupings, discipline policies, and schedules, to determine if the learning environment is "brain-friendly" as opposed to "brain-antagonistic."

Some simple adjustments to traditional daily classroom practices that may produce stress responses can keep students out of the reflex response and ultimately produce great rewards regarding student success.

Attend to the Physical Learning Environment to Assure Safety and Comfort Appropriate lighting and sounds as well as odors, tastes, and temperature can all enhance or deter the brain from focusing on learning. Frequent interruptions from intercom announcements can distract students' attention. Inadequate classroom furniture or items in disrepair can be perceived as potential threats. Many students can be frustrated with inadequate lighting and annoying ambient noises. Trying to learn in unpleasant classroom environments can add to student stress.

- ***Orchestrate intentional inclusion activities to assure that students feel part of a positive learning community***. We learn better when we feel included and have positive social relationships. The brain has a natural instinctive need to seek out others. We are social beings and feeling included is important. Classroom instruction that organizes students into small cooperative learning groups can reduce student anxiety and stress levels.
- ***Reduce perceived threats by not tolerating put-downs or bullying of any kind.*** Classroom agreements and structures should promote and maintain respectful treatment of everyone. Social standards that are positive, supportive, and maintained by the instructor will provide a sense of safety and security.
- ***Post and practice clear procedures for how everything is done in the classroom***. Clear organizational systems can alleviate chaos and confusion which is often a stressor for many students. Posting a daily agenda provides a game plan for the day. When students know the expectations and goals of the lesson, have clear task directions, understand the expected behaviors, and are aware of the estimated time frames, it can reduce *anticipatory anxiety.*
- ***Promote curiosity and attention by integrating novelty and appropriate challenges.*** When students are interested and engaged in meaningful relevant tasks, they are less likely to experience stress. Providing opportunities to correct mistakes or try a task again will foster a "can do" atmosphere that can promote the development of a *growth mindset.* First-hand learning experiences with real-world materials encourage positive student engagement.
- ***Offer opportunities for students to choose how they complete certain tasks and with whom they might collaborate***. For many students the feeling of having no options or being totally out of control can be stressful. Providing regular opportunities for students to choose a learning task, decide where they might work, and choose with whom they will work will promote student engagement and efficacy.

Maintain a Learning Environment That Promotes the Joy of Learning and Community Humor and laughter relieve stress and tension. A shared moment of joy and happiness releases endorphins (neurotransmitters) – our natural pleasure chemicals – and can bond us with others and enhance retention. Starting a class with a fun game, a clever problem, or an interesting anecdote changes the learners' brain state from a survival mode and allows them to experience joy.

19.7 Learning Strategies to Help Manage Student Stress

Knowing how the brain reacts to stress and perceived threats can help teachers design "brain-friendly" environments to maximize student engagement and learning. Many teachers also understand how imperative it is to help students develop social and emotional skills for self-management. Effective strategies can enable one to *respond* rather than *react* in stressful situations. Students lacking simple calming and coping skills will find it difficult to return to homeostasis once the reflex response has been triggered. There are a variety of evidence-based relaxation and mindfulness techniques to help students (and teachers) control their personal, physical, and psychological reactions to stress and enhance well-being.

Mindfulness: An intentional and self-regulated focusing of attention on the present moment, whose purpose is to relax and calm the mind and body.

- **Simple Breathing Practices:** Teach students how to do slow *diaphragmatic deep breathing (a.k.a. belly breathing)*. Through your breath, you can activate your parasympathetic nervous system – the calming response in your body. Drawing attention to one's breath is a powerful way to regulate emotions.
- **"Take 5" Area:** Especially helpful in classrooms with younger students, a special chair or quiet place to relax and calm down.
- **Healthy Distractions:** LET IT GO! Change attention away from the source of the stress. Do something else for a while to try to ignore the stressor. Listen or dance to music, go for a walk, get out of doors, enjoy a hobby, spend time with friends, etc. Take time out for enjoyable activities that are mentally restful and fun!
- **Laugh it up!** Shift your perspective to see an opportunity to laugh. Giggle! Releasing endorphins can immediately begin to relieve stress and tension.
- **Lighten-up on yourself!** Forgive your own mistakes. They are just learning experiences. Beating yourself up doesn't help. Note your "self-talk" and change it to more positive statements.
- **Movement, exercise, and play!** Stretching and exercising can draw one's attention away from stress and relieve the physiological response. Experiencing some play time will trigger the release of **dopamine**, our natural pleasure chemical.
- **Balance time!** By identifying the source of our stress, one can consider what activities in life may be out of balance. Consider checking the balance of these activities to help reduce stress.

  – Time with technology
  – Reflection and down time
  – Time to get up and move around
  – Play time

Teaching students how to better manage school stressors helps them experience less stress, allowing them to perform to their fullest potential during learning and exams. It's not possible to eliminate stress completely, but we can help students learn how to avoid it when possible and how to manage it when it's unavoidable.

19.8 Orchestrating Optimum Stress Levels

If the classroom climate and environment are welcoming, interesting, safe, and secure, students will be less likely to perceive threats and be more productive. When a teacher assigns a project or task to the class, it will prompt a wide variety of responses from the students. Each student will react to various stimuli differently – from excitement and compliance to boredom. Students will experience a negative or positive response depending on how they perceive the difficulty of the task or the challenge involved and the interests they have. Motivation is enhanced if the task appears to have a high probability of success and is exciting. There is also a high likelihood of frustration and fatigue when facing tasks that one perceives as being too challenge for one's current level of skills.

The Yerkes-Dodson Law of Arousal The relationship between one's level of pressure (arousal) and one's ability to perform and learn is known as the Yerkes-Dodson law of arousal. It asserts that there is an optimal level of arousal (stress) that we all try to maintain. As mild stress and pressure increase, performance usually improves. This moderate level of arousal is generally considered most productive. One reaches ***eustress*** "maximum cognitive efficiency" when there is a tolerable degree of pressure and stress (Damasio 2003). Even if additional pressure or stress is added, one's performance will not likely improve. One's overall performance and general motivation may begin to diminish if the stress and excessive pressure continue. Our performance can improve when we increase our level of stimulation by pushing ourselves physically or mentally, but there is a tipping point. Just like the famous "Goldilocks story," the Yerkes-Dodson law demonstrates that sometimes there could be either too low or too intense an arousal. For each learner to maintain his/her motivation, and for his/her performance to be "just right," there must be a balance of stress to assure that each individual learner can maintain optimal performance (Fig. 19.2).

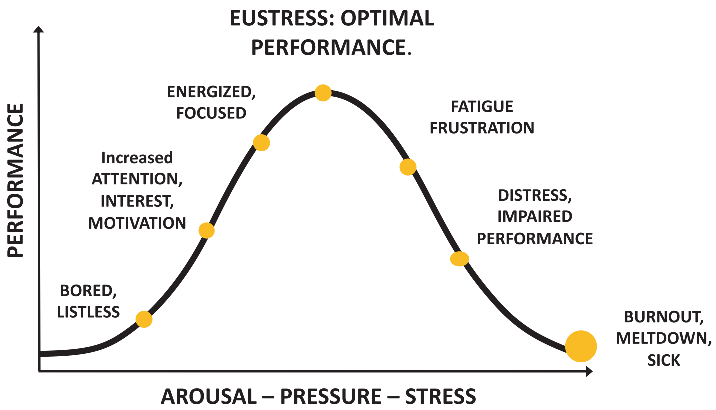

Fig. 19.2 The Yerkes-Dodson law of arousal

Educators should strive to provide a balance of excitement (arousal) and challenge (pressure) and avoid causing excessive stress for our students. It is a difficult dance to find the optimum level of challenge that can motivate, engage, is enjoyable, and is safe for each learner. Gathering data through pre-assessments can help determine if the task is within the range of a student's abilities. Relating the new experiences to prior learning with similar tasks may help influence a student's reaction and promote a higher degree of motivation.

Stress impacts learning and memory. Being sensitive to possible trauma students may be experiencing outside of school may help teachers understand their reflex triggers. Reducing excessive stressors at school should be a goal for all educators. Ultimately, teaching students about the stress response will help them be aware of their own stress and learn to manage it (Gregory and Kaufeldt 2015a, b).

References/Resources

Allostatic Load: A Review of the Literature. (2012) Page 7, Published by the Australian Department of Veterans' Affairs, Canberra, 2012. P02297. https://www.google.com/search?q=allostatic+-load+dept+of+veterans+affairs&oq=allostatic+load+dept+of+veterans&aqs=chrome.1.69i57j33.9937j0j4&sourceid=chrome&ie=UTF-8#

American Psychological Association. (2018). *Stress in America: Generation Z.* Stress in America™ Survey. https://www.apa.org/news/press/releases/2018/10/generation-z-stressed

Bergland, C. (2013, January 22) *Cortisol: Why the "Stress Hormone" is public enemy no. 1.*Psychology Today. https://www.psychologytoday.com/us/blog/the-athletes-way/201301/cortisol-why-the-stress-hormone-is-public-enemy-no-1

Damasio, A. (2003). *Looking for Spinoza: Joy, sorrow, and the feeling brain*. New York: Harcourt.

Ehrenfeld, T. (2018, December 7). The three types of stress. Psychology Today Accessed at https://www.psychologytoday.com/us/blog/open-gently/201812/thethree-types-stress

Fink, G. (2016, April 26). *Stress: The health epidemic of the 21st century.* Elsevier: SciTech Connect. http://scitechconnect.elsevier.com/stress-health-epidemic-21st-century/

Gallup Global Emotions Report. (2019). https://www.gallup.com/analytics/248906/gallup-global-emotions-report-2019.aspx.

Gregory, G., & Kaufeldt, M. (2015a). *The motivated brain: Improving student attention, engagement and perseverance*. Alexandria: Association of Supervision and Curriculum Development.

Gregory, G., & Kaufeldt, M. (2015b). *Best practices at Tier 1: Daily differentiation for improved instruction.* (Elem and Secondary versions). Bloomington: Solution Tree.

Hobson, N. (2018, April 2). *Why your brain on stress fails to learn properly.* Psychology Today. https://www.psychologytoday.com/us/blog/ritual-and-the-brain/201804/why-your-brain-stress-fails-learn-properly.

Innes, K., & Selfe, T. (2014). Meditation as a therapeutic intervention for adults at risk for Alzheimer's disease – potential benefits and underlying mechanisms. Frontiers in Psychiatry 5:40. https://doi.org/10.3389/fpsyt.2014.00040.

Kaufeldt, M. M. A. (2010). *Begin With the Brain: Orchestrating the Learner-Centered Classroom* (2nd ed.). Thousand Oaks: Corwin Press.

Kaufeldt, M. M. A. (2021) *De-Stress the Test: Brain-Friendly Strategies to Prepare Students for High-Stakes Assessments. Bloomington, IN: Solution Tree Press.*

McEwen, B. S., & Gianaros, P. J. (2010). Central role of the brain in stress and adaptation: links to socioeconomic status, health, and disease. *Annals of the New York Academy of Sciences, 1186, 190–222.* https://doi.org/10.1111/j.1749-6632.2009.05331.x

Munsey, C. (2010). *The kids aren't all right*. American Psychological Association. Monitor on Psychology. Vol. 41, No. Print version: p. 22. apa.org/monitor/2010/01/stress-kids
Romero, L. (2018). *Decades after 9/11, the American right is behind a terrorism surge.* Quartz. https://qz.com/1386318/9-11-anniversary-data-shows-us-terrorism-is-rising-on-the-right
Selye, H. (1974). *Stress without distress* (p. 171). Philadelphia: J.B. Lippincott Company.
Sincero, S. (2012, September 10).*Three different kinds of stress*. Retrieved Sep 18, 2020 from Explorable.com: https://explorable.com/three-different-kinds-of-stress
Willis, J. (2014, July 18). *The neuroscience behind stress and learning*. Edutopia MD. https://www.edutopia.org/blog/neuroscience-behind-stress-and-learning-judy-willis
World Health Organization. (2019). *The WHO special initiative for mental health (2019–2023): Universal health coverage for mental health,* p. 1. https://apps.who.int/iris/handle/10665/310981

Chapter 20
Communication Beyond Learning: Knowledge Management and Technology Transfer into Education

Beatrice Bressan

20.1 The Learning Process

The analysis of the various levels involved in the learning process of various disciplines described in this chapter is fundamental to introduce crucial communication elements.

Before entering into the description of the communicative elements, it is necessary to analyse the levels that are involved in the learning process of different disciplines, including the technical-scientific ones (Fig. 20.1).[1]

In the learning process, a primary distinction occurs between the:

- *Deductive approach*, which develops hypotheses based on existing theory to design adequate strategies to test the hypothesis. When a causal relationship is implied in a theory, it could be true and explained by the means of hypotheses deriving from the theory propositions. Thus, deductive approach is related to deducting conclusions from premises.
- *Inductive approach*, which starts with the proposed observations and theories to the conclusion of the research process as a result from observations. It requires the search for pattern from observation and the development of explanations for

[1] B. Bressan, *A study of the research and development benefits to society resulting from an international research centre, CERN*, p. 60, Helsinki University, Finland, 2004; *Knowledge Management in an International Research Centre*, p. 48, Lambert Academic Publishing, 2010; *From Physics to Daily Life,* p. 39, Wiley Blackwell, 2014.

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https://doi.org/10.1007/978-3-030-72400-9_20

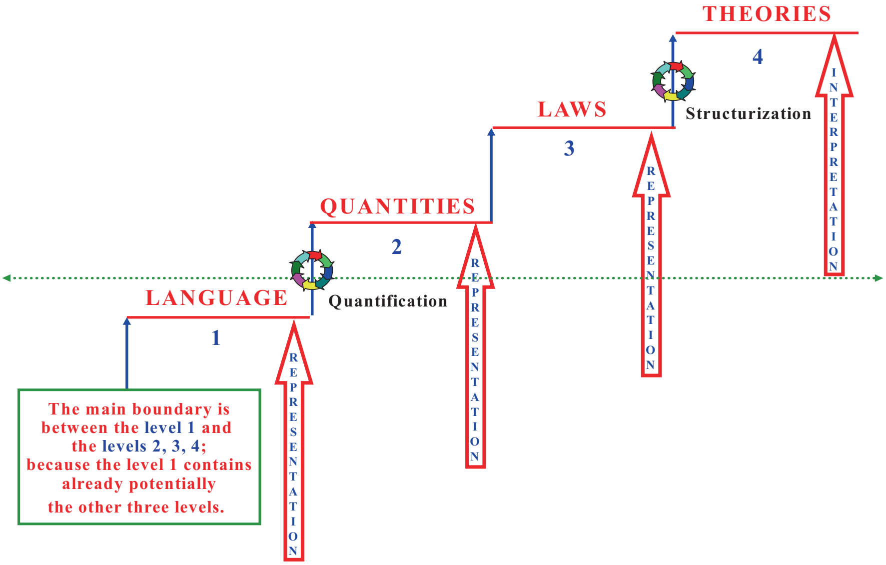

Fig. 20.1 The hierarchical levels of the learning process

those patterns via hypotheses to generate meanings from data for identifying relations to build a theory.

The primary and basic level while learning any discipline is the *language* because potentially it contains all the other levels, which follow, that can be regrouped in *quantities*, *laws* and *theories*. The first three levels describe a *representation* of the nature, whereas the last one gives an *interpretation* of phenomena. To complete the learning path, other two components are essential: the *quantification* process, representing the transition from language to quantities, and the *structurization* process, representing the transition from laws to theories.

20.2 The Communication Process

The following chapter introduces the fundamental elements of the communication process in order to put the basis of new methodologies for didactic purposes.

From the stages of knowledge creation, acquisition and learning, it is possible to move on to the transfer of knowledge through the usage of the theoretical and practical elements of the communication process.[2] In order to do that, the identification of the actors involved in the communicative act is needed, namely, the:

[2] N. Visalli, *Collaborare e Apprendere in Rete Strumenti di Comunicazione Sincrona e Asincrona*, Modulo 5, Percorso formativo, Liceo Ginnasio G. Garibaldi, Palermo, Italy, 2004; A. Battistelli,

- *Transmitter*, or the subject conveying the communication.
- *Communicator*, or the intermediary facilitating the communication.
- *Audience*, or the recipient receiving the communication.

The communicative act is explicit in the content, and therefore in the object of the communication that identifies what is communicated, whose quality depends on the available reliable sources of information.

The means of communication are identified in different tools or *channels* and are made explicit in different circumstances (*occasions*) or contexts (*environments*), for example, via a publication, conference, exhibition, meeting, lesson, interaction and so on. Whatever is the content or the medium, the intrinsic principle of communication must fulfil a cause, which manifests itself in the *purpose* and the effect or the *result* of the communicative act. The communication act is completed only when the purpose coincides with the result.

The reason why people communicate can be manifold and have different aims, as the:

- *Instrumental aim*: to get something.
- *Constitutional aim*: to fulfil a profession.
- *Informative aim*: to transfer knowledge.
- *Stimulative aim*: to activate an interest.
- *Relieve aim*: to ease concerns.
- *Expressive aim*: to arouse feelings.
- *Formative aim*: to educate others.
- *Manipulative aim*: to influence someone.

The nature of the content of communication can be subjective (*law* or *theory*) or objective (*experience* or *experimentation*) and must be included in a space-time and in a conceptual framework. The correctness and substantiation of the content must be guaranteed and checked by *referees*, who play a crucial role in the communication among the community of experts, various-type institutions and society.

The main incompatibilities in communication can be identified between the language used and the audience, and between the content and the mean used for the transmission of the message.

The ability to overcome these incompatibilities depends on the competence of the communicator, which, especially in the oral act, can be represented by the:

- *Linguistic skill*, namely, the ability to use verbal signs.
- *Kinesic skill*, namely, the ability to use gestural signs.
- *Paralinguistic skill*, namely, the ability to use cadences and emphasis.
- *Proxemic skill*, namely, the ability to use spatial orientations.

Master in Comunicazione Pubblica, Università degli Studi, Cagliari, Italy, 2002; S. Livingstone, *On the cutting edge, or otherwise, of media and communication research*, Nordicon information 22, London School of Economics and Political Sciences, 2000; B. Bressan, *The many aspects of science communication*, Master thesis in Science Communication, International School for Advanced Studies (ISAS), 1998.

- *Sociocultural skill*, namely, the ability to distinguish roles.

All these abilities, when combined, form the *performative skill*, namely, the capability to effectively fulfil the communicative intention.

20.3 The Multimedia for Education

As reported here, in training and information processes, the usage of multimedia techniques for learning is necessary to ensure the management of knowledge.

The use for didactic purposes of the new communication methodologies in the training and information processes in specific fields or other much broader ones, such as dissemination in science and teaching in education, is limited essentially for economic reasons since the cost per minute of a finished and refined communication product is normally quite high.[3]

The products would be marketable only if they can be widely distributed. Therefore, they should be available in various languages or equipped with comments at various explanatory levels according to the target population (elementary, secondary and high schools, universities, professors, students, the general public, etc.).

It would be appropriate foreseeing programmes for educational use embedded in a united vision and conceived with their specificity also for a wider audience than only for the national ones. This will simply help in considering cultural differences as an advantage and not as a barrier.

Nowadays, for example, looking at the television programmes of different countries, it is still possible to realize how some specific references on speeches or other gags do not necessarily produce the same effect in various cultures. This only means that trying to develop educational audio-visual communication systems and tools is necessarily a challenging and delicate operation. In addition, the edition of the multimedia products must be as concise as possible. Above all, the final adaptation should be carried out by people from the country to which the product is intended.

Today, multimedia information and training systems have made great strides, thanks also to the notable contribution of the lightning-fast development of the World Wide Web (WWW) conceived in 1989 at CERN,[4] the European Laboratory

[3] M. Bianchi, *New problems in the field of information and training created by the use of methodologies interactive and audiovisual systems*, Elementary Particle Physics course, CERN, 1991.

[4] On the basis of the vision of few scientists from Europe and North America, who identified back to the late 1940s the need for Europe to have a world-class physics research facility, in 1951 a provisional body was created: the European Council for Nuclear Research, or CERN, from the French *Conseil Européen pour la Recherche Nucléaire*. Later on the 29th of September 1954, when its establishment was officially ratified by the parliaments of the 12 founding Member States (Belgium, Denmark, France, the Federal Republic of Germany, Greece, Italy, Norway, the Netherlands, the United Kingdom, Sweden, Switzerland and Yugoslavia), CERN became a central laboratory near Geneva, Switzerland.

for Particle Physics located near Geneva in Switzerland. This is why science and technology-related programmes, such as those at research institutions like CERN, represent once again the ideal platform for testing the validity, the limitations and the developments necessary for the application of various multimedia techniques. In this perspective, the production of specific learning, training and information programmes has to be framed to be made available to different kinds of users at national and international levels.

20.4 The Knowledge Management

Learning is needed to create new knowledge to boost innovation. This chapter illustrates specific studies carried out to describe the knowledge pattern within organizations.

Knowledge while learning occurs between exchange partners, and its diversity is necessary for the new knowledge transfer to occur. This knowledge generation is of particular importance for economists and sociologists as it is at the basis of societal and technological innovation as well as of the educational and industrial environment.

Many studies[5] have been done to understand the learning and communication mechanism within different types of organizations. Among them, an inquiry has been achieved at CERN on the knowledge pattern, from creation to acquisition and transfer, in order to analyse the following two main objectives:

1. The benefits on society deriving from research and development in the scientific programmes of the Large Electron-Positron Collider (LEP).[6]
2. The knowledge management on individuals participating in the scientific programmes of the Large Hadron Collider (LHC) experiments.[7]

[5] M. Boisot, et al., *Collision and collaboration*, Oxford University Press, 2011; E. Autio, et al., *Social Capital*, *Knowledge Acquisition, and Competitive Advantage in Technology-based young Firms*, Strategic Management Journal, 2001; B. Bressan, et al., *Knowledge creation and management in the five LHC experiments at CERN: implications for technology innovation and transfer*, Helsinki University, Finland, CERN, Switzerland, 2008; B. Bressan, *A study of the research and development benefits to society resulting from an international research centre*, *CERN*, Helsinki University, Finland, 2004; F. J. Varela, E. Thompson, E. Roch, *Embodied mind: Cognitive science and human experience*, MITPress; 1991.

[6] The Large Electron-Positron Collider (LEP), one of the largest particle accelerators, built at CERN (1989–2000), circular with a 27 km circumference in a 100 m tunnel underground beneath Switzerland-France border near Geneva, collided electrons with positrons at energies that reached 209 GeV.

[7] The Large Hadron Collider (LHC), the world's largest and highest-energy particle accelerator, built at CERN (1998–2008), in collaboration with more than 10,000 scientists, 100 universities, laboratories and countries, in the same 27 km circumference tunnel used for the LEP at a 175 m depth.

The analysis carried out of the knowledge process (creation, acquisition and transfer) is performed on the new model, created by the combination of the two existing approaches:[8]

3. Kaarle Kurki-Suonio's,[9] which analyses the creation of knowledge in learning processes (to improve teaching in educational environments).
4. Ikujiro Nonaka's,[10] which analyses the creation of knowledge in commercial companies (to identify innovation in industrial environments).

20.5 The Scientific, Technological and Social Processes

The individual and organizational knowledge creation process stands from typical processes triggered by fundamental queries, namely, the incipits of the below chapter.

Galileo Galilei was used to say that *how* is the correct way to address *why*. The answers to the questions why and how are represented by the understanding and the use, i.e., the two principal elements of the knowledge creation process, bifurcating it into the bi-directional arms, the *scientific process* and the *technological process*, that are the interaction types of nature and mind or empiry[11] and theory, operating as follows:

1. The *scientific process* moves back and forward from nature to theory: from nature to theory leads to the *representation* of perceived visions from senses' excitation forming mental pictures of real phenomena and relative properties; from theory to nature leads to *interpretations*.
2. The *technological process* steers back and forward from theory to nature: from theory to nature leads to the *application* in different sectors, governed by hypotheses, verifications, predictions and inaccuracies; from nature to theory leads to *inventions*.

The scientific and technological processes, co-dependent and intertwined, form a loop rotating clockwise mediated and governed by the *social process*, so that:

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[8] K. Kurki-Suonio, *Principles supporting the perceptional teaching of physics: A «practical teaching philosophy»*, Springer, 2010; I. Nonaka, H. Takeuchi, The knowledge-creating company, Oxford University Press, 1995; K. Kurki-Suonio, R. Kurki-Suonio, *The meanings and structures of physics*, 1994; I. Nonaka, *A theory of organizational knowledge creation*, Nihon-Keizai-Shimbunsha, 1990; *Creating organizational order out of chaos: Self-renewal of Japanese firms*, California Management Review, 30, US, 1988.

[9] Kaarle Kurki-Suonio is a Professor Emeritus at the Department of Physical Sciences of Helsinki University in Finland, best known for his study in scientific learning for teaching and education.

[10] Ikujiro Nonaka is a Professor Emeritus at the Graduate School of International Corporate Strategy of Hitotsubashi University in Japan, best known for his study of knowledge management.

[11] Empiry: observation and experimentation, term used in opposition to theory embedding both scientific activity's classes (*Empiry*, L. Palmer's e-mail to physl@atlantis.uwf.edu, 1998).

1. The scientific process constructs world conceptions to understand phenomena.
2. The technological process changes world structures to satisfy uses and needs.
3. The social process negotiates agreed meanings within the other two processes.

The scientific and technological processes, as incentives of the interconnected science and technology,[12] produce as results (thanks to the common meanings achieved in the social process), respectively, the intellectual concepts and the technological products.

The formation of a concept implies all the three processes to be taken into account. Each concept has already its application's seeds and contains both the scientific and the technological meaning, agreed in the social process, allowing individual cognition towards a shared social understanding to ensure the creation of common concepts.

The three processes' loop represents a macro-scale structure and a micro-scale feature of the knowledge creation process. Their inseparable intertwined existence and interconnection can be identified from the beginning of a child development.[13] In particular:

- When perceiving entities, phenomena and properties, organizing the whole-perceived visions with the relative practical applications, taken into account and used elsewhere, the child starts to develop the scientific process.
- When intuitively adapting the behaviour and when searching possibilities and limits via trials and errors, the child starts to slowly develop the technological process.
- When interacting with the parents, as obvious indispensable and significant condition for both child and parents, the child starts to develop the social process.

The three processes' roles, relationship and significance in action can be equally recognized in learning: during planning and interpretation, the scientific process dominates, while nature control via requirements design and performance implies the technological process, and finally the agreement of common meanings requires the social process.

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[12] In the philosophical approach, technology, as a discipline, could be considered as applied science; in some other cases, it could be still considered as the synonym of applied science (P. M. Gulati, *Research management: Fundamental and applied research,* Global India Publications, 2009; M. Bunge, *Technology as applied science*, Technology and Culture, 7(3), 1996).

[13] Hämäläinen, *An open microcomputer-based laboratory system for perceptional experimentality*, Ph.D. thesis, Helsinki University, Finland, 1998; K. Kurki-Suonio, R. Kurki-Suonio, *Perceptional approach in physics education*, Proceedings of the Finnish-Russian symposium Information Technology in Modern Physics classroom, Helsinki University; *The concept of force in the perceptional approach*, Tampere University, Finland, 1994; M. F. Pajares, *Teachers' beliefs and educational research: Cleaning up a Messy Construct*, in review of Educational Research, 62, 1992; T. F. Green, *The activities of teaching*, McGrwa-hill Kogakuska, 1971.

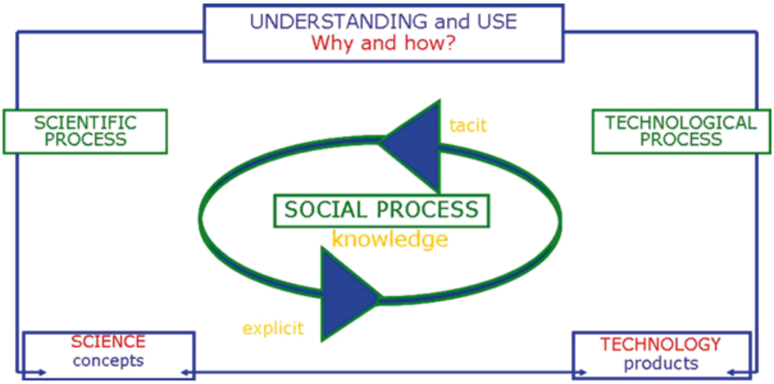


Fig. 20.2 The knowledge pattern model: from creation, acquisition and transfer

20.6 The Knowledge Management Model

This chapter explains the features of the new management model of the creation, acquisition and transfer of knowledge from individuals to organizations and beyond.

The new knowledge management model, bringing together features of Kurki-Suonio's one with those of Nonaka's, starts from the two main motives of the knowledge creation process, the *understanding* and the *use*, answering, respectively, to the questions *why* and *how*. These questions split the process into two branches: the *scientific process*, which builds conceptions to understand natural phenomena, and the *technological process*, which changes structures to satisfy human needs. Both processes are intertwined in a closed circuit by the intervention of the *social process*, which negotiates meanings to find common agreements between the other two processes. The final result of the scientific process is the *science* system via the creation of new *concepts*, and of the technological process is the *technology* system via the creation of new *products*. Thanks to the three processes' loop, it is possible to create, acquire and transfer knowledge, which occurs through the continuous conversion from the *tacit knowledge*, difficult to transmit with the usage of the communication elements, to the *explicit knowledge*, easy to share with the usage of the communication elements (Fig. 20.2).[14]

The inquiry carried out at CERN highlighted that the social process exploited in the meetings' participation, the expertise's acquisition in different sectors and the interests' development, thanks to the interaction among colleagues, is an essential element for the learning process. In particular, the social interactions among individuals of a same project team are important parameters for the knowledge transfer because of their common interests. The social interactions are also facilitated by the organizational structure and by the available communication tools' usage.

[14] B. Bressan, *From Physics to Daily Life*, p. 42, Wiley Blackwell, 2014.

People are capable to continuously create and spread knowledge via the social process, widening their interests and knowledge and expanding their social networks in educational institutions and industrial contexts.[15]

Furthermore, the self-evaluation of the individual contribution is characteristic of the success of the social process in encouraging the progress of the other two processes, the scientific and the technological ones, both capable of bringing further knowledge and innovation.

The two levels present in creating, acquiring and transferring knowledge are the individual learning, characterized by the research spirit, and the organizational learning, characterized by the multiculture. The multicultural aspects contain concurrently constraints, needing a mediation language to negotiate the meanings, and freedom, creating an environment where discoveries can be made. Thus, the best interaction between these two levels is carried out by the right balance between constraints typical of multicultural environments and freedom typical of learning organizations: too much freedom implies considerable financial support, whereas too many constraints lead to lack of ideas, thus reducing innovation.

In learning organizations such as CERN, the formalization of knowledge and technology transfer processes, bridging the interaction between pure scientific research at organizational level and daily technological application at individual level, could represent the right feasible balance between constraints and freedom.[16]

20.7 Social Capital and Competitive Advantage

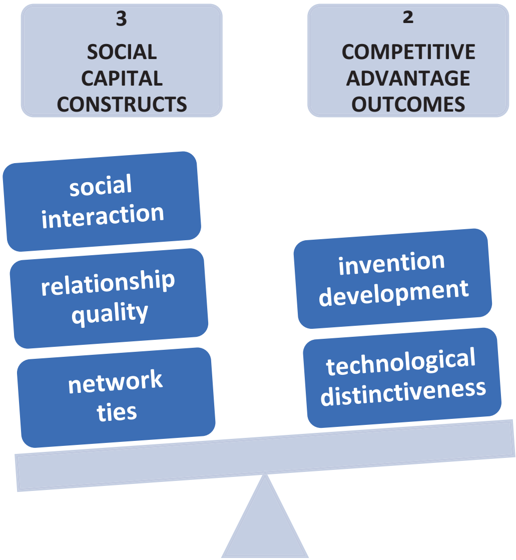
The knowledge acquisition's mediation between interactions and innovations enhances competitive advantage's insights to benefit learning processes, as described below.

Knowledge acquisition plays a mediating role between the three social capital constructs and the two competitive advantage outcomes. The three constructs of the social capital are the social interaction, the relationship quality and the network ties,

[15] J. Wilson, *Essentials of business research: A guide to doing your research project*, SAGE Publications, 2014; E. R. Babbie, *The practice of social research*, Cengage learning, 2010; R. Snieder, K. Larner, *The art of being a scientist: A guide for graduate students and their mentors*, Cambridge University Press, 2009; R. Pelissier, *Business research made easy*, Juta & Co., 2008; J. Swain, M. Monk, S. Johnson, *A comparative study of attitudes to the aims of practical work in science education in Egypt, Korea and the UK*, International Journal of Science Education, 21(12), 1999; K. Tobin, D. J. Tippins, A. J. Gallard, *Research on instructional strategies for teaching science, in*, D. L. Gabel (Ed.), *Handbook of research on science teaching and learning*, Macmillan, 1994.

[16] B. Bressan, *Knowledge management in an international research centre*, Lambert Academic Publishing, 2010; *A study of the research and development benefits to society resulting from an international research centre, CERN*, Helsinki University, Finland, 2004.

Fig. 20.3 Knowledge acquisition versus social capital constructs and competitive advantage outcomes



whereas the two outcomes of the competitive advantage are the invention development and the technological distinctiveness[17] (Fig. 20.3).

In people relationship, social capital facilitates the acquisition of knowledge by ameliorating the access to its sources; by increasing the partner's ability to its identification, exchange and assimilation; and by improving the efficiency of its transfer. This enhances capability for value creation leading to competitive advantage.

The positive association between social interaction and knowledge acquisition implies that learning, particularly when the information is difficult to transfer, is aided by repeated social interactions, building up the intensity, frequency and breadth of exchanged information. While explicit knowledge may be easier to obtain, via reading journals, for example, interactive learning implies both the acquisition of the explicit knowledge observables and of the tacit knowledge components.

Social interaction should facilitate knowledge acquisition by creating intense and multiple interactions and also enhance the ability to recognize and evaluate the suitable external knowledge with insights in specialized information, language and know-how related to invention development and technological distinctiveness.

[17] E. Autio, H. Ari-Pekka, M. Bianchi-Streit, *Can companies benefit from Big Science*? CERN Courier, December 9, 2003; E. Autio, et al., *Social capital, knowledge acquisition, and competitive advantage in technology-based young firms*, Strategic Management Journal, 22, 587–613, 2001; R. M. Grant, *Social capital, knowledge acquisition, and competitive advantage in technology-based young firms*, Strategic Management Journal, 22, 587–613, 2001; R. M. Grant, *Toward a knowledge-based theory of the firm*, Strategic Management Journal, 17, 1996; J.-C., Spender, *Making knowledge the basis of a dynamic theory of the firm*, Strategic Management Journal, 17, 1996; B. Kogut, U. Zander, *Knowledge of the firm, combinative capabilities, and the replication of technology*, Organization Science, 3, 1992.

Implicitly, the social capital affects competitive advantage outcomes via its effects on knowledge acquisition, which is then converted into tangible effects by the organizational learning process.

Via quality relationship and network ties, knowledge acquisition contributes to invention development by integrating and combining specialized knowledge inputs coming from several technological domains. Thus, the related learning provides the steppingstones for the development of organizational routines able to reinforce the available core competences and to form new capabilities.

External specific knowledge acquisition enhances the development of products by increasing the willingness to develop inventions. Providing access to diversified knowledge expands learning opportunities and allows the development of skills to integrate knowledge.

The mentioned case studies identified the following three types of direct results in matter of social benefits and knowledge management, coming from programmes of research learning organizations, as in the case of CERN:

1. New fields of applied technology may be created (e.g., soft-touch).
2. Created pioneering technology may address social need (e.g., WWW).
3. Acquired knowledge may be applied in other sectors (e.g., Medicine).

Furthermore, these inquiries confirm the importance of factors, such as the learning of new skills and the improvement of social networks in the occurring processes, which are in relationship with the labour market acquisition. The development of educational abilities should be managed, used and catalysed to target individual development in order to improve their future opportunities in the labour market and venture performance.[18]

Bringing together several outstanding examples of successful cross-disciplinary technology and knowledge transfers from education and learning environments can dramatically impact progresses and breakthrough developments and be applied also in disadvantaged countries to empower youth's business activities and to benefit society in a sustainable manner.[19]

Knowledge management and technology transfer solutions can indeed be applied also in complex contexts to boost humanitarian and social action and impact positively people's daily life through the creation of a new resilience culture based on innovations and inventions.

[18] B. Bressan, *Knowledge transfer: From creation to innovation*, CERN Courier, April 1, 2009; B. Bressan, et al., *Knowledge creation and management in the five LHC experiments at CERN: Implications for technology innovation and transfer*, CERN and Helsinki University, 2008.

[19] B. Bressan, *From physics to daily life: Applications in informatics, energy, and environment; From physics to daily life: Applications in biology, medicine, and healthcare*, Wiley Blackwell, 2014; H. Davies, B. Bressan, *A history of international research networking*, Wiley Blackwell, 2010; B. Bressan, M. Streit-Bianchi, *CERN technology transfers to industry and society*, CERN, 2005.

20.8 The Social Business Case

In a new resilience culture, solutions from education environment to private sector can offer sustainable social business opportunities to empower youth from complex contexts.

In regions where the movement of people and goods is severely restricted, possible solutions to this kind of limitations can be found in the creation of social enterprises, around the development of specific technologies, conceived as first end-to-end solution from education environments to the private sector, in order to possibly offer commercially sustainable opportunities.[20]

By creating an enduring, life-changing working environment where people can grow individually and improve their family socio-economic well-being, start-ups with hybrid business model, integrating economic returns with social impacts, can empower directly highly educated committed youth with a challenging life, who learnt to go the extra mile because of the hardship, while delivering real business value to local communities. Often, indicators of such social enterprises show consistent real high increases in only few years of operations.

The Nobel Peace Prize Muhammad Yunus[21] considers that a social business income is reinvested in the business itself with the aim of increasing social impact. As the Norwegian Nobel Committee stated: “Across cultures and civilizations, Yunus and Grameen Bank[22] have shown that even the poorest of the poor can work to bring about their own development” because “lasting peace cannot be achieved unless large population groups find ways in which to break out of poverty”.

Unlike a profit business, where the prime is to maximize profits, and unlike a non-profit business, where income is spent on the field, funds in a social business are invested to increase the profit on the field on an indefinite basis.

Based on Yunus’s philosophy,[23] where the profits made via social business’s operations are less important than the beneficial effects it has on society, it is possible to develop a social business around technology and knowledge transfers from research and learning organizations. This can be done specifically to foster inclusive, crosscutting solutions to promote good governance and strategy in addressing the emerging security challenges and shared global risks posed by the globalization,

[20] E. H. Latifee, *Social business: A new window of poverty alleviation; Tourism economics, pollution and social business*, The Financial Express, Retrieved June 28, 2015.

[21] Muhammad Yunus is a Bangladeshi social entrepreneur and economist who was awarded jointly with the Grameen Bank in 2006 the Nobel Peace Prize for pioneering the concepts of microfinance and “for their efforts through microcredit to create economic and social development from below”.

[22] Grameen Bank is a community development bank founded in Bangladesh that makes small loans (*grameencredit*) to the impoverished entrepreneurs, too poor to qualify for traditional bank loans, without requiring collateral.

[23] M. Yunus, *Building social business: The new kind of capitalism that serves humanity’s most pressing needs; Creating a World Without Poverty: Social Business and the Future of Capitalism*, Public Affairs, 2011 and 2009.

such as wars, pandemics, nuclear proliferation, human rights violation, poverty and so on.[24]

Furthermore, the assessment of the social return of social investments, being these a project, a business, a foundation, an association or an organization, helps the stakeholders to allocate the resources, to adjust the plan, to evaluate the social impact as well as the benefits that cannot be in a straightforward way monetarized and, last but not least, to ensure transparency.

More and more in business, there is a shift towards small groups' subdivision to facilitate decision-making process and the introduction of concepts such as human and environmental sustainability as part of the enterprise. Agility, adaptability, impermanence and sustainability are the main characteristics valued to propose new solutions and innovative visions beyond sociocultural barriers.

Especially because of the crisis resulting from the COVID-19 pandemic, a rapid implement of a fundamental change of paradigm versus the development of a holistic and systemic approach integrating education, economy, environment, health and social condition is needed to build a new ethic framework of society functioning beyond profitability.

In this respect, research and learning centres, such as CERN, in partnership with other governmental organizations, such as the United Nations, can promote emancipation processes leading to enhanced cooperation and operability for developing an intertwined framework among global members and stakeholders to make knowledge actionable from local to global. This has to be done in alignment with the 17 Millennium Sustainable Development Goals (SDGs)[25] of the 2030 United Nations' agenda, which provides a coherent way of thinking about the interaction of such issues (Fig. 20.4).

Applications of these fruitful collaborations can be found also in disadvantaged countries. One example has been the realization of an ICT local social enterprise, a spin-off of UNRWA[26] based in Gaza, Palestine, where almost 70% of the approximately 1,000 students, who yearly graduate in Information and Communications Technology (ICT) programmes from Gaza universities, remain unemployed in spite of the rapid local industrial growth in this sector.[27] Their high level of education,

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[24] W. L. Christman, *Building Global Resilience: Integrated Learning for Next Generation Global Citizens* (forthcoming).

[25] The 17 Sustainable Development Goals (SDGs) are : (1) No poverty; (2) Zero hunger; (3) Good health and well-being; (4) Quality education; (5) Gender equality; (6) Clean water and sanitation; (7) Affordable and clean energy; (8) Decent work and economic growth; (9) Industry, innovation, and infrastructure; (10) Reducing inequalities; (11) Sustainable cities and communities; (12) Responsible consumption and production; (13) Climate action; (14) Life below water; (15) Life on land; (16) Peace, justice and strong institutions; and (17) Partnerships for the goals.

[26] UNRWA (United Nations Relief and Works Agency for Palestine Refugees in the Near East): *Gaza Situation Report*, Issue n. 170, November 18, 2016.

[27] In 2012, Gaza's exports were valued at 2% of 1999 exports, while manufacturing has shrunk to less than one-half of its 1999 value. Goods exiting in Gaza in 2013 were equal to 73% of its weekly exports prior to the 2007 blockade. Gaza's real per capita gross domestic product (GDP) had fallen from 89% of that of the West Bank to less than half in 2010 (UNCTAD – United Nations Conference

Fig. 20.4 United Nations 17 Millennium Sustainable Development Goals (SDGs)

multi-lingual workforce and competitive costs make this particular region a high-potential outsourcing destination.

With the aim of offering recent ICT graduates a temporary employment and a capacity building environment, this non-profit initiative, launched with South Korean governmental funds, has supplied commercial areas yet to be covered by the local market with ICT services, envisaging to establish itself as a hub for ICT outsourcing solutions abroad with companies, non-governmental organizations and other entities as clients.

In order to fulfil its mission and to establish its high-potential socio-economic impact as a Gaza start-up with adequate preparation and support, CERN in agreement with UNRWA invited the enterprise management and apprentices to attend specific open-source software sessions in the CERN ICT Department. This allowed the social enterprise's employees to acquire the necessary knowledge to be transferred to their local context, to enrich its services' portfolio, to satisfy better its customers' needs, and to increase its market segment opportunities.

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on Trade and Development, Secretariat, 58th session, Geneva, Switzerland, 2011). In 2014, unemployment was 40.8%, including 79.2% for young women (PCBS – Palestinian Central Bureau of Statistics, Labour Force Survey, First Quarter, 2014). By 2020, Gaza already needed 75,200 new jobs, simply to maintain its current rate of unemployment (*Gaza 2020. A Liveable Place?* UNRWA, August 2012). In particular, according to a 2013 research, the 68% of the approximately 1,000 students, who yearly graduate in ICT programmes from Gaza universities (PITA – Palestinian Information Technology Association, Sector Strategy, 2012), remained unemployed or occasional freelancers (Mercy Corps D-LMNA – Labour Market Needs Analysis for the Digital Economy, April 2013), in spite of the recent rapid local industrial growth in this sector that has been static since 2012. Indeed, the ICT contribution estimation to Gaza's GDP growth for the first nine months of 2012 has been evaluated equal to 0.02% from the World Bank Ad Hoc Liaison Committee Report, AHLCR (UNSCO – United Nations Special Coordinator for the Middle East Peace Process, Socio-Economic Report, Palestinian Economy Overview, 2013). The statistical impact is bigger for women, taking into account that 30 Gaza ICT companies reported that 31% of their professional staff is female (Mercy Corps D-LMNA, April 2013).

Such initiatives enhance the social value and social capital of knowledge management in science and technology through transformative education and work as a compass for future young leaders. Thus, youth will be able to realize social businesses covering specific needs impacting positively their local society and improving their life quality, thanks to new innovative educational patterns.

20.9 The Education Pattern

By revisiting traditional roles, transformative education becomes crucial in managing knowledge for society via academics', organizations' and industries' new alliances.

The unfolding of transformative educational patterns, from the individual's learning process to the organization's knowledge acquisition for the knowledge transfer from such organizations to other entities, has two direct consequences, namely, the need of versatility of the traditional roles as well as the need of the realization of strong interactive infrastructures.

Firstly, traditional roles as educators have to be redefined by embedding innovative approaches, such as the individual learning and the e-learning, as well as the students' capability to directly manage their own knowledge acquisition, while those of librarians have to be diversified by including in their competences also those of both information specialists, in order to control the in-out knowledge flux in educational environments, and of trainers, in order to teach the knowledge management process.

Secondly, the introduction of ICT in the learning process and the knowledge flux has converted the learning infrastructures, such as libraries and classrooms, into dynamic platforms and spaces interconnecting people, departments, databases and electronic apparatus to be used for transformative training and education. Thus, both analog and digital devices serve as excellent tools for the development of cognitive and interpersonal skills, improving the attention to detail, the problem-solving, the critical reasoning, and the lateral thinking.

In education and industry, the potential of research centres and universities may well be under-utilized. Only when more explicit attention will be paid to the management of learning, the technological spectrum and educational impact will be enhanced. In this way, the knowledge management and technology transfer will be boosted up through the creation of ad hoc interconnected triangulations among the education and outreach departments of academic institutions, the corporate social responsibility of organizational contexts and the start-ups and small and medium enterprises (SMEs) of industrial environments (Fig. 20.5).

Such interactive triangles, involving the above-mentioned different types of actors, will help the transversal communication and information exchange from one recipient to another one, so that contextual languages will be enriched and new concepts and hints will be created. This will help the new knowledge creation, acquisition and transfer, thus the management process, beyond learning in

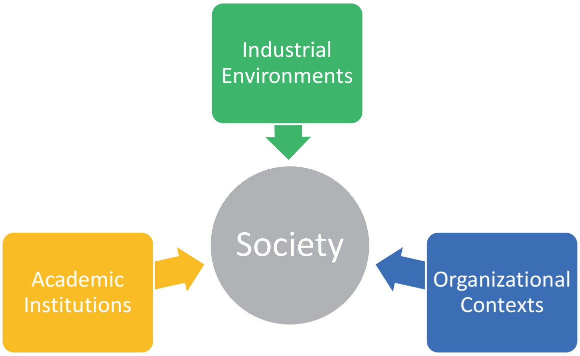

Fig. 20.5 The knowledge management triangulation

various-type institutions, including the scientific ones, such as research laboratories, universities, campus and so on. Their contribution to this holistic approach will allow the technology integration into the private sector in order to trigger innovation systems for helping worldwide sustainable development for future generations and improving the quality of their daily life and families.

In this way, the triangular intertwined alliances could also represent a future new engine able to boost transparent and ethical integrated mechanisms to empower future youth leadership and to promote a new culture of resilience in order to benefit society at large in many geographical areas, including the most disadvantaged, complex and impoverished ones.

This approach will also support ongoing worldwide activities in order to enable young leaders to become changemakers in their communities in pursuit of sustainable development by providing an adequate embedding umbrella for worldwide initiatives, such as social entrepreneurship, peace building, economic governance, environmental preservation, and tolerance advocacy, thus strengthening their scope and effectiveness locally and then globally.[28]

20.10 Conclusion

The dynamic process of knowledge creation is based on the assumption that human knowledge is created and expanded, in terms of both quality and quantity, via social interaction between tacit knowledge (personal and hard to formalize in

[28] In 2015, 1.2 billion people were aged between 15 and 24 predicting to grow by 7% in 2030 (*World Population Prospects: The 2012 Revision*, UN Publications, Sales No. 13.XIII.10). The project, *One Million Youth Leaders beyond 2030* (1M2030, 1m2030.org) under the Global Challenges Forum Foundation (GCF: globalchallengesforum.org) in collaboration with the United Nations Institute for Training and Research (UNITAR: unitar.org), aims to empower this growing youth, from countries in difficult situations, by offering them an integrated training platform in order to accompany them in their endeavours.

communication) and explicit knowledge (formal and easy to transmit with systematic language). This interaction, called knowledge conversion (tacit to explicit to tacit), represents a social process among individuals and is not confined within the single. It is precisely during this conversion, from individual learning to organizational acquisition, that knowledge is created. Knowledge creation fuels innovation, which is an essential part of the mechanism of knowledge transfer inside organizations such as CERN, the European Laboratory for Particle Physics located near Geneva in Switzerland.

Communicating specific disciplines must represent an engine of industrial promotion and transformative education integrated into the research and educational world, regardless of the assumptions that govern communications, so that a communication message is associated with knowledge and technology transfer. Finally, in this transfer lie the creation of new knowledge and therefore the ability to generate innovation. The theory of knowledge acquisition, creation and transfer has been integrated and applied to the communication strategy in learning environments and research centres such as CERN, bringing innovative elements into this approach.

An inquiry, carried out at CERN, highlighted that the social process exploited in the participation in meetings, the acquisition of expertise in different sectors and the development of interests, thanks to the interaction among colleagues, is an essential element for the learning process and the knowledge creation. The self-evaluation of the individual contribution is indicative of the success of the social process in encouraging the progress of other two processes, the scientific and the technological ones, both capable of bringing further knowledge and innovation.

The inquiry confirmed that there are three types of direct results in matter of social benefits and knowledge management coming from research programmes in organizations such as CERN: namely, new fields of applied technology may be created, the creation of pioneering technology may address social need, and acquired knowledge may be applied in other sectors.

The inquiry underlined also the importance of factors, such as the learning of new skills and the improvement of social networks, in the occurring processes in relation with labour market acquisition. The development of educational abilities should be managed, used and catalysed to target individual development in order to improve their future opportunities in the labour market.

Education environments should also be able to revisit their traditional roles and infrastructures and to introduce multimedia tools for training and information purposes in order to enlarge the effectiveness of their educational impact and to ensure the intent of their communication scope.

Individuals are able to continuously create and expand knowledge, thanks to the social process, widening their interests and knowledge and expanding their social networks in educational institutions and industrial contexts. Indeed, interactions among individuals are important parameters for the knowledge transfer and can also be facilitated by the organizational structure and by the frequent usage of the available communication tools.

Research centres, universities and their contributing member countries should encourage and create the conditions to make the collaboration feasible with industrial companies and educational institutions and communicate the impact achievements have on society and young generations, even in disadvantage countries and complex contexts.

A unifying number of outstanding examples of successful cross-disciplinary technology and knowledge transfers can dramatically impact innovation progresses and breakthrough developments and be applied also in deprived countries and complex contests. This will enhance the social value and capital of knowledge management in science and technology through transformative education and work as a compass for future young leaders who will be able to realize social businesses affecting positively their local realities.

Last but not least, a future new engine framework, involving different types of actors, is needed to boost holistic and ethical integrated mechanisms to empower future youth leadership and to promote a new culture of resilience in order to benefit society at large in many geographical areas, including the most impoverished ones. Thus, this will enable young leaders to become changemakers in their communities in pursuit of sustainable development by providing adequate innovative solutions to strengthen their scope and effectiveness.

Bibliography

Autio, E., et al. (2001). *Social capital, knowledge acquisition, and competitive advantage in technology-based young firms*. Strategic Management Journal, 22, 587–613.

Autio, E., Ari-Pekka, H., & Bianchi-Streit, M. (2003, December 9). *Can companies benefit from Big Science?* CERN Courier.

Babbie, E. R. (2010). *The practice of social research,* Cengage learning.

Battistelli, A. (2002). *Master in Comunicazione Pubblica*. Cagliari: Università degli Studi.

Bianchi, M. (1991). *New problems in the field of information and training created by the use of methodologies interactive and audiovisual systems. Elementary Particle Physics Course*. Geneva: CERN.

Boisot, M., et al. (2011). *Collision and collaboration*. Oxford: Oxford University Press.

Bressan, B. (1998). *The many aspects of science communication, Master thesis in science communication*. Trieste: International School for Advanced Studies (ISAS).

Bressan, B. (2004). *A study of the research and development benefits to society resulting from an international research centre, CERN*. Geneve: CERN, Helsinki: Helsinki University.

Bressan, B. (2009, April 1) *Knowledge transfer: From creation to innovation,* CERN Courier.

Bressan, B. (2010). *Knowledge management in an international research centre*, Lambert Academic Publishing.

Bressan, B. (2014a). *From physics to daily life: Applications in informatics, energy, and environment*, Wiley Blackwell.

Bressan, B. (2014b). *From physics to daily life: Applications in biology, medicine, and healthcare*. Wiley Blackwell.

Bressan, B., & Streit-Bianchi, M. (2005). *CERN technology transfers to industry and society*. Geneva: CERN.

Bressan, B., et al. (2008). *Knowledge creation and management in the five LHC experiments at CERN: Implications for technology innovation and transfer*. Geneve: CERN, Helsinki: Helsinki University.

Bunge, M. (1996). *Technology as applied science*. Technology and Culture, 7(3).

Davies, H., & Bressan, B. (2010). *A history of international research networking*. Wiley Blackwell.

Grant, R. M. (1996). *Toward a knowledge-based theory of the firm.* Strategic Management Journal*,* 17.

Green, T. F. (1971). *The activities of teaching*. Tokyo: McGrwa-hill Kogakuska.

Gulati, P. M. (2009). *Research management: Fundamental and applied research*. Global India Publications.

Hämäläinen, A. (1998). *An open microcomputer-based laboratory system for perceptional experimentality*, Ph.D. thesis. Helsinki: Helsinki University.

Kogut, B., & Zander, U. (1992). *Knowledge of the firm, combinative capabilities, and the replication of technology.* Organization Science, 3.

Kurki-Suonio, K. (2010). *Principles supporting the perceptional teaching of physics: A « practical teaching philosophy »*. Springer.

Kurki-Suonio, K., & Kurki-Suonio, R. (1994a). *The meanings and structures of physics*. Helsinki: Helsinki University.

Kurki-Suonio, K., & Kurki-Suonio, R. (1994b). *The concept of force in the perceptional approach*. Tampere: Tampere University.

Kurki-Suonio, K., & Kurki-Suonio, R. (1994c). *Perceptional approach in physics education, proceedings of the Finnish-Russian symposium information Technology in Modern Physics Classroom*. Helsinki: Helsinki University.

Latifee, E. H. (Retrieved 2015, June 28). *Social business: A new window of poverty alleviation, and Tourism economics, pollution and social business*, The Financial Express.

Livingstone, S. (2000). *On the cutting edge, or otherwise, of media and communication research.* Nordicon information 22. London: London School of Economics and Political Sciences.

Nonaka, I. (1988). *Creating organizational order out of chaos: Self-renewal of Japanese firms*, California Management Review, 30, US.

Nonaka, I. (1990). *A theory of organizational knowledge creation*. Tokyo: Nihon-Keizai-Shimbunsha.

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company*. New York: Oxford University Press.

Pajares, M.F. (1992). *Teachers' beliefs and educational research: Cleaning up a Messy Construct.* In review, Educational Research, 62.

Pelissier, R. (2008). *Business research made easy*. Juta & Co.

Snieder, R., & Larner, K. (2009). *The art of being a scientist: A guide for graduate students and their mentors*. New York: Cambridge University Press.

Spender, J.-C. (1996). *Making knowledge the basis of a dynamic theory of the firm*. Strategic Management Journal, 17.

Swain, J., Monk, M., & Johnson, S. (1999). *A comparative study of attitudes to the aims of practical work in science education in Egypt, Korea and the UK.* International Journal of Science Education, 21(12).

Tobin, K., Tippins, D. J., & Gallard, A. J. (1994). *Research on instructional strategies for teaching science.* In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning*. New York: Macmillan.

Varela, F. J., Thompson, E., & Roch, E. (1991). *Embodied mind: Cognitive science and human experience*. Cambridge, MA: MITPress.

Visalli, N. (2004). Percorso formativo, Modulo 5: *Collaborare e apprendere in rete. Strumenti di Comunicazione Sincrona e Asincrona*, Palermo: Liceo Ginnasio G. Garibaldi.

Yunus, M. (2009). *Creating a World Without Poverty: Social Business and the Future of Capitalism*. New York: Public Affairs.

Yunus, M. (2011). *Building social business: The new kind of capitalism that serves humanity's most pressing needs*. New York: Public Affairs.

Chapter 21
Integration of Technology Initiatives with Educational Neuroscience and its Impact on Technology Readiness to Technology Adoption by HSS Teachers, Kerala

Genimon V. Joseph and Kennedy Andrew Thomas

21.1 Introduction

The modern world is almost fully driven by the technology systems, and the mutual collaboration of multiple branches of knowledge with transdisciplinary researches is fuelled through the technology platforms. The constant modifications of the digital technologies became the essential part of the developments throughout the globe. The rapid advent of a plethora of new technologies in all fields of social existence demands an accelerated digital learning and proficiency in creating high-performing work systems (Collins and Halverson 2018). The time and quality concerns of the product and services of the industrial world are supported with the emergence of neuroscience and artificial intelligence systems of the Industry 4.0. The human resource development process being the backbone of the sustained industrial developments needed to be evolved with these digital technology backdrop (Calderón and Izquierdo 2020). Hence, the facelift in education process needed to be harmonized in tune with the industrial demands and technology advancements. The socio-psychological studies on the education technology incorporation reported a secondary digital divide in terms of the quality of the Technology Adoption between the educators and the student community. The student community with their digital native characteristics thrives for the innovative digital learning facilities and maintains an ever-inclined disposition to the digital experimentation in their learning environments. The learning facilities with the emergence of the Semantic Web 3.0

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connectivity open up even surfeit learning opportunities for the students, and the dependency of the student on traditional education styles is getting substituted through digital learning platforms (Vaidya et al. 2018; Benešová and Tupa 2017; Calderón and Izquierdo 2020).

The secondary digital divide causes a considerable lag in the educational Technology Adoption process mainly due to the technology retarding attitudes of the teachers. The unlearning process of the traditional pedagogy for the digital learning process is rather sluggish for the educators. The propositions of the neuroscience on pedagogy, learning and memory have contributed towards the emergence of the educational neuroscience and brain skills increasingly incorporated in curriculum also (Antonenko 2019). The reductionist predispositions related to the technological determinism of the educators also needed to be addressed to bridge the chasm of this secondary digital divide. The s-shaped curve for the diffusion of technology initiatives indicates the need of digital scaffolding process for enhancing educational Technology Adoption, and technology incorporation attitudes of the teachers needed to be addressed with regular digital training programmes (Jones and Pimdee 2017; Kim and Lee 2018; Lawrence and Tar 2018).

The analytical part of this study concentrates more on the Technology Adoption aspects of the teachers, which is the essential virtual scaffolding in the digital education systems. The analysis of Technology Adoption of the teachers with respect to their Technology Readiness and the digital learning initiatives provided by the State of Kerala through Kerala Infrastructure and Technology for Education (KITE) in state syllabus schools are addressed in this part.

The added fervour of the students towards the technology-based education systems could even surpass the teacher's technology hurdles, and the Covid-19 situation became the cradle of many such innovations beyond the limits of physical lockdown situation. These learning initiatives are intended for seamless flexible education systems suiting to millennium learners' expectations. The case study part of this chapter deals with these successful applications of the technology learning with tools of neuroscience for enhancing learning process and memory.

21.2 The Fluidity of Learning Through Technology and Educational Neurosciences

The education technology supported by the innovations of neuroscience could offer seamless e-learning experiences to the new-Gen learners of education 4.0. The educational neuroscience is transdisciplinary in nature which associates closely to the brain science, pedagogical sciences and socio-cognitive philosophies of learning (Cavanaugh et al. 2016). The theoretical and pedagogical perspectives of education systems integrated with technology and neuroscience could offer a better learning experience to the new-Gen learners. The attributes and enablers of the learning and memory brought through the domains of social, affective and cognitive neuroscience contributed significantly towards the design of technology-based education systems (Antonenko 2019). The application of educational neuroscience aspects in classrooms can mainly influence the pedagogy than the curriculum.

The screen learners were often blamed for their peripheral learning with gadgets. The studies suggest the application of educational neuroscience on the digital learning process to overcome the peripheral learning trends of the millennium learners. The deep learning can be resulted with the adaptive learning process, reduced cognitive learning load and integration of social learning with fun (Howard-Jones et al. 2015; Cavanaugh et al. 2016). The metacognition with personalized learning and enhanced teacher-student relationship became critical to the virtual learning process also. Understanding the learners' peripherals, realizing their needs and collaborating with their learning process are to be considered as more significant in education than loading with learning chunks. The unprecedented array of existential learning challenges can be better faced where the education systems aptly incorporated the fluidity of learning with the support of the neuroscience tools (Cavanaugh et al. 2016; Nayar 2018).

This chapter addresses how the seamless technology integration established with tools of the educational neuroscience influenced the educators' attitudes. These educational neuroscience tools as paced learning atmosphere, mixed learning from home, embedded cues with the support of the parents, after-class student-teacher interaction, learning with digital demonstrations, incorporation of the augmented reality and other narrative methods, creating social supporting systems for learners, ensuring media support and broadcasting channel collaborations made tremendous influence in the technology-based virtual learning process and were readily accepted throughout the State of Kerala.

This study discusses how the skills of educational neuroscience integrated with the digital initiatives of KITE and its role on providing uninterrupted education during the Covid-19 pandemic in Kerala. The initial part of the study is devoted to the digital initiatives of the KITE before and during the Covid-19 pandemic to provide uninterrupted education in Kerala. The analysis was done on Technology Adoption of the teachers based on these novel teaching systems adapted from the educational neuroscience through the digital learning process.

21.3 Education System of the State of Kerala

The State of Kerala has undergone remarkable education reforms during the colonial and post-Independent periods. The school education systems in the State of Kerala consisted of mainly three main streams of schooling as Central Board of Secondary Education (CBSE), Indian Certificate of Secondary Education (ICSE) and the state syllabus schools. The home schooling and private schooling systems are not well established in the state. The CBSE and ICSE curriculum-based school education are mostly provided through the private sector on self-financing basis. In addition to this private sector schools Kendriya Vidyalaya and Jawahar Navodaya

Vidyalayas were also available in limited numbers in Kerala. Trade-based education through Industrial Training Institutes (ITI), Industrial Training Centres (ITC) and Vocational Higher Secondary School (VHSE) were also operating in the state (Valatheeswaran and Khan 2018; Mehendale and Mukhopadhyay 2019). The university education system begins after the higher secondary schooling with multiple options for the specialized disciplines as per choice.

In Kerala, the public education sector is predominantly supported by the state syllabus schools. The state syllabus schools during the post-National Education Policy (NEP) 2020 are offering education as per the Guidelines of the State Council of Educational Research and Training (SCERT) and based on the management of schools; there are three systems differentiated as:

- Government schools, established and governed by the government systems. The infrastructure development, maintenance, salary and recurring expenses were met by the General Education Department of the State of Kerala.
- Government-aided private schools whose infrastructure was established with the contribution from private educational agencies. They were managed by the educational agencies funded by the government for salary and recurring expenses.
- Private-unaided schools were established and managed by the private educational agencies with own funds and with fees from the admission (Fig. 21.1).

There were vernacular (Malayalam) and English medium state syllabus schools in the above three categories. The schools followed a triple language system in Kerala as English, Malayalam and Hindi. The syllabus and the academic contents were supported by Kerala SCERT. The details of the students and staff under the state syllabus school system are given below (Table 21.1).

The Kendriya Vidyalayas, Jawahar Navodaya Vidyalayas and other centre government schools funded fully by the Central Government schemes and other centre syllabus schools were functioning on self-finance or unaided basis under the private educational agencies. The State of Kerala invested heavily in the education sector to develop its human resource capital. Around 80% of the education expenditure was allocated for the general education sector which included the school education and higher education (Mehendale and Mukhopadhyay 2019). This study was conducted before the implementation of National Education Policy 2020. The National

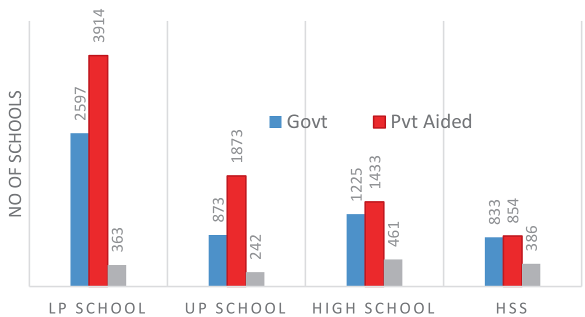

Fig. 21.1 The distribution of state syllabus schools. (Source: Kerala Economic review-2017)

Table 21.1 Summary of state syllabus school system in Kerala 2020

Districts	Schools	Teachers	Non-teaching staff	Students
15	16,028	169,373	20,297	4,542,678

Source: Data updated on 05.05.2020 from http://education.kerala.gov.in/

Education Policy 2020 envisages many substantial changes in the education systems of India and the state. The current education system of the state consisted of Lower Primary Schools (LPS) from first to fourth years, upper primary school (UPS; fifth to seventh classes), high school (eighth to tenth classes) and the higher secondary schools (HSS; 11 and 12th classes). The pre-schooling education with lower kindergarten (LKG) and upper kindergarten (UKG) was considered as preparatory to the formal education system (Kumar n.d.).

21.3.1 New National Educational Policy 2020

With the new National Education Policy (NEP) 2020, the Government of India seeks to address the existing disparity in education systems with an integrated vision from the pre-school to the research level. NEP 2020 was intended to provide an amicable solution to the issues related to access, equity, quality, affordability and accountability of the current education system. It is to be noted that as per the recommendation of New Education Policy 2020 the school education system in India will incorporate the pre-schooling systems and be restructured to a new '5 + 3 + 3 + 4' design from the existing model (Kumar et al. 2020). The modification of the school categories as per the NEP 2020 will have:

A. Foundation stage of education. This initial stage consisted of five years of pre-primary education and two classes of the existing system. Before the new NEP 2020 the initial education through the kindergarten education was considered as a preparatory stage for the formal classes.
B. Preparatory stage of 3 years (classes 3rd, 4th and 5th).
C. Middle class with 3 years (6th, 7th and 8th).
D. Secondary school stage with 4 years (classes 9–12). Thereafter the students will move to the degree education system with advanced specialized choices (Ramachandran 2019; Malhotra 2019; Kumar et al. 2020).

21.4 Learning Enhancement Through Education Technology Initiatives of Kerala

The State of Kerala has a well-maintained education system, modernized with the development of Information and Communication Technology (ICT) in par with the developed countries of the world. The application of the educational neuroscience tools for enhancing the cognitive, social and affective domains of the technology-based learning and memory is integrated in the projects. The educational neuroscience tools as flexible, collaborative and personal learning models were given priority in the various schemes of this technology initiative. Having a well-networked technology frame and administrative system, Kerala made a leap in technology-based education, integrated under the Department of Education, Kerala. These technology initiatives of the state were organized with the IT@School initiative established in 2001 under the General Education Department, which made very remarkable technology interventions in the education fields. All the technology initiatives brought by a Special Purpose Vehicle (SPV) company named Kerala Infrastructure and Technology for Education (KITE) under the Education Department of Kerala in 2017. The KITE continued the digital initiatives of the IT@School, with its effective multi-levelled functional structure (given in Fig. 21.2) and it fully integrated the technology-enabled education formation of the State (Nayar 2018; KITE 2020).

KITE has now extended its scope beyond the school levels to higher education systems by fuelling the technology initiatives of professionals and other colleges. The technology interventions through KITE in the school education system of the state were in a paced manner without inculcating resistance from the teachers. The well-appreciated and effective technology-based learning was intended for deep learning and greater memory retention. It is to be noted that the technology advancement and its prompt implementation in education were achieved along with digitalization of the different public service departments of the State of Kerala. The KITE could coordinate the virtual education systems for all the students of the state during the Covid-19 pandemic situation in academic year 2020 through online channels, social media, VICTERS TV channels, etc. (Anupama and Sreekala 2020).

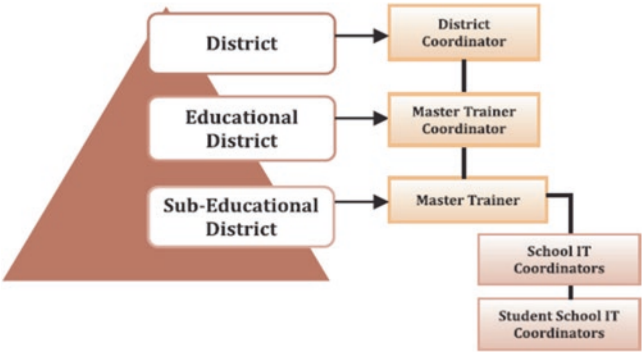

Fig. 21.2 Kerala Infrastructure and Technology for Education (KITE)

21.4.1 Traditional Pedagogy to Learning Technology with IT@ School and KITE

The education system of the State of Kerala was mainly concentrated around the traditional pedagogy with classroom lecture, blackboards and charts. The remarkable roll-out of traditional models was initiated by the IT@School projects. In a short span of time, the public schooling under the state NCERT curriculum was revamped with technological initiatives from the IT@School. The technology integration with educational neuroscience tools was initiated and coordinated under the IT@School project after 2001 (Nayar 2018). The major milestones on digital initiatives in education systems are given below.

- Introduced Information Technology (IT) subject from 2003 in schools to provide an in-depth digital training for the students and staff. Appointed IT instructors in all schools to train and maintain the digital infrastructure for better facilitation.
- The digital initiatives of the state based on the non-proprietary Linux systems were initiated in 2005. The Linux-based computational systems were adopted in all state syllabus schools by 2006 for school office management, digital labs, education management software and for all associated systems.
- VICTERS (Virtual Classroom Technology on Edusat for Rural Schools) channel was introduced in 2006. VICTERS channel was made available through the existing cable networks. VICTERS channel became digitalized by 2014.
- The shift to Linux-based system implementation was completed by 2007 in Kerala. It was appreciated as the world's largest simultaneous deployment of FOSS (Free and Open Source Software Systems).
- The well-connected IT training system was introduced with master trainers and IT coordinators for facilitating the IT training in schools. State-level IT trainings were imparted through this technology channels.
- ICT-enabled education was established by 2010 in Kerala syllabus schools. The shift was from IT as a subject to ICT-based education.
- In the next level, in continuation of the IT subjects in the lower classes, a compulsory IT theory and practical exam were included in SSLC public exam. The Information Technology theory exam conducted over the software by 2012.
- Introduced systematic and time-bound digital capacity building programme for teachers with regular cluster-based trainings on ICT in all sub-educational district levels. This was intended to promote teachers' skill in hardware and software management, content development for the lectures, use of relevant free software tools, etc.
- Capacity building for students through Student School IT Co-ordinator (SSITCs) was provided with basic and special training on technology as app development, animation, editing, etc. Technology trainings given to the SSITCs were coordinated throughout the state (Fig. 21.3).
- Regular IT melas (exhibitions) are conducted for the technology spread and awareness. It is also intended to provide technology gadgets on affordable prices

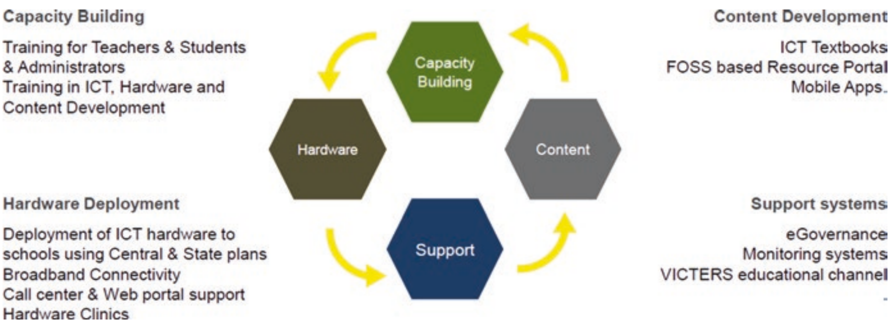

Fig. 21.3 Capacity building for students and staff. (Source: KITE 2019 (https://kite.kerala.gov.in/KITE/))

for educational purpose. In 2010 hardware clinics were established in schools with the support of in-house resources for self-dependency. Training on hardware repair was provided through the nodal centres.

- The infrastructure upgradation projects were introduced in 2016. It provided funds for the development of space and procuring the necessary IT instruments for the smart classroom, centre ICT facility, data connectivity, etc. for the government schools, while the aided sector schools built basic space requirements and availed the funds for procuring the necessary IT instruments.
- School's computer system was fully on custom-made GNU/Linux operating system, with prompt modification, upgradation and trainings given free of cost to teachers.
- Use and customization of software learning resources such as Dr. Geo, Rasmol, K-Tech lab, Geogebra, Chemtool and Kalcium for learning beyond curriculum. The outstanding contributions were appreciated.
- Establishment of Centres of Excellence in public education system in 2017. This project aims to create education system in international standards at public education systems in a phased manner with the Rejuvenation Campaign.
- Implemented 'Sampoorna' (complete) school management system. It is established under the Education Department of Kerala and serves as the complete automated system for student management in terms of admission, transfers, certificate issuing, etc.
- Introduced the 'Samanyaya' for transfer and posting of the teachers. It offers a paperless process for transparency and efficiency.
- Sametham school data bank for the administration of physical infrastructure and governance mechanisms of government schools.
- Hi-tech classroom project to enable ICT facilities to 45,000+ classrooms of 4752 schools as on 2019 Nov. It includes laptop, ceiling-mounted multimedia projector, HDMI cables and faceplates, whiteboard/projection screen, USB speakers, high-speed broadband Internet and access to Samagra resource portal.
- ICT textbooks for lower primary to higher secondary school students. Textbook supply monitoring systems, hi-tech surveys, etc.

21.4.2 Integration of Educational Neuroscience Tools in Curriculum and Pedagogy

The threat of non-adoption of education technology among teachers was addressed with the findings of the educational neuroscience. The social learning, collaborative learning, cognitive learning and deep learning process were integrated to the pedagogy development. Resource portal and tools were made available for teachers and students. Teachers' logins were used for content development, digital surveys, education management ERP and other enabling digital facilities (Nayar 2018). The main milestones were the following:

- Introduction of School Wiki (www.schoolwiki.in 2009) became a platform for knowledge sharing portal with collaboration of students and teachers. The use and development of the content were done under the Little KITE's units of schools under the leadership of the IT trainers. It has around 83,000 articles by mid of 2020.
- In 2017 new initiatives were added such as 'Kuttikootam' (kids' group) for students, 'Haritha Vidyalayam' (green school) 2nd edition, broadband connectivity to Lower Primary and Upper Primary (LP and UP) schools.
- In 2018 'Kuttikootam' is modified to form 'Little KITE IT Clubs' in the schools with more than one lakh students initially to support and maintain the technology in teaching learning process. Many programmes are organized for the 'Little KITE' such as mobile app development, programming, robotic workshops, familiarization of e-commerce, introducing the e-governance systems, providing infrastructure facilities and trainings for creating and editing video documentaries and web TV contents.
- Teachers were empowered to create their resources and use the available ones for the classroom sessions with 'Samagra resource portal'. More than 31,000 digital resources were made available in this resource portal. Free availability of updated OS and other software to cater the KITE-modelled education needs.
- KITE's Open Online Learning (KOOL) provided a custom-based Massive Open Online Course (MOOC) platform for teachers' technology skill development. The 45-hour technology training was made as a precondition to permanent lectureship in schools.
- ICT training for mothers. This is a unique technology training provided for the mothers of the students on Samagra resource portal and the hi-tech technology facilities made available for their students. More than 7 Lakhs mothers registered for this project as on mid of 2020.
- Virtual project named Lab on Lap for HSS science students. This project was designed in a paced way of learning apart from the traditional one.
- The digital initiatives in 2020 for the uninterrupted education through virtual classes.

Every year KITE supports the innovative projects in par with the development of the technology for the establishment of international education standards in the state. Trainings for the teachers, students and parents are provided under the KITE through its district nodal centres distributed in all districts. Technology-based and specialization-based hands-on trainings were regular and compulsory for the teachers (Krishnaswamy and Marinova 2012; Nayar 2018; Joju and Manoj 2019; KITE 2020; India Report 2020).

21.4.3 Virtual Learning Technology Support of KITE During the Covid-19 Pandemic

The Covid-19 situation interrupted the education process throughout the globe, and the State of Kerala also could not conduct academic sessions from March 2020. The exams and other ancillary works were pending due to the restrictions raised to fight against the pandemic situation. The Covid-19 regulations related to the social distancing were implemented throughout the state with lockdown protocols. Traditionally in every year the academic sessions were inaugurated in State of Kerala by first Monday of June. The grand beginning of the academic year in Kerala is conducted with 'Enrolment Festival' known as 'Pravesanotsavam'. The unaltered beginning of the academic year was necessary to reduce the anxiety of the parents, and the following initiatives were taken by the KITE to conduct the academic sessions in Kerala without delay to the normal education schedule (Tandon 2020; Baral 2020). These virtual technology learning initiatives incorporated the tools of educational neuroscience to enhance deep learning process with the support from all stakeholders of the education system. These initiatives are discussed below.

21.4.4 Technology Learning with Networked Support Through 'First Bell' Initiatives

Students' learning occurred with collaborative support from the teachers, parents and society during the Covid-19 pandemic. Academic sessions under the state syllabus schooling system were made available virtually throughout the State of Kerala under the name 'First Bell'. The First Bell project aimed to bring back the normalcy in education process with a slogan 'Physical Distance and Social Unity' in education. The First Bell programme was delivered through KITE VICTERS TV channel. The VICTERS TV channel (Versatile ICT Enabled Resource for Students) was established in 2005 as a full-fledged education channel to support the virtual education projects under the KITE. The VICTERS channels were used for delivering the classes from 1st standard to higher secondary schools. The sessions started from 8.30 AM to 5.30 PM Monday to Friday for all classes ranging from 30 minutes to 2 hours. The virtual sessions for Class 11th was scheduled after completing the admission process (denoted as the higher secondary first year) (First Bell 2020; Baral 2020).

These classes were prepared with the support of learning process experts and incorporated ultimate quality for deep learning with inclusion of multimedia explanations, virtual reality demonstrations and collaborative and peer social learning options with professionalism. The public support was ensured through the media and educational agencies. All the broadcasted classes were made available in the VICTERS channel, educational websites, mobile apps and social media for free. The streaming of the VICTERS channel in television cable networks and digital dish networks that were already available throughout the state could limit accessibility issues (First Bell 2020). Social support was initiated under the government administrative systems and the NGOs to provide for lack of infrastructure facilities like television sets, data connectivity and gadgets to economically marginalized students. Network operators coordinated through the official administrative systems to provide uninterrupted data connectivity services even for remote village students. The whole sessions were also made available in downloadable format, which can be compiled together for further reference (Tandon 2020; Anupama and Sreekala 2020; Reddy and Viji 2020). The active involvement of the KITE officials in this process was evident in which they 'entrusted the class teachers and school headmasters or principals to make sure that students have access to a television or a smartphone or a computer, and Internet for the classes. If not, they should find an alternative for the students to attend the online classes either in real-time or later' (Anupama and Sreekala 2020).

21.4.5 Technology for Deep Learning with Memory Skills with 'Classroom at Home'

The First Bell project of KITE successfully inculcated a complete e-learning education system in Kerala in a short span of time. Virtual classes were backed with real-time support from the faculty of respective students as in the physical classrooms. Online classes of the day normally ended with a homework, to be submitted and corrected by the respective teachers of the students. The modern developments of the educational neuroscience and the memory enhancement techniques were incorporated with this project. Classes through the technology platforms could integrate even certain features of augmented reality to enhance the memory skills of the students with the participation of the parents at home. The extended virtual learning interaction of the class was ensured through the apt social media groups (WhatsApp, Instagram, Facebook page, Google Classroom, emails). In addition to the vernacular classes, extended sessions in English, Tamil and Kannada were made available (Anupama and Sreekala 2020).

The teachers who were already empowered through the varied digital training programmes of the KITE could effectively support the online learning with virtual connectivity models. They corrected homeworks of students through video call with the students and parents, repeated and explained the broadcasted classes and evaluated the learning difficulties and connectivity issues on an individual basis to remedy any issues in attending the e-learning from home. After 3 months of the First Bell launching, class PTA (Parents-Teachers Association) was conducted to evaluate the e-learning projects and the feedbacks were incorporated as per need.

Wholistic education through online classes like Yoga, drill and stress management was also planned by KITE. The creativity of the students could be reported through Nerkazhcha programme, where the students can publish their e-learning experiences of First Bell programme through visual media. Parents are fully involved in this education process along with students and teachers. The collaborative study was also made available in Ayalpakka Padhanakendrangal (neighbourhood study centres), where the lockdown protocols were relaxed as per the local Covid-19 situations (Anupama and Sreekala 2020; Tandon 2020; Staff-reporter 2020; Reddy and Viji 2020).

21.4.6 Social Support for e-Learning: Infrastructure Development

The social support system mobilized for the e-learning infrastructure development and e-education was made as a joint affair of the society. The infrastructure for the financially marginalized was provided through the support of the multiple NGOs, LSG (local self-governing) institutions, local libraries, Akshaya e-Centres, Anganwadis (pre-schooling systems) and self-help groups of Kudumbashree units. The funds apportioned by the government through Asset Development Fund, MLA Special Development Fund and funding from government-controlled financial institutions like KSFE (Kerala State Financial Enterprises Limited), etc. were the main source for this infrastructure development (Staff-reporter 2020; Anupama and Sreekala 2020).

The above-mentioned educational technology leadership of the Kerala State before and after the Covid-19 pandemic was appreciated globally. The unparalleled advancement of the socioeconomic sectors in Kerala was mainly fuelled by the technology-based exponential growth in education sector and which in turn enabled its human resource to compete to the ever-evolving world of technology. So, it was worth studying this excellent leadership brought through by the digital initiatives of the KITE education system at the backdrop of the Technology Adoption process.

21.5 Theoretical Frame of the Quantitative Study

The Technology Adoption process can be explained with multiple theoretical frames as Technology Acceptance Model, Diffusion of Innovation model, TPACK model, UTAUT model, socio-cognitive theories, etc. The Technology Adoption of the teachers under this study is made with Fullan's educational change model and Technology Readiness frame by Parasuraman.

21.5.1 Technology Adoption in Education

Technology Adoption in education was initiated with the use of technology tools for the ease of pedagogy and was limited to computerized presentation systems in most of the cases during the millennium. In its fullest sense, the Technology Adoption is rather a higher version of technology usage where the technology became an integrated tool for the teaching learning process. It essentially connects and esteemed to integrate the multiple aspects of the education process. The Technology Adoption ultimately aims for a technology integration in a wholistic manner, where the professional and personal roles of the teachers get integrated with the efficient use of the technology platforms (Rogers 2004; Lawrence and Tar 2018).

Studies on the use of technology in education with respect to the teaching learning process identified multiple factors that affected the technology incorporation (Kotrlik and Redmann 2009). The studies based on the Technology Acceptance Model (TAM), Technological Pedagogical Content Knowledge (TPACK), Unified Theory of Acceptance and Use of Technology (UTAUT), Fullan's educational change model and socio-cognitive learning theories like Communities of Practice emphasized on multiple aspects of the education Technology Adoption process. This study uses the Fullan's educationl change model which incorporates the stages of Technology Adoption in education scenario (Fullan 2007, 2018; Kotrlik and Redmann 2009; Bahçekapili 2018).

21.5.2 Fullan's Educational Change Model

Most of the Technology Adoption studies were concentrated on the technology aspects and were less concentrated on the user's perspective. The study on the education Technology Adoption process with the perspectives of the teachers was necessary to have an in-depth understanding on the education process. Fullan's educational change model (1991) focussed on the adoption with respect to the various change agents and specific roles in the education adoption process. This model proposed that educational change happens through stages of initiation, implementation, continuation and desired outcomes.

The preliminary stage of this model is initiation; this stage of adoption is influenced by the features of technology innovation, its availability, management concerns, peer support and influence of external agents. In this stage the new technology is introduced for the teachers and the features are familiarized by the initial usage. Implementation stage is denoted by the characteristics of the technology, external and internal hierarchical factors. The features and uses of the technology are experienced by the teachers in this stage. The implementation is also dependent on the school-specific factors and governmental directives for the implementation. The institutionalization of an innovation is denoted by the continuation stage, where the technology is incorporated into the teaching learning process and subsequent modifications were made in the pedagogy, assessment, collaboration and administrative systems. Majority of teachers were fully devoted to this change, and innovation pioneers support the less technology incorporated teachers to assist in this process. The outcome of the educational change is denoted by the change in skills, committed actions and internalization of technology to overcome the hurdles (Fullan 2007, 2018; Tofur 2017). The studies on education Technology Adoption stressed that the technology initiatives have a positive impact on the Technology Adoption specially in the initiation and implementation stages of the educational change model (Buchanan et al. 2013; McKnight et al. 2016; Joseph and Thomas 2020; Tofur 2017).

21.5.3 Technology Readiness of Educators

Parasuraman (2000) has identified that Technology Adoption is greatly affected by the individuals' disposition towards the technology incorporation. The teachers' technology use depends on their readiness to use the technology-enabled systems. The Technology Readiness of the teachers acts as a critical actor in the education Technology Adoption process. Technology Readiness is defined as 'the people's propensity to embrace and use new technologies for accomplishing goals in home life and at work. The construct can be viewed as an overall state of mind resulting from a gestalt of mental enablers and inhibitors that collectively determine a person's predisposition to use new technologies' (Parasuraman 2000, p. 308).

The Technology Readiness is measured with Technology Readiness Index. Technology Readiness Index (TRI) is a multiple-item scale with sound psychometric qualities to measure the Technology Adoption attitude of the customers and employees. It consisted of two categories as 'optimism and innovativeness' towards Technology Adoption. The technology inhibitors retarded the individual's Technology Adoption process. The feeling of discomfort and insecurity in adopting technology are the two aspects of technology inhibitors. This study adopts the TRI 2.0 for the data collection from the teachers (Parasuraman 2000; Parasuraman and Colby 2015). The Technology Readiness based studies on the teachers' technology adoption process brought to light that TRI aspect of the teachers was significantly influenced their Technology Adoption. The positive aspects of the TRI contributed towards the Technology Adoption process while the inhibiting subdimensions of the TRI reduced teachers' Technology Adoption process (Mwapwele et al. 2019; Lopez-Perez et al. 2019; Joseph and Thomas 2020).

21.6 Research Methodology

This is a case study on the digital initiatives of the education system maintained by KITE in the State of Kerala which could impart an uninterrupted school education during the Covid-19 pandemic situation with ‘School at Home’ model. The case study is affirmed with quantitative analysis to identify the influence of the digital initiatives on the Technology Adoption of the teachers with respect to their Technology Readiness. This study addresses the research problems as what are the digital initiatives of the KITE before and during the Covid-19 pandemic to provide uninterrupted education. How are the digital initiatives of KITE influenced the teachers’ Technology Adoption with respect to their Technology Readiness Index?

Based on the research problems the following objectives were identified for this study:

1. To study the influence of Technology Readiness, digital initiatives and Technology Adoption by teachers
2. To understand the Technology Adoption, Technology Readiness and digital initiatives of the teachers
3. To study the mediation effect of digital initiatives on Technology Readiness to Technology Adoption by teachers

Based on these research objectives and review of the studies, the alternative hypothesis was formed for testing:

1. Technology Adoption of the teachers was significantly influenced by their Technology Readiness.
2. Technology Adoption of the teachers was significantly influenced by the digital initiatives of education process.
3. The digital initiatives of education process moderated between Technology Adoption and Technology Readiness of the teachers.

The quantitative part of this study was conducted among the higher secondary school teachers who belong to the Kerala state syllabus curriculum, where the KITE implemented multiple digital initiatives. The sampling frame consisted of six educational districts from the northern part of the State of Kerala. Structured questionnaires were administered physically to collect data in multilevel cluster sampling model, and 857 responses were used for this study. The qualitative data were collected through interaction with the KITE trainers, teachers, management personnel of the schools and from the secondary sources.

21.6.1 Instruments of Data Collection

The study used Technology Readiness Index 2.0 scale (Parasuraman and Colby 2015), Technology Adoption Scale (Kotrlik and Redmann 2009) and KITE digital initiatives for the quantitative analysis.

Technology Readiness Index 2.0 scale consisted of two subdimensions of Technology Readiness. These scales were used to measure the 'propensity of the users to embrace technology' which varies from individual to individual (Parasuraman 2000, p308). The TRI 2.0 has a battery of 16 items with four divisions to measure the dimensions of optimism, 4 items; innovativeness, 4 items; discomfort, 4 items; and insecurity, 4 items. The first two are contributors of Technology Adoption, while the other two inhibits the Technology Adoption process as defined as:

- "Optimism: A positive view of technology and a belief that it offers people increased control, flexibility, and efficiency in their lives.
- Innovativeness: A tendency to be a technology pioneer and thought leader.
- Discomfort: A perceived lack of control over technology and a feeling of being overwhelmed by it.
- Insecurity: Distrust of technology and skepticism about its ability to work properly." (Parasuraman 2000, p308)

Technology Adoption Scale was developed from the Fullan's educational change model (1991) (Kotrlik and Redmann 2009) to measure the Technology Adoption of the teachers. This scale consisted of 15 items to measure the four stages of the Technology Adoption at schools. This scale measures the Technology Adoption of the teachers with respect to the stages of initiation, implementation, continuation and outcomes. The teachers' self-reported use of digital technology initiatives was captured in a 5-point scale (Kotrlik and Redmann 2009).

21.7 Results

The data from 857 teachers were analysed with Statistical Package for the Social Sciences (SPSS) v21 and PROCESS macro v3.4 for SPSS. The data consisted of 65.8% females, 38.5% below 40 years and 82.3% with more than 5 years of teaching experience. The standard instruments adopted have a satisfactory level of validity when tested with Cronbach's alpha. The data were assumed to be normal with respect to the skewness (−0.839 − +1.23-) and kurtosis (+1.23 − +0.167) and parametric tests are done.

The Technology Adoption of the teachers has a mean value of 3.75 with a standard deviation of 0.596, Technology Readiness has the value 3.07 with a standard deviation of 0.393 and digital initiatives have the value 3.94 with a standard deviation of 0.863 in a 5-point scale.

The Technology Adoption was statistically correlated with Technology Readiness (Pearson correlation $r = 0.242$), and the first alternative hypothesis accepted that there was significant positive relationship between Technology Adoption and Technology Readiness.

The Technology Adoption was statistically correlated with subdimensions of Technology Readiness. The positive correlation existed with optimism (0.436) and innovation (0.336), while negative correlation existed with discomfort (−0.081) and insecurity (−0.218) with $p < 0.01$. The Technology Adoption statistically correlated with digital initiatives (Pearson correlation $r = 0.379$) with $p < 0.01$ level (2-tailed). Thus, the second alternative hypothesis accepted that Technology Adoption of the teachers was significantly influenced by digital initiatives of the education process.

The regression analysis was statistically significant with unstandardized coefficient $B = 1.837$, $R^2 = 0.184$, $F(2, 854) = 96.361$, $p = 0.000$. The mediation analysis between Technology Readiness and Technology Adoption was done with SPSS PROCESS macro v3.4, model 4, and partial mediation path was affirmed through the digital technology initiatives. The direct path from TRI to Technology Adoption was statistically significant ($p < 0.05$) with $B = 0.3332$ and indirect path through digital technology initiatives with $B = 0.0476$. Thus, the third alternative hypothesis accepted that the digital initiatives of education process moderated the Technology Adoption to Technology Readiness of the teachers.

21.8 Inference and Conclusion

This study was aimed to identify the digital initiatives of the KITE in the State of Kerala with respect to the post-Covid-19 and during the Covid pandemic situations. The development of the digital initiative was identified, and KITE established a flawless digital learning system implemented in the schools through state syllabus system. The State of Kerala supported this digital initiative with multiple hi-tech projects through the funding, implementation and monitoring of the facilities established. The student cooperation was incorporated to the education Technology Adoption process to support the digital initiatives, and the collaborated support of the students was ensured through more than one lakh Little KITE units.

The adoption of the Free and Open Source Software (FOSS) systems for this digital movement is well appreciated in the student community. The emphasis on the FOSS in schools considerably reduced the cost of the proprietary software and omni available FOSS technology systems used for the multiple purposes in the digital labs of the schools. The KITE made sure the availability of free downloadable software and provided even virtual training in an interactive model. The lectures, teaching materials, virtual learning tools and students' projects were made available to all the logins and encouraged the teachers to contribute to the resource pool.

Regular hands-on training sessions on digital technologies were provided during the Onam and summer holidays. The regular follow-ups in small cluster basis, peer training facility, mentoring for the technology incorporation, loan facility for the laptops and gadgets, data and power availability with hi-tech classrooms and multimedia labs, Little KITE groups, etc. supported the technology trainings of the teachers. Regular and compulsory training were supported to develop a technological outlook in teachers, and the technology-based educational change was incorporated in the teaching learning systems before the outbreak of the Covid-19.

During the Covid-19 pandemic situation, the KITE launched its virtual education through the launch of 'First Bell' programme and started the classes exactly on the regular reopening day after the summer holidays. The uninterrupted school education process made tremendous consolation for the parents and students amidst the pandemic. The 'Classroom at Home' project extended its scope beyond the online classes through the teacher-assisted assignments, evaluation process, creative collaboration of the students, class PTA, Yoga and drill, and aimed to provide a full-fledged education system beyond the physical classes.

The quantitative analysis on teachers' Technology Adoption proves that their self-reported Technology Adoption was rather higher in 5-point scale, and the coefficient of variation of Technology Adoption was 15.89% among the sample. This level of Technology Adoption achieved through the constant trainings and peer support extended through the trainers' training programmes of the KITE nodal centres spread throughout the state.

The statistically significant correlation between Technology Readiness and Technology Adoption was weak. It implied that the Technology Readiness of the teachers positively influenced their Technology Adoption process. The optimism and innovativeness aspect of the TRI subdimensions positively contributed towards the Technology Adoption of the teachers. The inhibiting subdimensions of the Technology Readiness aspects negatively correlated with Technology Adoption. It implies that the inhibiting aspects of the technology attitudes needed to be reduced from the teachers. The studies revealed that the regular availability and hands-on sessions of the technology practice can reduce the discomfort and insecurity aspect of the teachers towards the technology.

The correlation between the Technology Adoption and Digital initiatives of the education system was positive. It implies that the digital initiatives of the KITE increased the Technology Adoption of the teacher. The regular trainings, availability of the technology platforms, support systems, peer and expert availability, availability of the lecture materials, discussion forums and availability of troubleshooting tips, regular follow-ups of the trainings, etc. could considerably increase the Technology Adoption of the teachers.

The regression analysis on the Technology Adoption with Technology Readiness and digital initiatives was significant. The mediation analysis showed the partial mediation path of the digital initiatives on Technology Readiness to Technology Adoption. It implied that the Technology Adoption was fostered with the presence of both digital initiatives and Technology Readiness aspects of the teachers. The education trainers and policy formulators needed to provide emphasis on these two factors to better digital initiatives on Technology Adoption of the teachers. This Technology Adoption factor manifested during the virtual classes during the Covid-19 pandemic.

This case study concluded that the digital initiatives of the KITE in the state syllabus schools of Kerala and its continuous support for the development of the digital technology-based education system have successfully empowered the teachers and education systems as a whole. The immediate result of this digital empowerment was the uninterrupted education process during the Covid-19 pandemic restrictions. This education technology incorporation model could be comparable with outstanding systems of the developed countries in terms of efficiency and acceptance.

21.9 Scope for the Future Research

This chapter is a case study attempt to bring out the features of digital initiatives and teachers' Technology Adoption process with respect to the digital initiatives of the State of Kerala. As the researchers in the educational neuroscience propose more tools for the deep learning and memory enhancement in learning process, further study can be warranted on the impact of 'Classroom at Home' through the First Bell virtual education project. The impact of the technology learning culture on social and emotional aspects with respect to Covid-19 pandemic restrictions is to be well researched. A wide longitudinal study on the impact of digital initiatives on the Kerala education system on teachers, students, society and higher education can be another unexplored area of research.

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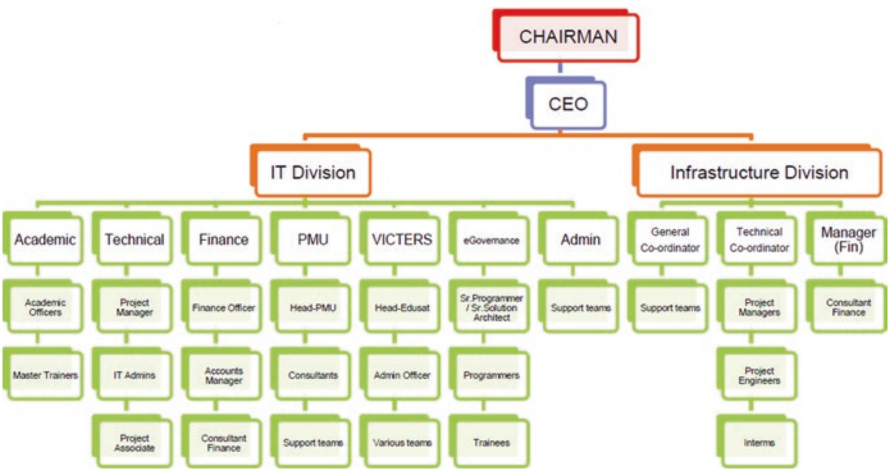
Appendixes

Appendixes A: Organization Structure of the KITE



Appendixes B: The Details of the Projects Under the KITE

Project name	Details and website
Sampoorna	Management software for 163 educational subdistricts http://https://sampoorna.kite.kerala.gov.in
Samagra	Edutainment e-Resources for kids General resources e-Resources Question pool Textbooks https://samagra.kite.kerala.gov.in
KOOL	Customized MOOC programme for the teachers https://mooc.itschool.gov.in/
VICTERS channel	https://victers.kite.kerala.gov.in
School Wiki	https://schoolwiki.in
Sametham	https://sametham.kite.kerala.gov.in/
Samanwaya	https://samanwaya.kite.kerala.gov.in
Little KITEs	Student technology support club. It has activities as: Hardware trainings Mobile app development Basic electronics training Language computing system Cyber security Internet of Things Animation, camera handling training https://kite.kerala.gov.in/littlekites/
Sasthrolsavam	http://schoolsasthrolsavam.in
First Bell	Complete virtual class programme due to Covid-19 pandemic https://kite.kerala.gov.in/KITE/firstbell/
Hi-Tech School Project	ICT infrastructure project for the schools https://kite.kerala.gov.in/KITE/index.php/welcome/ict/1

References

Antonenko, P. D. (2019). Educational neuroscience: Exploring cognitive processes that underlie learning. In T. Parsons, L. Lin, & D. Cockerham (Eds.), *Mind, brain and technology. Educational communications and technology: Issues and innovations*. Cham: Springer. https://doi.org/10.1007/978-3-030-02631-8_3.

Anupama, A. R., & Sreekala, M. V. (2020, July 07). How the Kerala Model of Bringing Classrooms Home Works. *The Wire.* Retrieved from https://thewire.in/education/kerala-covid-19-education

Bahçekapili, T. (2018). *An investigation of 1: 1 technology initiative through the lens of Fullan's educational change model: A three-year study.* Doctoral dissertation, Middle East Technical University.

Baral, M. (2020, June1). virtual classes for Kerala School students Begin. *NDTV education*. Retrieved from https://www.ndtv.com/education/virtual-class-for-kerala-school-students-begins

Benešová, A., & Tupa, J. (2017). Requirements for education and qualification of people in industry 4.0. *Procedia Manufacturing, 11*, 2195–2202.

Buchanan, T., Sainter, P., & Saunders, G. (2013). Factors affecting faculty use of learning technologies: Implications for models of technology adoption. *Journal of Computing in Higher Education, 25*(1), 1–11.

Calderón, R. R., & Izquierdo, R. B. (2020, March). Machines for Industry 4.0 in higher education. In *2020 IEEE World Conference on Engineering Education (EDUNINE)* (pp. 1-4). IEEE.

Cavanaugh, J. M., Giapponi, C. C., & Golden, T. D. (2016). Digital technology and student cognitive development: The neuroscience of the university classroom. *Journal of Management Education, 40*(4), 374–397. https://doi.org/10.1177/1052562915614051.

Collins, A., & Halverson, R. (2018). *Rethinking education in the age of technology: The digital revolution and schooling in America*. New York: Teachers College Press.

First Bell. (2020). *KITE*. Retrieved from https://kite.kerala.gov.in/KITE/firstbell/

Fullan, M. (2007). *The new meaning of educational change*. New York: Routledge.

Fullan, M. (2018). *Surreal change: The real life of transforming public education*. New York: Routledge.

Howard-Jones, P., Ott, M., van Leeuwen, T., & De Smedt, B. (2015). The potential relevance of cognitive neuroscience for the development and use of technology-enhanced learning. *Learning, Media and Technology, 40*(2), 131–151.

India Report. (2020, June). *Digital education* (pp. 1–182). New Delhi: Department of School Education and Literacy, Ministry of Human Resource Development, Government of India.

Joju, J., & Manoj, P. K. (2019). Digital Kerala: A study of the ICT: Initiatives in Kerala state. *International Journal of Research in Engineering, IT and Social Sciences, 9*, 692–703.

Jones, C., & Pimdee, P. (2017). Innovative ideas: Thailand 4.0 and the fourth industrial revolution. *Asian International Journal of Social Sciences, 17*(1), 4–35.

Joseph, G. V., & Thomas, K. A. (2020). Moderating effect of social media usage on technology barriers to technology adoption by teachers. *International Journal of Advanced Science and Technology, 29*(03), 5504–5512. Retrieved from http://sersc.org/journals/index.php/IJAST/article/view/6058.

Kim, H. J., & Lee, J. M. (2018). Determinants of Mobile digital information usage among senior consumers: Focusing on secondary digital divide. *Family and Environment Research, 56*(6), 493–506.

KITE. (2020). Retrieved from https://kite.kerala.gov.in/KITE/index.php

Krishnaswamy, G., & Marinova, D. (2012). Free and Open Source Software (FOSS) in Education: IT@ School Project, Kerala Region of India. *Journal of Free Software & Free Knowledge, 1(1).*

Kotrlik, J. W., & Redmann, D. H. (2009). Technology adoption for use in instruction by secondary technology education teachers. *Journal of Technology Education, 21*(1), 44–59.

Kumar, V. S. (n.d.). *The Education System in India*. Retrieved from https://www.gnu.org/education/edu-system-india.en.html

Kumar, K., Prakash, A., & Singh, K. (2020). How National Education Policy 2020 can be a lodestar to transform future generation in India. *Journal Public Affairs,* 1–5, Retrieved from https://doi.org/10.1002/pa.2500

Lawrence, J. E., & Tar, U. A. (2018). Factors that influence teachers' adoption and integration of ICT in teaching/learning process. *Educational Media International, 55*(1), 79–105.

Lopez-Perez, V. A., Ramirez-Correa, P. E., & Grandon, E. E. (2019). Innovativeness and factors that affect the information technology adoption in the classroom by primary teachers in Chile. *Informatics in Education, 18*(1), 165–181.

Malhotra, S. (2019). The draft National Education Policy: A distressing attempt to redefine India. *Journal of the Gujarat Research Society, 21*(11), 103–115.

McKnight, K., O'Malley, K., Ruzic, R., Horsley, M. K., Franey, J. J., & Bassett, K. (2016). Teaching in a digital age: How educators use technology to improve student learning. *Journal of Research on Technology in Education, 48*(3), 194–211.

Mehendale, A., & Mukhopadhyay, R. (2019). School system and education policy in India: Charting the contours. In *Handbook of Education Systems in South Asia* (pp. 1–35). Singapore: Springer.

Mwapwele, S. D., Marais, M., Dlamini, S., & Van Biljon, J. (2019). Teachers' ICT adoption in south African rural schools: A study of technology readiness and implications for the South Africa connect broadband policy. *The African Journal of Information and Communication, 24*, 1–21.

Nayar, A. (2018). *Teaching and learning in technology empowered classrooms—Issues, Contexts and Practices*. Partridge Publishing company, Chennai, India.

Parasuraman, A. (2000). Technology readiness index (TRI) a multiple-item scale to measure readiness to embrace new technologies. *Journal of Service Research, 2*(4), 307–320.

Parasuraman, A., & Colby, C. L. (2015). An updated and streamlined technology readiness index: TRI 2.0. *Journal of Service Research, 18*(1), 59–74.

Ramachandran, V. (2019). *Draft NEP: How does it affect teachers?* ACER Research repository, Australia, (Vol. 13, No. 3). retrieved from https://research.acer.edu.au/cgi/viewcontent.cgi?article=1001&context=teacher_india

Reddy, S., & Viji. (2020, August 25). Remote learning Initiatives in Kerala. *Vikaspedia.* Retrieved from https://vikaspedia.in/education/education-best-practices/remote-learning-initiatives-in-india/remote-learning-initiatives-in-kerala

Rogers, E. M. (2004). A prospective and retrospective look at the diffusion model. *Journal of Health Communication, 9*(S1), 13–19.

Staff reporter. (2020, July 26). Kerala First Bell touches a milestone. *The Hindu*. Retrieved from https://www.thehindu.com/news/national/kerala/first-bell-touches-a-milestone/article32197310.ece

Tandon, T. (2020, June 02). Kerala students attend online classes from June 1. *Timesnownews.com* retrieved from https://www.timesnownews.com/education/article/kerala-begins-virtual-classes-for-school-students-on-kite-victers-channel-from-june-1-check-details-here/599691

Tofur, S. (2017). Examining the indexes of the journal of announcements between 1980–2014 in terms of Fullan's educational change model. *Pegem Egitim ve Ogretim Dergisi= Pegem Journal of Education and Instruction, 7*(2), 313.

Vaidya, S., Ambad, P., & Bhosle, S. (2018). Industry 4.0–a glimpse. *Procedia Manufacturing, 20*, 233–238.

Valatheeswaran, C., & Khan, M. I. (2018). International remittances and private schooling: Evidence from Kerala, India. *International Migration, 56*(1), 127–145.

Chapter 22
Crux Role of Neurocomputing in Teaching Learning Pedagogy

Arun Meyyazhagan, Haripriya Kuchi Bhotla, Murugesh Easwaran, Balamuralikrishnan Balasubramanian, Joseph Varghese Kureethara, and Manikantan Pappusamy

22.1 Introduction

Human beings are distinctive with their faculty of knowledge accumulation. Apart from the instinctive knowledge what they have, like any other living organism, they can acquire knowledge stored by others in the past, they can evaluate and create knowledge individually and in the company of others, and they can anticipate and predict knowledge and knowledge-based actions in the future. Some call knowledge as a static resource such as stock. Nevertheless, effectively utilizing it allows combining traditional amenities and potentials in a variety of innovative ways to provide value (Bontis 2002). Hence, a need for a dynamic catalyst like learning is needed to generate the knowledge statures in a human.

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Learning facilitates an individual to adapt with its surrounding, and this phenomenon is complex, involving knowledge inflow and adapting to deviate from the existing neural process to obtain the requisite behaviour (Bassett et al. 2011). Learning occurs in two ways, i.e. by explicit mode like classroom surrounding or implicitly through experiences in one's regular life from external surrounding (Aslin and Newport 2012). Implicit learning is often studied separately by cognitive psychologists as they differentiate learning based on one's actions (Chrysikou et al. 2014). They are usually learning results in alteration of neural mechanisms (Dayan and Cohen 2011), synapse formation (Smolen et al. 2016) and the reward for the sensible signals (Keiflin and Janak 2015) along with re-establishing one's expectations (Scholl et al. 2015). Learning is creating, demolishing or re-establishing links of various kinds like the association between word, a face, name, specific food or reward, particular image and motor response. The images, words, motor reactions and rewards are underlying neural representations signifies learning as a purely brain-associated task. Modern ever-changing world of network sciences came out with a set of mechanisms and perspectives to get a deeper insight into learning mode and its types supported by neural connection development. The foundation of learning is creating new associations or removing or altering the learnt associations based on experiences.

22.2 Learning as a Matrix

Learning is a dynamic motif that aids in facilitating various levels of knowledge piled up in an individual. It is an everyday event in our lives (Boal and Hooijberg 2000) to alter what we know, how does that happen, why did it happen and why do we care (Garud 1997). In general, learning occurs at an individual level at the beginning, followed by group and organizational levels. Some experimental studies highlighted relative alterations in neuroanatomy based on some learning mechanisms like visual, intuitive learning is linked with orientation tuning in V1 (Vogels 2010) or forming vivid memory at one shot episode attached to synaptic plasticity in the hippocampus (Nakazawa et al. 2003). Usually, new skills acquisition, i.e. visuomotor, is supported by considerable alterations in neurophysiological changes throughout neural circuits serving the visual and motor responses (Bassett et al. 2011), for instance, activity alteration is observed in the motor cortex, visual cortex, basal ganglia, precuneus, dorsolateral prefrontal cortex and cerebellum, while learning via motor skills (Dayan and Cohen 2011) implying the changes are interlinked and computational in one region of the brain is linked with alteration in the other part of the brain. These changes, interaction patterns, communication or this data transmission results in circuit formation (Matrix) linked to a behavioural output (Friston 2002; Happel 2016).

Figure 22.1 explains the common learning categories, for the optimal survival of an organism in response to an external environment (Sejnowski 1994). Based on the complexity of stimuli, the nervous system allows the host to modulate behaviour to

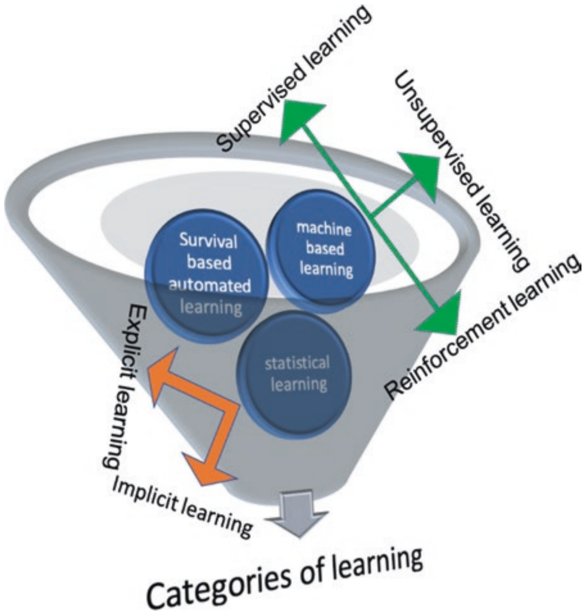

Fig. 22.1 Basic categories of learning

add on knowledge and facilitate learning (Schunk 1996) known as survival-based automated learning. When learning occurs by the information provided by the external agent is called learning for skill and knowledge acquisition. If the learner's response is correctly mapped for the corresponding stimulus, it is called supervised learning (Schunk 1996; Ayodele 2010). When the response by learner is said as excellent or correct, it is known as reinforcement learning (Niv 2009).

Learning or the acquisition of knowledge with the help of an instructor or some instructors is highly effective. However, the absence of the instructor makes the learning process slow; it is called non-instructive or discovery-based learning (Barlow 1989). Similarly, learning can happen consciously (explicit) or unconsciously (implicit) from the constant stimulations from the environment daily (Seger 1994). When you observe a statistical connection between stimuli, it is called statistical learning. Generally, it helps in predicting boarders and features of the environment (Aslin and Newport 2012; Turk-Browne et al. 2005). It has been observed that learning is fast and effective if it is done through comparing and contrasting the learning materials.

22.3 Neurological Sciences Mesh

Mathematical code system which describes the interaction patterns between components or the dynamics of a pattern is network sciences (Newman 2010; Newman 2011). Network sciences are the combination of visual concept in mathematics, algorithm construction from computer science, statistical mechanics from physics and systems engineering. With the foundation from mathematics, these tools can be flexibly applied in other fields to get more profound knowledge of complex biological functions (Baldassano and Bassett 2016). Utilizing network sciences in postulating neuroscientific hypothesis is known as a "neuro-networking" (Misic and Sporns 2016). This flourishing branch utilizes network sciences in analysing the connectivity design in genes, neurons, living organism and social behaviour of fauna to ascertain and gain insight on the impact of this connectivity in reproducing the behaviour (Bassett and Sporns 2017). As these studies fundamentally rely on mathematical principles (Hermundstad et al. 2011) which can be utilized as a precious rational data to analyse the interaction between nervous system constituents and plausible behavioural adaptations (Bassett et al. 2011). As a broad encompassing subject from genes to social settings, network neuroscience can be utilized in understanding the dimensions of learnings in human (Fornito et al. 2013).

22.4 Stumbling Blocks of Educational Neurosciences

The mechanism of learning more often is highly complicated and complex. With unclear goals for education from the society, it is difficult to translate the science behind education into practice. Learning is supposed to occur in a classroom surrounding making the brain to have varied realization, for example, episodic or autobiographical memory we produced by memorizing specific moments usually involving the hippocampus and its surrounding area. These memories can rapidly change to snapshots, or the brain assembles information by associating it with perceptual data and our motor reactions by spotting complex spatial and temporal types in knowledge called concepts occurring in the cortex part of the brain, where alterations in connections take seconds or hours. Sometimes the learning association is made unconsciously by our limbic structure known as classical conditioning lasting from seconds to minutes.

Learning can be content-specific or reward-based. The content-specific learning is controlled by the prefrontal cortex, along with the interaction of the limbic region to fuse planning and emotions. Alternatively, reward-based learning operating for a few minutes or seconds helps in identifying good or bad. On the other hand, we have procedural learning for our frequently performed activities, including unconscious activities like tying shoelaces, as these skills took hours to learn in the beginning. This is like connecting circuits looping from the outer to the inner cortex via the basal ganglia to the thalamus and vice versa to the cerebellum. Our brains can learn things by merely observing called modelling via its already made circuits to analyse other peoples. Eventually, by utilizing the brain of the circuit uses language to develop novel plans, concepts and learn those skills with instructions. All these operations are carried out automatically, at a faster pace, crisply without any cognitive effort or awareness as these skills are repeatedly shifted to basal ganglia and cerebellum parts. The more you use the skill, the more it becomes automatic.

The effectiveness of learning is associated with the speed of retention, the power of coordination and the application of various learnt items. What is opposite to retention is forgetfulness. Theoretically, forgetfulness is the lack of retention within a required time-frame. Forgetfulness occurs in varied pace in learning process. All these processes occur in an integrated manner and respond alternatively over time and training, along with other modulating factors like motivation or emotional states. Due to these complexities, understanding the entity learning is considered as a huge challenge for educators. Regarding Bronfenbrenner's ecological theory (Bronfenbrenner 1992), learning outcome comprises the heart of educational pedagogy along with the influence of other prime factors like governmental, societal, educational, institutional and the internal psychology of the learner. Hence, the prime role of neuroscience in the educational framework is to alter the proximal hindering factors to its maximum by providing motivation, attention, health and nutrition. Figure 22.2 helps to know the proximal factors based on Bronfenbrenner's ecological theory. We should keep in mind that behavioural characteristics play a significant role and must be considered into the broader framework of scientific implementation to obtain optimal learning (Michie et al. 2011).

For understanding the science of learning, it is observed that translating it into classroom surrounding seems ineffective. Still, psychologists battle to postulate the

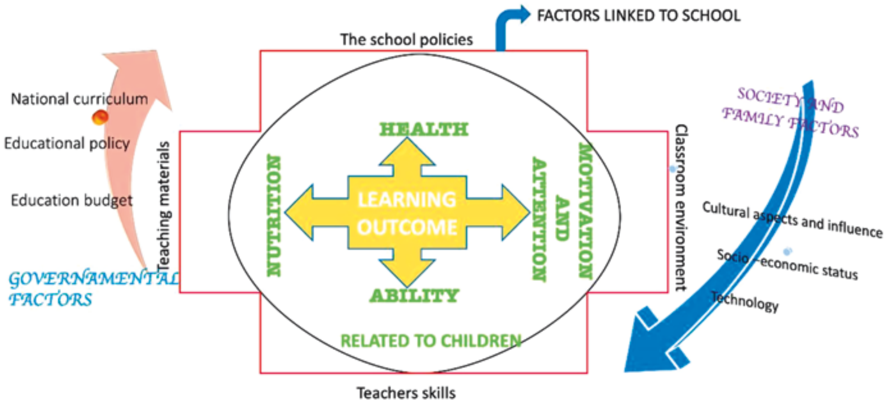

Fig. 22.2 The immediate (core) and remote (peripheral) factors influencing the learning outcomes in children other than the behavioural aspects, as stated by Michie et al. (2011). This figure also elaborates the relationship between the child and the environment, as suggested by Bronfenbrenner (1992), including technology suggests that the child information via digital media beyond the classroom setup other than technology can also be considered in the form of teaching resource/materials under a teacher's supervision. Hence, it can come under the categories of both socio-economic factors and school-associated factors

teaching techniques. Preferably few techniques are still used even if the result is not effective (Roediger 2013). Intrinsically, highlighting or underlining the text for increasing efficacy of learning, which is proven ineffective by psychologists (Dunlosky et al. 2013). It is not possible to trace the improvement in the mode of learning via instructions and translating the cause of impairments in learning for interventions (Bowers 2016a).

There are many projects in the core areas like the health of the brain, developing core skills and cognitive skills, adolescence, functional approach, social cognitive skills, developmental disorders and emotions etc. for the basic strategies to enhance cognitive power.

In 2014, the United Kingdom launched a scheme with regard to education and neurosciences by collaborating with the Education Endowment Foundation and Wellcome Trust to enhance the funding for collaborative works between the facilitators and neuro-researchers to build evidence associated with enhancing learning in classroom practice (Howard-Jones 2014b). They funded six projects like examining the pattern of sleep in adolescence to assess the impact of sleep in the educational setup achievement (Espie et al. 2016; Kelley et al. 2015). The project investigates the medium of instruction to cardiovascular dynamics while achievement in an educational setup using brain imaging (Johansen-Berg and Duzel 2016). Some project is based on the rewarding mode in education (Howard-Jones and Jay 2016). Similarly, other project viewed the importance of spacing learning, i.e. repeating the unit thrice with different activities (Kelley and Whatson 2013).

22.5 The Health of the Master Organ: Brain

It is suggested that the learning outcome is enhanced with the increase of operational capacity of the brain. It can be termed as brain optimizing, generally involving the ideas beyond the classroom setup. Brain optimizing involves a lifestyle of child and parents, physical fitness, environmental conditions, sleep pattern, stressors and diet. These can be reduced by relaxations and meditation and considering the environmental concerns. After the consideration of all the abovementioned aspects, the child can be considered at an optimal state of learning in the class. Studies have shown sleep pattern effects on cognitive thinking and working memory ability in teenagers (Jiang et al. 2011; Lo et al. 2016).

In contrast, raising physical training regularity and intensity can aid in increasing the academic and cognitive performance in the children (Ruiz-Ariza et al. 2017). Researchers have shown that the implication of meditation has positively increased in children with declining psychopathology cases. A study by Sunyer et al. (2015) suggested overpolluted environment relates to delaying development on cognitive dimension too (Sunyer et al. 2015). It is predicted that inhaling ultrafine components can cause low-level neural inflammations and oxidative stress, causing the injury of the white matter and glial cell activation (Donaldson et al. 2005). These studies compel to restrict pollution around school zones. More resounding evidence is still needed to obtain policy recommendation to correlate the brain functioning with pollution and poverty.

22.6 Developing the Core Skills and Cognition Capacity

There are several theories associated with cognitive neurosciences that build and that can be used to evaluate the effectiveness of classroom learning. Some of these theories help in identifying the chief cognitive skills necessary for the acquisition of the knowledge domains like numeracy and literacy, along with the identification of the deficits to train the target skills. Imaging techniques have highlighted the association of learning with its corresponding core skill, for example, numeracy corresponds to perception skill for identifying the symbols of the number in the occipitotemporal lobes; similarly, manipulation in quantities and spatial capabilities correspond to the intra-parietal sulcus. The angular gyrus within the parietal lobe was as concepts, principles and protocols coordinated with prefrontal cortex region of the brain (Butterworth and Varma 2013). Science is usually the fusion of skills like formulating concepts and trying to find the cause for it. Presently the main target is to integrate the scientific acquisition concepts with initial intuitive concepts, like the world around us (e.g. the Earth is flat; heavy objects fall faster than lighter), and with intuitive reasoning to test these hypotheses (Mareschal 2016; Fugelsang and Mareschal 2013). We do not have content-specific educational neuroscience linked to topics like history, geography, art and sports (music an exception) (Koelsch 2012; Peretz and Zatorre 2003).

Enormous literature is seen concerning educational neuroscience in adolescence (Blakemore 2018; Fuhrmann et al. 2015) as brain development is faster in adolescence and early adulthood (Dumontheil 2016). Works of Ramsden et al. (2011) showed fluctuations in individual's IQ score in standardized verbal and non-verbal test vary at adolescence age due to change in the morphology of the brain (Ramsden et al. 2011). It is presumed that the hormonal influence during puberty causes this uneven development in the brain (Piekarski et al. 2017). Usually, the temporal and frontal region of the brain is least developed, suggesting us the delayed development of responsible decision-making skills and lesser perception (Mills et al. 2014). Besides, to change in the reward processing amongst teenagers along with peer influence vulnerability can mark those specific alterations in teenagers (Crone and Dahl 2012; Van Hoorn et al. 2016).

Cognitive skills impacting the other domains in individuals are studied as "executive functions", a group of connected processes involving cognitive control and flexibility. The academic accomplishment is presumed using these executive functional skills like assuming till three variances in reading score and mathematics. Associating neuroscience with cognitive skill helps to find enhancement of executive functions with regard to age as the regions of the prefrontal brain can constrain. Executive functions help in making younger children ready for school and able to grasp the instructions and involving and engrossing the learner in the classroom activities. These skills can be trained (Diamond and Ling 2016) and can act as a remedial action in children with deprived home care and broken families.

Fusing education with neurosciences helps in regulating emotions by cognitive controls. Emotions play a crucial role in early childhood development along with educational context. Works by Martin and Ochsner showed the role of emotions in the development of the prefrontal parts of the brain, which control the executive functions and link with the limbic circuit. Emotions are correlated with academics sector too, especially with mathematics as maths anxiety. Emotions do play a significant role in the socio-classroom setup along with the bond between student-teacher and student-student. Educational neurosciences help in characterizing the blooming of social brain with the inclusion of underlying capacities like gazing, group attention, face recognition, observing actions and rationally thinking about the mental state of other people and especially in adolescence the emotions linked to acceptance or rejection by peers (Van Hoorn et al. 2016). Executive functions focus on social and emotional capability at the base level. Hence, more in-depth insight is requiring for implying neurosciences in the classrooms.

22.7 Developmental Disorders

The prominent role of neurosciences in the educational setup can be more considerate in the domain of special needs like children with developmental problems linked to language/communication barrier, dyscalculia, dyslexia, attention deficit and hyperactivity along with socio-emotional disorders of executive functional disorders (Bruer 2013). There is a massive set of literature peculiar to these areas (Rinehart et al. 2017). The prime focus is to identify the root cause of the particular deficit either brain parts being underdeveloped or poor connection between the brain regions. These data so obtained can act as a source for postulating cognitive theories. Hence, in the school/educational sector, these issues are addressed by the special educational needs department (SEN). SEN addresses the inclusion and exclusion of the children based on the mainstream education remarks and psychological state of the family or child with a disability (Woolfson 2011). Deeper learning into the reason behind the deficit, along with transforming it via pedagogical rules into interventions, can help in evaluating the effectiveness in behaviour with regard to education.

One intriguing chronicle shows that the emergence of novel mechanistic postulate on developmental dyslexia with new interventions is known as “temporal sampling” theory for dyslexia (Goswami 2017). Electrophysiological findings have shown that dyslexics usually have an obstruction in using temporal parts for speech and scaffolding the concept of syllable and sentence prosody. Experimental data on the postulate mentioned above suggested pinpointing and underlining the information of auditory rhythms in both verbal and non-verbal stimuli can effectively improvise phonics knowledge in people with dyslexia as directly emphasizing the phonics (Thompson et al. 2013). Henceforth, the dyslexic children are intervened with music and rhythms than reading alone (Flaugnacco et al. 2015; Goswami 2017).

Till now, we have ample examples showing neuroscience contribution in understanding the reason for deficits during development like atypical development of the parietal lobe that leads to dyscalculia (Butterworth et al. 2011). Similarly, abnormal development in the prefrontal cortex's executive and attention neural circuits can lead to hyperactivity (Shaw et al. 2013). Research on learning mechanism in the brain can allow us to predict the efficiency of the various intervention methods based on the disorder. For example, people with dyslexia showed a predictive response to intervention methods in reading task to the behavioural measure with no predictive score (Hoeft et al. 2011).

Works on brain (Peters et al. 2018) and genetic levels (Kovas et al. 2007) showed besides genetic anomalies, most of the deficits occur due to ability continuum variation in the primary set of population. Whereas fewer evidence shows the implication of unique methods to teach for the specific disorder can be useful as per SEN-specific pedagogy (Davis and Florian 2004). Educational neuroscience helps in diagnosing and labelling the deficits with its pros and cons. As such the learns can face common symptoms of the different disorder than the variability of symptoms higher of the same diagnosis (Gathercole et al. 2016). These points must be considered against pragmatic benefits of diagnosis allotment for resource attraction, guide choice and prompt interventions with good results.

22.8 General Techniques Used to Obtain Maximum Benefit from Educational Neuroscience

Educational neurosciences have strived continuously to obtain elusive tasks to get the ultimate benefit of cognition training. Currently, educational neurosciences are trying to find possibilities for the training of executive functions (Diamond and Ling 2016), training for mindfulness (Felver et al. 2016), developing cognition via playing chess (Sala and Gobet 2016), action video games, training in a musical instrument or learning a new language, sleep pattern and aerobic fitness exercise (Ruiz-Ariza et al. 2017). Less participants with the specific condition making it difficult for researchers to find the possibility as some time the possibilities are found in a group like bilinguals might have higher education, or musical learners can be more intelligent or dedicated, or the video game player can have higher sensorimotor functions along with the challenges intervene designing to do successful allocations. A recent review lists the beneficial effects of playing action video games. The review suggests intervening studies on random allotted group yield an adequate size of about one-third of the size observed in the corresponding study without random allotment (Altarelli et al. 2020) plausibly suggesting the training effect along with prior existence of a difference between young adults playing action video games and non-players. Detailed analysis showed the translation of the learnt skill is not as anticipated like the selective translation of audio-visual attention into working memory and to improve the performance. As a training of working memory is supposed to improve the performance rate without any enhancement in components of executive skills like inhibition or alteration of cognition (Diamond and Ling 2016; Melby-Lervag et al. 2016). Usually, the investigator suggests and evaluates the desired activity with regard to its influence on the cognitive ability and brain structure for perfect translation of trained activity into cognitive skills. The lesser the plausibility of underlying translation mechanics, the greater the favour of the published evidence to be examined critically.

22.9 Major Infamy of Educational Neurosciences

With diverse scrutiny, challenges and support, the role of neuroscience in education has made to implement the techniques to improvise the efficacy of learning in the classroom setup. Constant assessment in the educational neuroscience which does not even belong to science like the neuromyths. These are the misinterpretations about the brain and education amongst the teachers and public with few or no data, or they contradict with the scientific concepts (Goswami 2006; Howard-Jones 2014a; Macdonald et al. 2017), for example, students accepting growth mindset (Sisk et al. 2018) or teachers providing individual specific teaching materials or learning style (Rohrer and Pashler 2012). These are considered as the critical aspects of science communication and a junction to collate stakeholders with neurosciences in the educational field. As of now, there are three types of substantive criticism faced by educational neurosciences: an argument showing the relevance of neurosciences in education, second on the current implemented practical approaches and, finally, questioning the viability of the techniques for diagnosing the disorder or finding the differences between the children.

For the first criticism, few researchers have observed neurological data as a principle not required for education, for example, Bowers (2016a) describes "education is solely gets effected by the instructions on outcomes with respect to behaviour and does not rely on the neural mechanism underlying in learners claiming neuroscience as an irrelevant tool to design and evaluate teaching" (Bowers 2016b). According to Willingham's (2018) recommendations criticizing with psychology with a slight variation saying neurosciences does not give any new information, this information can be obtained based on behavioural observation, and measuring or assessing the behaviour is viewed under psychology. If education aims to provide behavioural change, then definitely it is not related to alteration in the brain's activity (Bishop 2014). Philosophically, the criticism suggests the educational neuroscience is inappropriate, suggesting education as a social problem, requiring social solution (Breckler 2006; Lalancette and Campbell 2012). These criticisms hinder interdisciplinary research suggesting psychology is enough.

For the second criticism's point, it mainly targets the practical orientation of neurosciences in education by the way research is carried out along with the pace of progress (Anderson and Della Sala 2012). The research focus on the traditional teaching way and question why does it work, with expectations from neurosciences to quickly yield effective teaching prodigy for larger sample size (Thomas 2013) along with collecting the neuroscience data like images of the brain from controlled condition away from the naturalistic behaviour in the classroom, there is a valid question. Besides, the imaging data are complex and challenging for interpretation. In interdisciplinary dynamics, educational neuroscientists lecture teachers about the protocols to follow in the classroom with least motivations from the teacher towards neuroscience research (Turner 2011). Neurosciences have influenced educational policies and practices in its initial stage (Bruer 1997). Universally, these criticisms increase the pains in the area and field requiring improvement.

Finally, the last criticism is seen to utilize neuroscience data for predicting the developmental outputs like dyslexia and autisms by using brain imaging or genetics. Though neurosciences help in identifying the underlying cause of the repetitive behaviour, they can highlight the process not evident in behavioural studies like inhibition of task-irrelevant outcomes. If the examination is done early, it can help in predicting the developmental outputs. Still, it is believed that the neuroscience methods are not specific or sensitive for screening and they are quite expensive (Bishop 2013, 2014). Neurological studies can ascertain the behavioural and environmental risks before the child enters the school via genetic testing at birth or checking the language process by electrophysiology in infancy stage to pre-predict the risk of dyslexia (Guttorm et al. 2009). Early prediction and recognition can give ample time to intervene and give useful implementation at a developmental stage, thereby reducing the risk before the child enters the school.

22.10 Conclusion

Based on the literature search, it can be an epilogue that educational neurosciences are intuitively providing us with the insight on the mode of action of brains while learning mechanism to aid teaching efficacy in the schools rather than just providing the essential findings. The theoretical knowledge is practically hard to apply as the brain has multiple centres for learning and the factors influencing the mode of learning differ from individual to individual. Most importantly, the implementation of theoretical concepts in the classroom setup is quite hard. As per Roediger ready made model educational neuroscience is like a branch of medicine showing continuous upgradation and new findings while dealing with a small group of populations in the general world population. Once it passes the test, then the new finding is indulged in the practice. The projects mentioned in this work are in trail testing in the United Kingdom, and the evaluation is done by measuring the cognitive enhancement through behavioural interventions. The studies are supposed to be categorized based on hierarchy to find out the feasibility in establishing it, followed by checking its effectiveness and efficacy. The advantages and disadvantages of these random clinical trials are still on the plate. For neuro-researchers, the learning techniques and activities will be perspective, and the facilitators are supposed to work based on the design given by the researchers, which can undermine the teacher autonomy in the classroom, plus teachers must adapt to individual techniques for the specified learner, thereby reducing the uptake of teachers in the educational setup. It is hard to establish the effectiveness of enhancement based on small clinical trials; these can be effective in small sample sizes and require isolation to obtain significant children educational outcome. Similarly, the neurosciences have to obtain novel ethical clearance as the goal of the research is to enhance the cognitive and non-cognitive abilities in the children involved in the random clinical trials. For this purpose, the teachers can be hopeful as the overall motive is the goal of education, and varied technologies are being already implemented around the globe. Educational neurology research is confined to developed areas, whereas in developing nations, the educational outcomes may be conditioned due to varied factors like socio-economic and nutrition. Hence, more focus must be paid on a social and political factor other than just cognitive enhancement. In the end, the researchers must keep in mind the desires of the policymakers until a sufficiently significant and convergent positive result is not obtained; the policymakers will weight it behind as the alterations in guidelines and policy are slow. It can be futuristic to engage directly with the policymakers and can be challenging for the researchers.

Key Points

- Educational neuroscience translated the research outputs of neural mechanism obtained during the learning process in the educational surrounding. It also allows us to analyse the emphasis of education on brain building and hence is considered as an interdisciplinary research field.
- Educational neuroscience is an interdisciplinary research field that seeks to ... needs to be in the optimal condition to learn ('brain health').
- There can be indirect interaction between education and neuroscience based on psychological theories involved in education.
- Policymakers are always keen to integrate cognitive neuroscience in the educational area to obtain a proper decision about the mode and mechanism of education.

References

Altarelli, I., Green, C. S., & Bavelier, D. (2020). Action video games: From effects on cognition and the brain to potential educational applications. In M. S. C. Thomas, D. Mareschal, & I. Dumontheil (Eds.), *Educational neuroscience: Development across the lifespan*. London: Routledge.

Anderson, M., & Della Sala, S. (2012). *Neuroscience in education: The good, the bad, and the ugly*. Oxford: Oxford University Press.

Aslin, R. N., & Newport, E. L. (2012). Statistical learning: From acquiring specific items to forming general rules. *Current Directions in Psychological Science, 21*, 170–176.

Ayodele, T. O. (2010). Types of machine learning algorithms. In: Zhang, Y (Ed.), *New advances in machine learning* (pp. 19–48). INTECH.

Baldassano, S. N., & Bassett, D. S. (2016). Topological distortion and reorganized modular structure of gut microbial co-occurrence networks in inflammatory bowel disease. *Scientific Reports, 6*, 26087.

Barlow, H. B. (1989). Unsupervised learning. *Neural Computation, 1*, 295–311.

Bassett, D. S., & Sporns, O. (2017). Network neuroscience. *Nature Neuroscience, 20*, 353–364.

Bassett, D. S., Wymbs, N. F., Porter, M. A., Mucha, P. J., Carlson, J. M., & Grafton, S. T. (2011). Dynamic reconfiguration of human brain networks during learning. *Proceedings of the National Academy of Sciences of the United States of America, 108*, 7641–7646.

Bishop, D. V. (2013). Neuroscientific studies of intervention for language impairment in children: Interpretive and methodological problems. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 54*, 247–259.

Bishop, D. V. M. (2014). *What is educational neuroscience?* Available from: https://figshare.com/articles/What_is_educational_neuroscience_/1030405

Blakemore, S.-J. (2018). *Inventing ourselves: The secret life of the teenage brain*. New York: Doubleday.

Boal, K. B., & Hooijberg, R. (2000). Strategic leadership research: Moving on. *The Leadership Quarterly, 11*(4), 515–549.

Bontis, N. (2002). Managing organisational knowledge by diagnosing intellectual capital: Framing and advancing the state of the field. In C. W. Choo & N. Bontis (Eds.), *The strategic management of intellectual capital and organisational knowledge* (pp. 621–642). Oxford: Oxford University Press.

Bowers, J. S. (2016a). The practical and principled problems with educational neuroscience. *Psychological Review, 123*, 600–612.

Bowers, J. S. (2016b). Psychology, not educational neuro-science, is the way forward for improving educational out- comes for all children: Reply to Gabrieli (2016) and Howard-Jones et al. (2016). *Psychological Review, 123*, 628–635.

Breckler, S. J. (2006). The newest age of reductionism. *Monitor of Psychology, 37*, 23.

Bronfenbrenner, U. (1992). Ecological systems theory. In U. Bronfenbrenner (Ed.), *Making human beings human: Bioecological perspectives on human development* (pp. 106–173). Thousand Oaks: Sage.

Bruer, J. T. (1997). Education and the brain: A bridge too far. *Educational Researcher, 26*, 4–16.

Bruer, J. T. (2013). Afterword. In D. Mareschal, B. Butterworth, & A. Tolmie (Eds.), *Educational neuroscience* (pp. 349–363). Oxford: Wiley Blackwell.

Butterworth, B., & Varma, S. (2013). Mathematical development. In D. Mareschal, B. Butterworth, & A. Tolmie (Eds.), *Educational neuroscience* (pp. 201–236). Oxford: Wiley Blackwell.

Butterworth, B., Varma, S., & Laurillard, D. (2011). Dyscalculia: From brain to education. *Science, 332*, 1049–1053.

Chrysikou, E. G., et al. (2014). A matched filter hypothesis for cognitive control. *Neuropsychologia, 62*, 341–355.

Crone, E. A., & Dahl, R. E. (2012). Understanding adolescence as a period of social-affective engagement and goal flexibility. *Nature Reviews Neuroscience, 13*, 636–650.

Davis, P., & Florian, L. (2004). *Teaching strategies and approaches for pupils with special educational needs: A scoping study* (Department for Education and Skills research report RR516). London: The Queen's Printer.

Dayan, E., & Cohen, L. G. (2011). Neuroplasticity subserving motor skill learning. *Neuron, 72*, 443–454.

Diamond, A., & Ling, D. S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. *Developmental Cognitive Neuroscience, 18*, 34–48.

Donaldson, K., Tran, L., Jimenez, L. A., Duffin, R., Newby, D. E., Mills, N., et al. (2005). Combustion-derived nanoparticles: A review of their toxicology following inhalation exposure. *Particle and Fibre Toxicology, 2*, 10.

Dumontheil, I. (2016). Adolescent brain development. *Current Opinion in Behavioral Sciences, 10*, 39–44.

Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest, 14*, 4–58.

Espie, C. A., Luik, A. I., Cape, J., Drake, C. L., Siriwardena, A. N., Ong, J. C., et al. (2016). Digital cognitive behavioural therapy for insomnia versus sleep hygiene education: The impact of improved sleep on functional health, quality of life and psychological well-being. Study protocol for a randomised controlled trial. *Trials, 17*, 257.

Felver, J. C., Celis-de Hoyos, C. E., Tezanos, K., & Singh, N. N. (2016). A systematic review of mindfulness interventions for youth in school settings. *Mindfulness, 7*, 34–45.

Flaugnacco, E., Lopez, L., Terribili, C., Montico, M., Zois, S., & Scho€n, D. (2015). Music training increases phonological awareness and reading skills in develop- mental dyslexia: A randomized control trial. *PLoS One, 10*, e0138715.

Fornito, A., Zalesky, A., & Breakspear, M. (2013). Graph analysis of the human connectome: Promise, progress, and pitfalls. *NeuroImage, 80*, 426–444. https://doi.org/10.1016/j.neuroimage.2013.04.087.

Friston, K. (2002). Beyond phrenology: What can neuroimaging tell us about distributed circuitry? *Annual Review of Neuroscience, 25*, 221–250.

Fugelsang, J., & Mareschal, D. (2013). The development and application of scientific reasoning. In D. Mareschal, B. Butterworth, & A. Tolmie (Eds.), *Educational neuroscience* (pp. 237–267). Oxford: Wiley Blackwell.

Fuhrmann, D., Knoll, L. J., & Blakemore, S.-J. (2015). Adolescence as a sensitive period of brain development. *Trends in Cognitive Sciences, 19*, 558–566.

Garud, R. (1997). On the distinction between know-how, know-what, and know-why. In J. P. Walsh & A. S. Huff (Eds.), *Advances in strategic management* (Vol. 14, pp. 81–101). Greenwich: JAI Press Limited.

Gathercole, S. E., Woolgar, F., Manly, T., Astle, D. E., Kievit, R., Holmes, J., & Team, C. A. L. M. (2016). How common are WM deficits in children with difficulties in reading and mathematics? *Journal of Applied Research in Memory and Cognition, 5*, 384–394.

Goswami, U. (2006). Neuroscience and education: From research to practice? *Nature Reviews Neuroscience, 7*, 406–413.

Goswami, U. (2017). A neural basis for phonological awareness? An oscillatory 'temporal sampling' perspective. *Current Directions in Psychological Science, 27*, 56–63.

Guttorm, T. K., Leppänen, P. H. T., Hämäläinen, J. A., Eklund, K. M., & Lyytinen, H. J. (2009). Newborn event-related potentials predict poorer pre-reading skills in children at risk for dyslexia. *Journal of Learning Disabilities, 43*, 391–401.

Happel, M. F. (2016). Dopaminergic impact on local and global cortical circuit processing during learning. *Behavioural Brain Research, 299*, 32–41.

Hermundstad, A. M., et al. (2011). Learning, memory, and the role of neural network architecture. *PLOS Computational Biology, 7*, e1002063.

Hoeft, F., McCandliss, B. D., Black, J. M., Gantman, A., Zakerani, N., Hulme, C., et al. (2011). Neural systems predicting long-term outcome in dyslexia. *Proceedings of the National Academy of Sciences of the United States of America, 108*, 361–366.

Howard-Jones, P.A. (2014a). Neuroscience and education: Myths and messages. Nature Reviews Neuroscience, 15, 817–824

Howard-Jones, P. A. (2014b). *Neuroscience and education: A review of educational interventions and approaches informed by neuroscience*. London: Education Endowment Foundation.

Howard-Jones, P. A., & Jay, T. (2016). Reward, learning and games. *Current Opinion in Behavioral Sciences, 10*, 65–72.

Jiang, F., Van Dyke, R. D., Zhang, J., Li, F., Gozal, D., & Shen, X. (2011). Effect of chronic sleep restriction on sleepiness and working memory in adolescents and young adults. *Journal of Clinical and Experimental Neuropsychology, 33*, 892–900.

Johansen-Berg, H., & Duzel, E. (2016). Neuroplasticity: Effects of physical and cognitive activity on brain structure and function. *Neuro Image, 131*, 1–3.

Keiflin, R., & Janak, P. H. (2015). Dopamine prediction errors in reward learning and addiction: From theory to neural circuitry. *Neuron, 88*, 247–263.
Kelley, P., & Whatson, T. (2013). Making long-term memories in minutes: A spaced learning pattern from memory research in education. *Frontiers in Human Neuroscience, 7*, 589.
Kelley, P., Lockley, S. W., Foster, R. G., & Kelley, J. (2015). Synchronizing education to adolescent biology: 'Let teens sleep, start school later'. *Learning, Media & Technology, 40*, 210–226.
Koelsch, S. (2012). *The brain and music*. Oxford: Wiley-Blackwell.
Kovas, Y., Haworth, C., Dale, P., & Plomin, R. (2007). The genetic and environmental origins of learning abilities and disabilities in the early school years. *Monographs of the Society for Research in Child Development, 72*, 1–144.
Lalancette, H., & Campbell, S. R. (2012). Educational neuro-science: Neuroethical considerations. *International Journal of Environmental & Science Education, 7*, 37–52.
Lo, J. C., Ong, J. L., Leong, R. L., Gooley, J. J., & Chee, M. W. (2016). Cognitive performance, sleepiness, and mood in partially sleep deprived adolescents: The need for sleep study. *Sleep, 39*, 687–698.
Macdonald, K., Germine, L., Anderson, A., Christodoulou, J., & McGrath, L. M. (2017). Dispelling the myth: Training in education or neuroscience decreases but does not eliminate beliefs in neuromyths. *Frontiers in Psychology, 8*, 1314.
Mareschal, D. (2016). The neuroscience of conceptual learning in science and mathematics. *Current Opinion in Behavioral Sciences, 10*, 114–118.
Melby-Lervag, M., Redick, T. S., & Hulme, C. (2016). Working memory training does not improve performance on measures of intelligence or other measures of "Far Transfer": Evidence from a meta-analytic review. *Perspectives on Psychological Science, 11*, 512–534.
Michie, S., van Stralen, M. M., & West, R. (2011). The behavioural change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science, 6*, 42.
Mills, K. L., Goddings, A.-L., Clasen, L. S., Giedd, J. N., & Blakemore, S.-J. (2014). The developmental mismatch in structural brain maturation during adolescence. *Developmental Neuroscience, 36*, 147–160.
Misic, B., & Sporns, O. (2016). From regions to connections and networks: New bridges between brain and behavior. *Current Opinion in Neurobiology, 40*, 1–7.
Nakazawa, K., et al. (2003). Hippocampal CA3 NMDA receptors are crucial for memory acquisition of one-time experience. *Neuron, 38*, 305–315.
Newman MEJ. Networks: An introduction. Cambridge: MIT Press; 2010. (Google Scholar)
Newman, M. E. J. (2011). Complex systems: A survey. *American Journal of Physics, 79*, 800–810.
Niv, Y. (2009). Reinforcement learning in the brain. *Journal of Mathematical Psychology, 53*, 139–154.
Peretz, I., & Zatorre, R. J. (2003). *The cognitive neuroscience of music*. Oxford: Oxford University Press.
Peters, L., Bulthe, J., Daniels, N., Opde Beeck, H., & DeSmedt, B. (2018). Dyscalculia and dyslexia: Different behavioral, yet similar brain activity profiles during arithmetic. *Neuro Image: Clinical, 18*, 663–667.
Piekarski, D. J., Boivin, J. R., & Wilbrecht, L. (2017). Ovarian hormones organize the maturation of inhibitory neurotransmission in the frontal cortex at puberty onset in female mice. *Current Biology*, *27*, 1735–1745.e3
Ramsden, S., Richardson, F. M., Josse, G., Thomas, M. S. C., Ellis, C., Shakeshaft, C., et al. (2011). Verbal and non-verbal intelligence changes in the teenage brain. *Nature, 479*, 113–116.
Rinehart, N. J., Bradshaw, J. L., & Enticott, P. G. (Eds.). (2017). *Developmental disorders of the brain (brain, behaviour and cognition)* (2nd ed.). Oxford: Routledge.
Roediger, H. L. (2013). Applying cognitive psychology to education: Translational educational science. *Psychological Science in the Public Interest, 14*, 1–3.
Rohrer, D., & Pashler, H. (2012). Learning styles: Where's the evidence? *Medical Education, 46*, 630–635.

Ruiz-Ariza, A., Grao-Cruces, A., Marques de Loureiro, N. E., & Martınez-Lopez, E. J. (2017). Influence of physical fitness on cognitive and academic performance in adolescents: A systematic review from 2005–2015. *International Review of Sport and Exercise Psychology, 10*, 108–133.

Sala, G., & Gobet, F. (2016). Do the benefits of chess instruction transfer to academic and cognitive skills? A meta-analysis. *Educational Research Review, 18*, 46–57.

Scholl, J., et al. (2015). The good, the bad, and the irrelevant: Neural mechanisms of learning real and hypothetical rewards and effort. *The Journal of Neuroscience, 35*, 11233–11251.

Schunk, D. H. (1996). *Learning theories, an educational perspective* (2nd ed.). Englewood Cliffs: Merrill.

Seger, C. A. (1994). Implicit learning. *Psychological Bulletin, 115*, 163.

Sejnowski, T. J. (1994). *The computational brain*. Cambridge: MIT Press.

Shaw, P., Malek, M., Watson, B., Greenstein, D., de Rossi, P., & Sharp, W. (2013). Trajectories of cerebral cortical development in childhood and adolescence and adult attention- deficit/hyperactivity disorder. *Biological Psychiatry, 74*, 599–606.

Sisk, V. F., Burgoyne, A. P., Sun, J., Butler, J. L., & Macnamara, B. N. (2018). To what extent and under which circumstances are growth mind-sets important to academic achievement? Two meta-analyses. *Psychological Science, 29*, 549–571.

Smolen, P., et al. (2016). The right time to learn: Mechanisms and optimization of spaced learning. *Nature Reviews Neuroscience, 17*, 77–88.

Sunyer, J., Esnaola, M., Alvarez-Pedrerol, M., Forns, J., Rivas, I., Lopez-Vicente, M., et al. (2015). Association between traffic-related air pollution in schools and cognitive development in primary school children: A prospective cohort study. *PLoS Medicine, 12*, e1001792.

Thomas, M. S. C. (2013). Educational neuroscience in the near and far future: Predictions from the analogy with the history of medicine. *Trends in Neuroscience and Education, 2*, 23–26.

Thompson, J. M., Leong, V., & Goswami, U. (2013). Auditory processing interventions and developmental dyslexia: A comparison of phonemic and rhythmic approaches. *Reading and Writing, 26*, 139–161.

Turk-Browne, N. B., et al. (2005). The automaticity of visual statistical learning. *Journal of Experimental Psychology. General, 134*, 552.

Turner, D. A. (2011). Which part of 'two way street' did you not understand? Redressing the balance of neuroscience and education. *Educational Research Review, 6*, 224–232.

Van Hoorn, J., Fuligni, A. J., Crone, E. A., & Galvan, A. (2016). Peer influence effects on risk-taking and prosocial decision- making in adolescence: Insights from neuroimaging studies. *Current Opinion in Behavioural Sciences, 10*, 59–64.

Vogels, R. (2010). Mechanisms of visual perceptual learning in macaque visual cortex. *Topics in Cognitive Science, 2*, 239–250.

Willingham, D. T. (2018). Unlocking the science of how kids think: A new proposal for reforming teacher education. *Education Next*, p. 18. http://educationnext.org/unlocking-science-how-kids-think-new-proposal-for-reforming-teacher-education/ (downloaded 11/4/18).

Woolfson, L. M. (2011). *Educational psychology: The impact of psychological research on education*. Harlow: Pearson Education Limited.

Chapter 23
Effect of Audiovisual Aids and Blended Teaching on English Performance and Self-Confidence of IX Standard Students in Government Schools of Manipur

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23.1 Introduction

Education is a process of acquiring information, skills, beliefs, habits, and values through teaching-learning process and one's experiences. With the advancement in the field of technology, multiple ways of teaching-learning process have been introduced breaking the barriers of time, place, and accessibility. According to the Association for Educational Communications and Technology (AECT 2008), "Educational technology is the study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources." It can also be defined as a methodical and systematic approach to recognition of educational problems by means of human and material resources in the planning, designing, implementation, and evaluation of strategic solutions which are aimed at the enhancement of performance of the students and education system as a whole. Ringstaff and Kelly (2002) view educational technology as the integration of computer-based tools in instructional process of the curriculum while developing technology skills in students. Computer-based technology includes hardware, software, online applications, and computer-based multimedia as tools for knowledge acquisition. The term was first coined as "technology in education," implying the use of various audiovisual aids for teaching purposes. As

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the concept of educational technology developed, the term "technology of education" became a trend. The concept viewed education in a wider sense and incorporated a range of aspects such as learned behavior of the students, objectives, content analysis, assessment, etc.

Educational technology includes various types of medium that delivers transcript, auditory, pictures, film strips, and live videos and also includes technology-based applications such as video or audio tapes, CD-ROM, satellite TV, and computer-mediated learning and online learning. Teaching aids are the materials used by a teacher in a classroom to help students in having an effective learning process; aids such as pictures, illustrations, video, or tapes are intended to encourage learning and achieve a beneficial outcome. From the point of view of teaching and learning, the adequacy of these resources is concerned with psychological learning and maintenance. In addition, the execution criteria of learning resources are focused on understanding, conceptualizing, and retention. Edgar Dale's Cone of Experience states that the more the senses are involved in the learning process, the better is the learning and retention of the students. According to Edgar Dale, after 2 weeks of exposure, students recollect 50% of anything that is heard and seen and 90% of anything that is said and done by the students, which in connection to the use of audiovisual aids in classroom indicates that the more the exposure to visual and audio aids, the better the retention and learning of the students.

Audiovisual aids are sensory objects and imageries which stimulate and emphasize the learning process (Burton 2013). These are the learning materials utilized in teaching-learning process to enhance knowledge acquisition process of the learners creating an easier platform to grasp knowledge and retaining learner's interest. Learning tools, such as models, charts, film strips, radio, flipcharts, television, etc., are called instructional aids. Audiovisual aids offer the learners with practical experiences, which confine their attention and help in the understanding of past phenomena. They appeal to the intellect through visual and auditory senses (Jain 2004). The utilization of optical aids like images, posters, film strips, and projectors motivates learners to comprehend learning materials with attentiveness, which makes understanding the abstract ideas in the text with great ease (Bowen 1982). This statement proves that these aids operate as a means which can be utilized to develop and improve learning among the students. Likewise, in many researches related to the utilization of teaching aids for instruction of language and literature, it has been assured that the incorporation of visual aids in instruction enables reliable contact between the students and the literary texts. According to Carlos Yorio (1987), a combination of various methods and resources is the most logical and receptive way of approaching students in a language classroom. Language educators utilize an assortment of instructional aids to create interactive and interesting classroom exercises.

The major advantages of audiovisual aids are that these aids are great methods for interaction with individuals and students. The use of these aids encourages and helps the regular and conventional method of teaching. They help in keeping up and holding students' attention nearly to the completion of the classroom session. The utilization of audiovisual aids in a classroom or other instructional courses enhances the achievement of the students. At the point when an instructor gives utmost exposure alongside different points of view, utilizing assortment of audiovisual aids for specific concept results in having most of the students in the class capable of comprehending and understanding the given concept.

The use of audiovisual aids has an effect on the teaching and learning process; they develop enhanced understanding and create an emotional equilibrium which provides space for personality growth, and they also increase experience through films, thus aiding students to share understanding of other cultures and formulate individualized learning likely through programmed instructions (Ode 2014). The use of these aids in teaching improves classroom instruction and student understanding. At present, technology offers various possibilities for the educator who wants to benefit from the enthusiasm of a new generation of multimedia presentations. Adding up to helping students retain vital information, audiovisual aids have other merits; when accurately utilized, they assist achievement and grasp the attention of learners. Visual aids are constructive in supporting the topic in question, and the combination of audio and visual stimuli is predominantly efficient given that the two chief senses are involved. Teachers should take into account the ways to keep students interested in the classroom; a major goal of the teaching-learning process is to enhance retention of the concept taught in class as well as their performance. Bonwell and Eison (1991) attempted to establish how these teaching aids serve the purpose of retention and performance of the students.

The utilization of audiovisual materials helps the students retain the concept for a longer duration of time. These resources put across the same meaning as the conventional way of instruction, but it gives comprehensible concepts, thereby facilitating effective learning. The use of audiovisual aids assists in maintaining obedience in the classroom as all the students' concentration is fixed on knowledge acquisition. This interactive session in addition develops critical thinking and reasoning that are fundamental components in the teaching-learning process. Uses of audiovisual resources provide means for effective communication between educators and learners in learning. In a study conducted on English as Foreign Language (EFL) classroom, the challenges faced by EFL learners are being short on motivation, exposure to the specified foreign language, and lack of articulation by the teacher, and such challenges can be overcome by audio tapes as a function of communication and visuals as additional exposure (DeBernardes and Olsen 1948). Utilization of these resources in classroom and guidance sessions improves the presentation of the learners. Activity-based learning leads to reasoning, critical thinking, originality, and expansion of problem-solving skills which are the actual objectives of education. Audiovisual aids involve activity for teachers plus students that maintain interest and attentiveness and motivate them to become independent thinkers and raise questions which are a result of profound understanding about what is being delivered in the classroom (Mangal 2008). Studies reported that learners learn better when they are encouraged and are inquisitive about a topic or concept. Conventional oral instructions can be tedious and uninteresting for students. However, the use of audiovisual resources provides central motivation for the students by making them curious and inspiring their interests in the subjects (Mishra and Yadav 2004).

Advancement in technology and a quickly developing media outlook consistently change the ways we approach teaching and learning. Among these progressions is the development of use of multimedia as an educational idea, online degree programs, and hybrid courses that mix conventional strategies with new innovation. Innovation is an important means for changing the existing teaching and learning process. It can help assert and progress connections among teachers and students, reinvent our ways to deal with learning and cooperation, lessen longstanding value and inaccessibility, and regulate learning encounters to address the issues of all students. Zameer (2010) found out that recent development in educational technology improves accessibility of education, along with full degree courses enabling incorporation for part-time student, and in enhancing communications between educators and learners. Learning resources can be utilized for distance education, and these resources are made available to a wider audience and are easily accessible. The Canadian Radio-television and Telecommunications Commission (CRTC 2014), in their report, stated that 79% of families have Internet accessibility and students have access to learning resources and take on various online learning resources at home. Major schools such as MIT have made few of their course materials accessible online free of cost. Utilization of online learning materials does deprive students of some of the aspects of classroom situations; these aids are useful to put in supplementary support to the educational organization. The cost of commute to institutions has been removed since learning is made available online. Kemp and Grieve (2014) stated that students value the ease of e-learning, but reported better interaction in face-to-face educational settings.

Educational technology is an ethical routine with regard to encouraging learning and enhancing execution by creating, utilizing, and overseeing fitting technological procedures and resources. Educational technology is not restricted only to high innovation. In any case, electronic instructional technology has turned into an essential part of society today. Computer-mediated teaching presents new band of educational options for teachers and students today. Computer-mediated teaching breaks the barrier of distance and time and delivers learning materials, lectures, educational videos, etc. Online conferencing empowers the improvement of time and autonomous learning condition in which a large number of students can participate.

The main function of instructive multimedia resources is to upgrade learning. Consequently, the objectives of these instructive multimedia is to help current ways to deal with learning and educating where learners are perceived as active constructors of information while educators as facilitators of that learning process. As educators endeavor to link new strategies with generally accessible innovations, an opportunity emerges to consider about hybrid or blended course models. According to Heinze and Procter (2004), blended teaching is a term concerned with transmitting knowledge. Kyei-Blankson and Ntuli (2013) defined blended courses are those that “integrate online with traditional face-to-face class activities in a planned, pedagogically valuable manner.” Bielawski and Metcalf (2003) have stated that blended teaching is the style of teaching which is enabled by an efficient amalgamation of diverse modes of delivery, different teaching models, and various learning styles, which is founded based on clear communication between all the parties involved in the course. Blended teaching is a kind of e-learning which utilizes a scope of instruments and instructive guides to make a learning environment interactive in real time and also in pre-recorded sessions; it serves both the instructor and the learner and improves the learning procedure by offering courses and projects electronically by means of various mixed media specialized devices including email, texting, mailing records, and online forums to overcome the customary issues where the educator has restricted opportunities to monitor students and rectify their mistakes in the learning process. Blended courses are as well used interchangeably as hybrid learning or combined learning in scholastic theories. Bonk and Graham (2005) stated that blended teaching system is an amalgamation of face-to-face and computer-mediated education.

Blended teaching is an educational foundation designed using learning theories, which can be related with three major learning theories, namely, the cognitive learning theory, the constructivist learning theory, and the socially situated learning theory. Jean Piaget's cognitive learning theory provides a base for understanding the analysis of concepts and events in terms of the program. The fundamental argument identified in this theory is how to understand information and build a meaning associating it with the acquired knowledge. With regard to blended instruction, with the application of cognitive approach in the teaching and learning process, the learners will be able to focus, comprehend, and apply the knowledge in provisions of their relationships. Students will be able to comprehend the association among the information, the breakdown of this said information, and the construction of new information from the already-existing information. The theoretical foundation of blended teaching based on the constructivist theory is predicated on the understanding of amalgamation of the community and the individual worlds, collaboration and cooperation in the knowledge acquisition process, and interaction and consideration of the process of learning. Further, the socially situated learning theory (Lave 1988) believes that knowledge is found in the ways communities interact and learning is the outcome of the way an individual interacts with the community. Based on this theory, blended courses act as a community or as a network that connects people through knowledge; individuals interact through group activities and assignments and acquire knowledge.

Various opportunities have been created to expand and redefine our concept of a teacher with the spread of blending learning while creating an array of roles which require a distinctive amalgamation of skills and strengths to carry out blended courses. The shift from the traditional concept of a teacher to a forward-looking profession has the potential to attract a much wider range of learners. Schools adopting models of blended learning must reflect upon re-examining and intensifying the already-existing talents to enhance it into a talent pool and to build up teams that reflect upon the range of necessary skills required for success (TNTP 2014). Several scholars claim that for school students, blended approaches are much more suitable as compared to full-fledge online classes because in a blended learning situation, a student receives enhanced support online as well as traditional face-to-face contact with the teachers which facilitates learners to engage more easily in a self-directed learning (Doering and Veletsianos 2008).

The chief advantage of blended teaching is that it offers scale, whereas one teacher can only educate so many people. Blended approach, in general, has many advantages over conventional way of teaching and learning process; the cost-effectiveness is one of the most advantageous factors for accrediting both educational institution and the students. The profits of blended approach include giving the learners a range of ways to exhibit their knowledge although engaging in various learning styles and fostering autonomous education and independent learning skills in students. Blended approach incorporates computer-mediated tools into the students' toolkits, which have consisted of notebooks, paper assignments, and face-to-face classroom presentations, in the past. This helps students increase their skills in procuring knowledge as well as helps them become independent learners. Blended teaching expands the teaching-learning process beyond the classroom walls; it helps in developing problem-solving skills, communication, teamwork, critical thinking, and global alertness.

Blended courses are one of the most efficient ways for individualized learning as it encourages the application of values as a means of managing worth and ease of use. Provisions of time management and flexibility in blended learning are considered another main advantage of this approach. In the blended approach, learners are equipped with the skills to decide upon the means of learning which are practical to them, and they can choose from a wide range of means such as PowerPoint, storybook, web pages, pictures, and so on. This leads to diverse learning and correspondence styles of the learners which eventually makes learning more interesting. Blended teaching is reported to be more useful than entirely face-to-face or online classes. Blended teaching methods can furthermore result in comparatively higher achievement of students than the students in face-to-face learning (Saritepeci et al. 2015). With an amalgamation of digital training and face-to-face interaction, learners work on their own with new lessons at their own pace which gives the teachers ample time to circulate and support individual students who require individualized guidance.

23.2 Impact of Instructional Aids on English Performance

English performance is one of the domains that come under academic performance. The importance of English language in enhancing academic performance through better communication skills cannot be overemphasized. Students who face challenges in understanding and comprehending the English language may not perform effectively, not only in English language but in other academic subjects too. Roy-Campbell and Qorro (1997) stated that education is conceded chiefly through the medium of instruction; thus, language plays a key role in the educational process. Furthermore, ADEA (2005) argues, "Language is not everything in education, but without language, everything is nothing in education." Language plays a significant role in the teaching and learning process, and if the student is unable to comprehend the medium of instruction, then learning might not have an effect at all as the educator and the learner will not be communicating (Malekela 2003). When students' performance in English language is high, it will definitely affect the academic performance of the students, since English is a global language and is a medium of instruction in majority of the states and the printed books and articles are mostly in English language. So, it can be said that an enhanced performance in English may lead to better academic performance.

In recent times, inclination is more in the direction of communicative language instruction rather than conventional grammar. While, in the past, taking in another language implied figuring out how to pay particular attention to the writing of the language, now the need of taking in another language has turned into a communicative requirement. Individuals take on other languages after their native language for keeping up communication with the general population of other group conversing in an alternate language. Accordingly, languages are learned as a method for communication, not as a discipline in schools. That is the reason with the transformed need of language acquisition, the teaching strategies and methodologies have been accordingly adjusted. Language instructors are attempting to get new developments in their method of educating to make their language instruction powerful. Teaching language is not a simple undertaking, and it should be intriguing enough to relinquish the anxiety of the students. Consequently, language instructors have a tendency to adjust diverse procedures to instruct language all the more viably and all the more curiously. With the quick development and accessibility of innovation, language instructors are combining diverse extra guides alongside the course readings to teach language. The utilization of teaching aids in teaching language is more efficient and valuable since the approach toward learning is deciphered in terms of psychological capacities. Also, cognitivists would emphasize here on short-term memory and long-term memory storing of the learned and obtained effects of a language. As far as that is concerned, one can gather the reality that the more utilization of teaching aids in educating a specific object of language, the more certain we are that either a definite thing has been practiced to the long-term memory which is the real objective of learning. As such, all bits of data which are not practiced to the long-term memory will be straightforwardly and naturally erased from the short-term memory. Integration of teaching aids in both language instruction and learning is significantly beneficial when utilized appropriately. In other words, an instructor can create an environment in his or her class more appealing, additional learning chances particularly for difficult language which require more clarifications, and more effectual teaching and most essentially can help his or her student construct several relations for a certain linguistic item which results in more comprehension and understanding. Alternatively, the method of learning by itself is becoming more efficient and more individualized, and students are exposed to genuine language, chiefly in the case of using aids of teaching and learning a foreign or second language. The utilization of visual resources creates interest among the students; visual aids such as pictures, videos, and projectors assist the learners to understand abstract ideas of the concept.

Teachers use diverse approaches and significant resources to enhance the learning of the students. In the course of time, new process and techniques are introduced in the educational field, and teachers use various kinds of aids to make learning successful and efficient. Audiovisual aids stimulate the curiosity of students and help the teacher clarify the concepts in ways that are easier for students to comprehend. Audiovisual resources make the teaching and learning process efficient making the class appealing, motivating, and attractive for the students, facilitating language skills. Garzon (2012) stated that the use of audiovisual aids in classroom and other teaching sessions improves the performance of the students. Learning using various audiovisual aids leads to reasoning, critical thinking, creativity, and development of problem-solving skills which are the real objective of education. Audiovisual aids involve activity for teachers as well as students that keep them interested and attentive and encourage them to become independent thinkers and raise questions which are a result of profound understanding about what is being delivered in the classroom.

Blended teaching-based program has a helpful effect on the students' performance and self-directed learning skills. Blended course implementation leads students to reflect, inquire, and investigate the concept, share opinions, interact, and evaluate others' opinions. Learners gain various perspectives and are enabled to reflect profoundly and critically. Blended teaching considerably outperforms traditional face-to-face classroom instruction. Hence, the students are capable to shift learned concepts to real-life experiences. Ziyabaat (2013) points out that blended approach enables student-teacher or student-content or student-student interaction via direct exchange of ideas in order to overcome the obstacles of conventional face-to-face instruction and computer-mediated education and develops students' knowledge and skills efficiently. Blended approach helps overcome the social segregation imposed by e-learning, by integrating it with conventional classroom instruction. In the situation of blended learning, the main focus of blended approach is the students and to cater to their needs through studying educational content through face-to-face instruction and online communication. With the integration of computer-mediated instruction and face-to-face teaching, blended teaching settings produce improved student achievements and assist acquisition of skills that may otherwise be not achieved. This type of instruction increases student interaction with the learning process, boost critical thinking development, and enhance learning outcomes. Most of the studies on blended teaching also found that blended teaching increases the academic performance averages. Various studies on blended instruction show that qualities and quantities of interaction in a blended teaching setting directly influence the academic achievement, experiences, skills, and learning of students.

23.3 Impact of Instructional Aids on Self-Confidence

Self-confidence is generally defined as belief in oneself and one's abilities, describing an internal state invented of what we believe and feel about ourselves. An individual's state of mind is changeable according to the situation the individual is in and his responses to the happenings around him (Benabou and Tirole 2002). In general, individuals feel quite confident in some situations like performing a task or playing a game they are good at compared to other contradictory situations. Self-confidence is viewed as a standout among the majority compelling inspirations and controllers of behavior in individuals' daily existences (Bandura 1986). A budding group of proof proposes that one's view of capability or self-assurance is the central arbitrate inbuilt of accomplishment strivings (Bandura 1977; Harter 1978; Nicholls 1984; Kuhl 1992; Ericsson et al. 1993).

Basavanna (1975) defined "self-confidence as an individual's perceived ability to act effectively in a situation to overcome obstacles and to get things goes all right." A self-confident person views himself as proficient, befitting to the opportunities presented to him. Self-confidence is further analyzed as a function of perceived maternal child-rearing behavior (Agnihotri 1985). Their study revealed that gender does not have a significant difference with regard to self-confidence; however, subculture affiliation played an important part in affecting the self-confidence of adolescents.

It was found that students with high performance have higher confidence which possibly encourages them to take on greater responsibility to profitably complete tasks (Zimmerman and Kitsantas 2005). Pajares and Johnson (1996) stated that students who perform better obtain more constructive evaluation report and have high probability to developing better self-confidence. Students with low achievement report less confidence, and students with high achievement report higher self-confidence (Zusho et al. 2003). Teachers' behavior and the way they treat their students also greatly affect the self-confidence of the students. In a research conducted on University of California, Los Angeles (UCLA) students, males compared to their counterparts and adolescents with more number of siblings (compared to those with lesser siblings) had higher self-confidence. Lack of self-confidence in students resulted in greater anxiety, depression, and emotional vulnerability and shyness (Cheng and Furnham 2002). Self-confidence is also influenced by an individual's past experiences and how they recall those experiences or incidents; for instance, recalling a previous accomplishment has a very different effect in terms of our confidence levels than recalling an occasion when we failed. One of the most common explanations of self-confidence is that it is mainly the belief of an individual in oneself (Bénabou and Tirole 2002). Self-confidence can vary throughout an individual's life, mainly during major life changes such as adolescence. It has been estimated that almost half of adolescents struggle with low self-confidence levels at some point in their teenage years. Self-confidence helps adolescents formulate informed and safe decisions. It has been also reported that teenagers who are confident have the ability to make right decisions and tend to avoid people and situations that are not essentially right for them. It is additionally proposed that self-confidence acts as a sort of defense. When individuals fail to corroborate their personalities, the confidence delivered by past successful endeavors at self-verification diminishes or shields people from the despair related with an absence of self-confirmation, subsequently safeguarding undermined basic courses of action. In securing the self against trouble while the circumstance is settled (Thoits 1994), be that as it may, confidence is exhausted or diminished. Along these lines, self-confidence is similar to a reservoir of energy. Similar to some other quality, confidence can be developed, yet as utilized, it is lost. At this point, the repository of confidence is topped off by effective introspection and spent when the self-confirmation procedure is disrupted. Like different parts of the self, confidence is very steady; however, it is receptive to changes in the social circumstances. At the point when these progressions incorporate constant issues in self-confirmation, confidence is certainly going to decrease significantly more as the vitality repository is drained.

Confidence is achieved by enabling students to set up constructive prospects for success. Additionally, confidence plays a vital role in motivating the learners. Use of audiovisual aids provides learners with opportunities to reflect upon, speak, and interact without apprehension and hesitation with educators and peers resulting in students' confidence and personality development (Brown et al. 1985). Confidence is an essential element in blended approach (Greener 2008). Ultimately, it is recommended that individuals seek out to keep up or enhance their self-confidence by making "opportunity structures" or settings for self-confirmation (Swann 1983). Individuals look for circumstances where they can confirm their characters and maintain a strategic distance from circumstances (and gatherings) where self-confirmation is risky. Such endeavors enable people to manage and keep up their confidence. Along these lines, confidence can be seen as a self-rationale, arranging and giving guidance for conduct. Such endeavors serve the person, as well as help represent the arrangement and maintenance of group relations.

The uses of audiovisual aids are viewed as an important tool for teaching and learning process. It has been found that the use of these aids bring changes in the classroom environment and motivates the students plus the teachers (Brown et al. 1985). Using audiovisual aids in an English language classroom provides the students an opportunity to listen to the correct pronunciations and the way of speaking; this motivates the students to speak out and have confidence while doing so. Arung (2016) reported that the results of improvements in some aspects of speaking skills, such as pronunciation, grammar, vocabulary, and fluency, add up to the confidence level of the students. The use of these aids enables better classroom interactivity and exercises where students are exposed to different group as well as individual learning. According to Brown et al. (1985), students' confidence and personality are improved by the utilization of audiovisual aids as students are provided with the opportunity to visualize, express, and interact with their teachers and peers without fear and uncertainty.

Blended instruction programs contribute more to students' attitude toward learning when compared to the traditional face-to-face learning process. Students are encouraged to participate more during the learning process, and the interactions among the students and the teachers help clarify doubts whether in an online instruction or in face-to-face setting. Parkes et al. (2011) claim that for school students, blended approaches are much more suitable as compared to full-fledge online classes because in a blended learning situation, a student receives enhanced support online as well as traditional face-to-face contact with the teachers which facilitates learners to engage more easily in a self-directed learning. According to Sivin-Kachala and Bialo (2000), technology has a positive result on student attitudes toward learning, self-confidence, and self-respect. Likewise Coley et al. (1997) reported that the use of technology has been found to progress attendance of students and reduce in the dropout rates with a constructive impact on students' confidence and feelings of liability for their own learning.

23.4 Visual Stimuli and Neural Connection in Learning

Teaching and learning, at the most fundamental level, are a neurological phenomenon ascending from the changes that brain cells go through physically. Most of our insights are derivatives of the sensory system, meaning we retain and learn better when the sensory system is stimulated. Dale's Cone of Experience presents us with the idea that the more senses are stimulated in learning, the more is the retention power of the learner. Up to 90% of retention is a result of action learning techniques; perceptual learning styles are considered a best method for learning. According to Dale, teaching should be designed based on activities which further builds up on real-life experiences. Swank (2011) stating the usefulness of visual materials in leaning estimated that about 40% of our concepts are based on visual experience, 25% upon auditory, 17% on tactile, 15% upon miscellaneous organic sensation, and 3% upon taste and smell.

While studying the brain in whole brain teaching, it is stated that the visual cortex occupies the largest portion in the brain, which resulted in the visual cortex being addressed as the "seeing brain." The visual cortex processes the inputs from the eyes and stores them as visual memories in the brain. Since memory stores and retrieves information, it plays an essential role in learning. Active learning theories report that almost 65% of visual information is retained by the learner after 3 days, while only 10–20% of written and spoken information were retained by the learners. Since 40% of the nerve fibers are linked to the retina, 90% of the information that are being transmitted to the brain are graphic information; and visual information are processed much faster than information in the form of text (Visual Teaching Alliance). Utilizing visual aids in teaching has been found to improve learning in students since it affects the students on cognitive level and stimulates imagination resulting in faster processing of information. When an instructor uses both dialogue and visual method in teaching, learners are able to create new knowledge with the assistance of their pre-existing knowledge. The use of visual aids in teaching has the potential to increase "human bandwidth" which is the capacity to absorb information, to comprehend the information, and to effectively synthesize the information into new knowledge (Robert E. Horn). Based on the findings of the aforementioned theories, it can be concluded that visual aids in instruction play a major role in learning and help build stronger retention power.

23.5 Need and Significance of the Study

In Manipur, the school dropout rate was high at the preliminary stage and continues to be above-average in the national level. This is mainly due to the economic condition and the state of government schools in Manipur. The functioning of govt. schools in Manipur is minimal; the conventional method of chalk and talk is still being employed regardless of the developments in the field of education and technology. There is barely any usage of teaching aids; even the basic aids such as charts, models, pictures, etc. are hardly used. The attendance of the students is poor due to lack of facilities in schools and the style of instruction being monotonous. There is less exposure to the happenings of the world, and the students are deprived of the basic knowledge of technology and multimedia.

In a recent study conducted by the Unified District Information System for Education (UDISE 2016), the dropout rate in Manipur is 18%, which is the second highest in the northeastern region, first being Nagaland with the dropout rate of 19.4%. As per the official report, in 2013, 28 out of 323 government schools had zero pass percentage in the High School Leaving Certificate (HSLC) examination which increased to 48 and 70 in the years 2014 and 2015, respectively. The ordeal continued in 2016 with the number coming up to 73 government schools in the state to have a zero pass percentage in the HSLC exam conducted by the Board of Secondary Education Manipur (BOSEM). All these expose the seriousness of the problem in the functioning of the government schools in the state. Many studies on pedagogy revealed that the utilization of teaching aids and multimedia has had a positive impact on performance and enhanced retention of the students; not only the abovementioned, the utilization of these aids and resources grasps the students' attention and keeps them engaged in the classroom. Teaching aids cater to the individual differences of the students, helping them learn visually, kinesthetically, through audio, etc. In order to achieve optimal learning, the brain needs to be stimulated in multiple regions which are associated with functions such as senses, memory, and different levels of cognitive functions. The hippocampus, the area of the brain responsible for spatial awareness and memory, is associated with retention and comprehension of information, which is prompted by the use of teaching aids as visual information processes faster than information in the form of text, and retention of information in the form of images are higher comparatively. These aids also help in arriving at a concrete idea from a rather abstract concept, as it creates an active learning environment which is more advantageous for learning as it involves a greater number of neural connection and brain stimulation. Active learning provides additional neurological cross-talk, stimulates various regions of the brain, and as a result enhances memory.

The present chapter discusses the impact of audiovisual and blended teaching on performance in English of IX Standard students in government schools of Manipur. The teaching carried out in the government schools in Manipur is bare minimum, and students are not exposed to any teaching aids or multimedia which will help them conceptualize abstract ideas. The learning is mostly rote learning, and students are deprived of the basic learning needs. With the advancement in technology and exposure of the students to these technologies, it is hard to grasp the attention of the students using the traditional method which results in having low performance in schools. Especially with the students between the ages of 14 and 16 years who are in the peak of adolescence, developing their self-confidence in this age is critical since, in this stage, individuals are more aware and conscious about themselves and any negative thoughts or reinforcement can affect the individual's confidence throughout their life. Nasab et al. (2015) found that the use of various teaching media has resulted in a positive impact on the students' performance in schools and how the implementation of new technology and various audiovisual aids help students retain knowledge over a period of time, sometimes resulting in permanent learning. In light of the above discussion, the study was undertaken to find out whether the use of audiovisual and blended instruction is helping the students learn better and if these methods are introduced in government schools, will the functioning and outcome improve and create a platform for better learning and understanding for students in government schools.

23.6 Objectives of the Study

1. To develop blended learning strategy for teaching English at high school level
2. To develop audiovisual learning strategy for teaching English at high school level
3. To study the difference between the pre-test and the post-test scores of the treatment groups
4. To study the difference between audiovisual and blended teaching groups with regard to their performance
5. To study the difference between the audiovisual and blended teaching group with regard to their self-confidence
6. To find out if the audiovisual and blended teaching has affected the English performance of the students
7. To find out if the audiovisual and blended teaching has affected the self-confidence of the students
8. To find out the percentage enhancement in English performance of the students before and after the intervention in both the groups, namely, audiovisual teaching group and blended teaching group

23.7 Method of the Study

The study was a between-group design study which had two different groups undergoing two different interventions, namely, audiovisual teaching group and blended teaching group. The study was conducted in 12 steps.

Step 1: Selection of two pre-existing IX Standard groups in two government schools of Manipur.
Step 2: Equating the groups.
Step 3: Developing content modules based on the recommended English literature and grammar textbook by the Board of Secondary Education Manipur (BOSEM).
Step 4: Validation of the content modules.
Step 5: Preparation of pre-test and post-test based on the content selected from the recommended books.
Step 6: Validation of the pre-test and post-test.
Step 7: Pilot study of the modules and pre-test and post-test.
Step 8: Administering pre-test based on teaching module and self-confidence.
Steps 9: In order to avoid internal and external threats, students from two different schools were taken as the samples for the two different interventions.
Step 10: Intervention of the two groups using their respective treatments.
Step 11: Post-test based on teaching modules and self-confidence.
Step 12: A delayed post-test for both English performance and self-confidence was administered after 8 weeks.

23.8 Research Design

The research design employed in the present study was between-group experimental design; it is an experimental design in which the groups are assigned to different experiments and each group experiences only one of the experiments. This design is adopted when the researcher wants to make a comparison between two or more groups.

Pre-test, post-test, and delayed post-test of both the groups were administered. Both the groups were administered with the validated pre-test, and the results were recorded. Following the pre-test, both the groups' audiovisual group and blended group were taught through their respective treatments.

23.9 Variables of the Study

Dependent variables: Performance in English and self-confidence
Independent variable: Method of teaching

23.9.1 Sample

The sample of the study is comprised of 73 IX Standard students from 2 government schools in Manipur. The students were grouped into audiovisual teaching group and blended teaching group after equating the students based on the results in their VIII Standard final exam.

23.9.2 Tools of the Study

The tools used for the study are:

(a) The evaluative tools consisting of pre-test and post-test developed by the researcher.
(b) Two evaluative tools, namely, pre-test and post-test questionnaires, were developed by the researcher and validated by experts to measure the performance of students in English. In the initial stage, a pilot study was conducted on 68 students from IX Standard to analyze each item in the test based on item difficulty index and validity. A total of 40 questions were constructed for each pre-test and post-test, out of which 25 questions each were selected after carrying out item analysis.
(c) The facilitative tool with 12 modules each for audiovisual aids and blended teaching groups was used in the study. The teaching modules were designed according to audiovisual teaching and blended teaching based on IX Standard English Grammar and Literature book recommended by the Board of Secondary Education Manipur (BOSEM) and validated by experts in the field.
(d) Self-confidence inventory by Dr. Rekha Gupta (2013).

23.10 Statistical Analysis

(i) t-test
(ii) Percentage improvement calculation

The results of the pre-test, post-test, and delayed post-test were statistically compared and were analyzed using suitable statistical procedures. The succeeding statistical tools were utilized for analysis of the gathered data, mean, t-test, and percentage improvement test, to find out the difference in the improvement among audiovisual teaching group and blended teaching group.

23.11 Findings and Implications of the Study

The results of t-test analysis present a significant difference in the English performance of students before and after the intervention with respect to audiovisual instruction; hence, this indicates that the use of audiovisual aids in teaching has had a definite impact on the post-test scores of the students. Several studies have shown that the use of these resources in the teaching-learning process has a positive impact on the performance of students. Burrow (1986) stated that when used accurately, these aids enhance students' performance and grasp the attention of the students. Visual aids are useful in supporting the topic in question, and the combination of both audio and visual stimuli is predominantly efficient since the two of the most important senses are involved.

There is a significant difference in the English performance of students before and after the intervention with respect to blended instruction; hence, this indicates that blended teaching also had an impact on the post-test scores of the students. It means that the students have performed better due to blended teaching; this could be due to the simulation of multiple senses of the students since multimedia, pictures, and videoconferencing have been employed in blended teaching. Serin (2011) reports that technology-aided instructions have a constructive impact on students' performance as compared to face-to-face instructions with notes and rote learning. Students learned better with the help of ICT tools and showed a positive attitude and appreciation toward the integration of technology in the teaching-learning process. It was also reported that the integration of these tools in education made the topics more interesting and attractive; it helped the students learn the concepts with ease and enhanced the comprehension (Heemskerk et al. 2011).

Furthermore, based on the above findings, the schools, government departments of school education, and respective school management should develop guidelines for integrating various teaching aids and promoting computer-mediated teaching and learning. The integration of blended courses in the school education system, specifically in states like Manipur, can act as an agent for escalating the accessibility of education to all, as there is less access to schools in the hilly region of the state.

The result of the analysis indicates that there is a significant difference in self-confidence of students before and after the intervention with respect to audiovisual instruction; this indicates that the use of audiovisual aids in the teaching-learning process has had an effect on the self-confidence of the students. The use of these aids enables better classroom interactivity and exercises where students are exposed to different group as well as individual learning. According to Brown et al. (1985), students' confidence and personality are improved by the utilization of audiovisual aids as students are provided with the opportunity to visualize, express, and interact with their teachers and peers without fear and uncertainty. The use of these aids also caters to the different learning styles of the individual students by stimulating various senses.

Likewise, there is a significant difference in self-confidence of students before and after the intervention with respect to blended teaching. This indicates that blended teaching has had an impact on the post-test scores of the students with regard to self-confidence. Studies report that the use of technology in classroom gives students the opportunity to work on their own which enhances their judgment of themselves and helps them discover their capabilities. According to Sivin-Kachala and Bialo (2000), technology has a positive effect on student attitudes toward learning, self-confidence, and self-esteem. Similarly, Coley et al. (1997) reported that the use of technology has been found to improve attendance of students and decrease in the dropout rates with a constructive impact on students' confidence and feelings of responsibility for their own learning.

The t-test analysis of the delayed post-test indicates a significant difference in the delayed post-test scores of English performance between the two groups, i.e., audiovisual teaching group and blended teaching group. This indicates that integration of teaching aids and resources in school education helps the students retain knowledge even after a longer period of time. According to Dale's Cone of Experience, students retain most of what they have done and said, so the incorporation of these aids in teaching has resulted in students utilizing their skills and having hands-on experience on the matter.

Likewise, there is a significant difference in the delayed post-test scores of self-confidence between the two groups, and the t-test results show that the use of these aids also helps in enhancing self-confidence of the students. The reason being, in an audiovisual aids class, the teacher is always present in the classroom which enables the students to clarify doubts immediately and the teacher is able to give individualized attention to the students. Technology and multimedia cannot replace the role of a teacher, and it is only available to supplement the teaching of the teacher and to enable the teacher to teach effectively and efficiently.

A percentage improvement test indicates that there is a significant difference in the percentage improvement among audiovisual and blended teaching. The result indicated that the difference in improvement between audiovisual and blended teaching is 24.39%, therefore signifying that the use of audiovisual aids helps the students better in terms of English performance in school level.

Based on the information of the analyzed data, the study conclusively presents that not only teaching through audiovisual aids and blended teaching has succeeded in bringing on an impact on the performance of English literature and grammar among IX Standard students but also shows that the usefulness of the resources and the learning from the sessions has sustained over a time period, with audiovisual instruction having an edge over blended teaching. The study also reports that there was an impact on the self-confidence of the students through the use of teaching resources.

23.12 Conclusion

The findings of the study indicated that overall use of audiovisual aids and blended teaching technology based on the interventions has a positive impact on the performance of students in English literature and grammar. Educational materials enable students to progress with words, pictures, and ideas in ways which develop their skills in listening, reading, reviewing, thinking, speaking, and writing and utilization of technology and media (George 2002). It further has an impact on the self-confidence of the students in IX Standard. The findings of the study show that the proper use of teaching aids in government schools can help students perform better in schools and help in improving their self-confidence. The students not only perform better in examinations but help them build their self-concept and confidence since they are exposed to classroom interactions and hands-on experience on the topic being taught in the classroom. Since more than one sense is used to grasp the knowledge disseminated through the teaching and learning process supplemented by audiovisual resources, it has been reported that students retain more when taught with the use of these aids because they are exposed not only to verbal instruction but also to visual and hands-on experiences, for instance, pictures, charts, models, crafts, etc. It helps both the students and the teachers to create a more interactive environment where the students can share their knowledge in front of their peers. These aids also help in building a strong foundation in terms of knowledge for the students as their doubts are cleared on spot using pictures and models inside the classroom. Instructional aids can be used for creating individualized learning by bringing in different types of aids to cater to individual differences among the students. It has also been reported that students are more interested and can concentrate better with the use of these resources compared to the traditional method of instruction.

The integration of teaching aids, technology, and learning is essential. The incorporation of videos in teaching language improves genuine language input to the students. Several studies revealed that these aids can be used for constructing individualized learning by bringing in different types of aids to cater to individual differences among the students (Cakir 2006). There is no doubt that the teaching aids engage and motivate the students; however, this assistance is only advantageous for learning if the use of these aids is efficiently aligned with the concept and what is to be learned in the classroom. The intervention on the use of audiovisual aids and blended teaching has no impact on gender. The research evidence over the years about the impact of teaching aids and integration of computer and digital technologies on teaching and learning process constantly reports positive benefits. The growing range of teaching aids and online modules and the range of contexts and settings researches have been conducted on shows that knowledge dissemination is much effective and efficient through proper utilization of these aids. The findings show that among the two methods, the use of audiovisual aids shows better improvement among the students than blended teaching. The difference in the improvement percentage of the audiovisual aids and blended teaching is 24.39%, with audiovisual aids teaching showing more improvement. The use of teaching aids helps the teachers to give more time for individualized attention to the students who are comparatively low in performance in the classroom. The teachers can use these teaching aids to further make the learning of the students more permanent and help in conceptualizing abstract ideas through visual and audio representation of the lessons. As a result, it has become one of the most important tools for the teachers to disseminate knowledge.

References

ADEA Newsletter. (2005). ADEA Newsletter Vol.17 No. 2, *Theme: Education and languages*.

Agnihotri, R. (1985). *Effects of sub-culture affiliation and sex on self-confidence*. International Seminar on Cross Culture Perspectives on Problems of National Relevance, Aligarh Muslim University, Uttar Pradesh

Arung, F. (2016). Language acquisition and learning on children. *Journal of English and Education, 1*, 1–9.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191–215.

Basavanna. (1975). *Manual for self-confidence inventory*. Varanasi: Rupa Psychological Centre.

Bénabou, R., & Tirole, J. (2002). Self-confidence and personal motivation. *The Quarterly Journal of Economics, 117*(3), 871–915. https://doi.org/10.1162/003355302760193913.

Bielawski, L., & Metcalf, D. (2003). *Blended e-learning: Integrating knowledge, performance support, and online learning*. Amherst: HRD Press.

Bonk, C. J., & Graham, C. R. (2005). *Handbook of blended learning: Global perspectives, local designs*. San Francisco: Pfeiffer Publishing.

Bonwell, C. C., & Eison, J. A. (1991). *Active learning: Creating excitement in the classroom*. ASHE-ERIC Higher Education Report No. 1. Washington, DC: George Washington University, USA

Brown, J., Lewis, R., & Harcleroad, F. (1985). *AV instruction technology, media and methods* (6th ed., pp. 112–113). New-York: McGraw-Hill. 118−119.

Burrow, T. (1986). *Horizons in human geography*. London: Macmillan.

Burton, W. H. (2013). *The guidance of learning activities* (2nd ed., p. 729). Appleton-Century-Crofts, Inc..

Cakir, D. I. (2006). The use of video as an audio-visual material in foreign language teaching classroom. *The Turkish Online Journal of Educational Technology, 5*(4), 67–72. Retrieved from http://www.tojet.net/articles/v5i4/549.pdf.

Cheng, H., & Furnham, A. (2002). Personality, peer relations, and self confidence as predictors of happiness and loneliness. *Journal of Adolescence, 25*(3), 327–339. https://doi.org/10.1006/jado.2002.0475.

Coley, R., Cradler, J., & Engel, P. (1997). *Computers and classrooms: The status of technology in U.S. schools (Educational Testing Service Policy Information Report)*. Retrieved from ftp://ftp.ets.org/pub/res/compclss.pdf

CRTC. (2014). *CRTC issues annual report on the state of the Canadian communication system*. Archived from the original on 2014-02-27.

DeBernardes, A., & Olsen, E. G. (1948). Audio-visual and community materials – some recent publications. *Education Leadership, Advances in Computer Science Research 59*, 256–266.

Doering, A., & Veletsianos, G. (2008). Hybrid online education: Identifying integration models using adventure learning. *Journal of Research on Technology in Education, 41*, 101–119.

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*, 363–406.

Garzon, S. P. (2012). *Impact of the audio-visual aids in the teaching learning process at the technical university of Cotopaxi during the academic period March-July 2012*. Latacuga, Ecuador.

George, J. F. (2002). Influences on the intent to make internet purchases. *Internet Research, 12*(2), 165–180.

Gupta, R. (2013). *Agnihotri's self- confidence inventory (ASCI)*. Prasad Psycho Corporation. New Delhi

Harcleroad, F. F. (1985). *An instruction; technology, Media and Methods* (6th ed.). New York: MCGraw Hill Book Company.

Harter, S. (1978). Effectance motivation reconsidered. *Human Development, 21*, 34–64.

Heemskerk, I., Volman, M., ten Dam, G., & Admiraal, W. (2011). Social scripts in educational technology and inclusiveness in classroom practice. *Teachers and Teaching: Theory and Practice, 17*(1), 35–50.

Heinze, A., & Procter, C. (2004). *Reflections on the use of blended learning: Education in a changing environment*. Conference Proceedings University of Salford, Education Development Unit.

Jain, P. (2004). *Educational technology*. Delhi: Moujpur Publication.

Kemp, N., & Grieve, R. (2014). Face-to-face or face-to-screen? Undergraduates' opinions and test performance in classroom vs. online learning. *Educational Psychology, 5*, 1278. https://doi.org/10.3389/fpsyg.2014.01278. PMC 4228829.

Kuhl, J. (1992). A theory of self-regulation: Action versus state orientation, self-discrimination, and some applications. *The International Association of Applied Psychology*. Vol. 41, Issue 2. https://doi.org/10.1111/j.1464-0597.1992.tb00688.x.

Kyei-Blankson, L., & Ntuli, E. (2013). *Practical applications and experiences in K-20 blended learning environments*. Hershey: Information Science Reference.

Lave, J. (1988). *Cognition in practice: Mind, mathematics, and culture in everyday life*. Cambridge: Cambridge University Press.

Malekela, G. (2003). English as a medium of instruction in post-primary education in Tanzania: Is it a fair policy to the learners'. In B. Brock-Utne, Z. Desai, & M. Qorro (Eds.), *Language of instruction in Tanzania and South Africa, (LOITASA)*. Dar es Salaam: E&D Limited.

Mangal, S. (2008). *Teaching of social studies* (pp. 187–189). New Delhi: PHI Learning Private Limited. 207, 226−227.

Mishra, S. K., & Yadav, B. (2004). Audio-visual aids & the secondary school teaching. *Global Journal of Human-Social Science, 14*(1). 15–24.

Nasab, M. Z., Esmaeili, R., & Sarem, H. N. (2015). The use of teaching aids and their positive impact on student learning elementary school. *International Academic Institute for Science and Technology, 2*(11), 22–27.

Nicholls, J. G. (1984). Achievement motivation: Conceptions of ability, subjective experience, task choice, and performance. *Psychological Review, 91*(3), 328–346. https://doi.org/10.1037/0033-295X.91.3.328.

Ode, E. (2014). Impact of audio-visual resources on teaching and learning in some selected private secondary schools in Makurdi. *International Journal of Research in Humanities, Arts and Literature, 2*(5), 195–202.

Pajares, F., & Johnson, M. J. (1996). Self-efficacy beliefs and the writing performance of entering high school students. *Psychology in the Schools, 33*(2), 163–175. https://doi.org/10.1002/(SICI)1520-6807(199604)33:23.0.CO;2-C. ISSN 1520-6807.

Parkes, S., Zaka, P., & Davis, N. (2011). The first blended or hybrid online course in a New Zealand secondary school: A case study. *Computers in New Zealand Schools: Learning, Teaching, Technology, 23*(1), 1–30.

Ringstaff, C., & Kelley, L. (2002). *The learning return on our technology investment*. Retrieved from West Ed: http://www.wested.org/cs/we/view/rs/619

Roy-Campbell, Z. M., & Qorro, M. A. S. (1997). *Language crisis in Tanzania: The myth of english versus education*. Dar es Salaam: Mkuki na Nyota.

Saritepeci, M. et al. (2015). The effect of blended learning environments on student motivation and student engagement: A study on social studies course. *Education and Science*.

Serin, O. (2011). The effects of the computer- based instruction on the achievement and problem solving skills of the science and technology students. *The Turkish Online Journal of Educational Technology, 10(1), 183–201. Retrieved from* http://eric.ed.gov/PDFS/EJ926568.pdf

Sivin-Kachala, J., & Bialo, E. R. (2000). *Research report on the effectiveness of technology in schools*. Washington, DC: Software and Information Industry Association.

Swank, R. C. (2011). *The educational function of university library*. http://www.ideals.illinois.edu/bitestream/handle/2142/5455/librarytrend

Swann, W. B., Jr. (1983). Self-verification: Bringing social reality into harmony with the self. In J. Suls & A. G. Greenwald (Eds.), *Psychological perspectives on the self* (pp. 33–66). Hillsdale: Erlbaum.

Thoits, P. A. (1994). Stressors and problem solving: The individual as psychological activist. *Journal of Health and Social Behavior, 35*, 143–159. https://doi.org/10.2307/2137362.

TNTP. (2014). *Reimaging teaching in a blended classroom*. http://tntp.org/assets/documents/TNTP_Blended_Learning_WorkingPaper_2014.pdf

Unified District Information System for Education. (2016). Available at: http://www.edudel.nic.in

Yorio, C. (1987). Building multiple bridges: Eclecticism in language teaching. TESL Canada *Journal, 5(1), 91–100.*

Zameer, A. (2010). Virtual education system: Current myth & future reality in Pakistan. *Informing Science and Information Technology, 7*(1).

Zimmerman, B. J., & Kitsantas, A. (2005). Homework practices and academic achievement: The mediating role of self-efficacy and perceived responsibility beliefs. *Contemporary Educational Psychology, 30*(4), 397–417.

Ziyabaat, B. (2013). The effectiveness of mixed learning method on first graders' achievement of teaching methodology and their attitude towards it at the Tafila Technical University. *Najah University Journal of Research (Humanities)*, *27*(1), 181–200.

Zusho, A., Pintrich, P. R., & Coppola, B. (2003). Skill and will: The role of motivation and cognition in the learning of college chemistry. *International Journal of Science Education, 25*(9), 10811094. https://doi.org/10.1080/0950069032000052207. ISSN 0950-0693.

Chapter 24
Adopting Evolving Technologies to Aid Cognitive Abilities in Classroom Learning-Teaching

Shanthi Rajan, G. V. Bindu, and Shibaji Mukherjee

24.1 Introduction

Tools are extensions of the human mind. Throughout history, human beings have developed mechanical tools such as levers and wheels to facilitate physical and mechanical work. The revolution in electronic and information technology accelerated these advantages in terms of speed and accuracy. Computers now perform task at speeds and scales which hugely surpasses what human mind can do. From a modest beginning of a calculating machine at the start of the century to computers have covered a huge distance, and now we are in the world of supercomputers and quantum computers which are churning out results, analysing workflows at an astonishing and mind-boggling speed and volume. Adopting computer-based tools in classrooms has greatly extended our learning and teaching experiences and assisted in widening the cognitive abilities.

24.2 Cognitive Tools and Learning

24.2.1 Cognitive Tools

Derry (1990) describes cognitive tools as both intellectual and technological aids that anchor, direct, and facilitate the thinking abilities of respective utilizers. A cognitive tool is a sort of machine learning strategy to analyse complex data in an efficient manner. It is widely used in day-to-day IT applications and encourages

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students to use their own learning perceptions to interact with computer-based education.

Further, these tools are used to foster meaningful information processing among its users. These tools help in constructing knowledge and can be applied to various other domains of knowledge. These cognitive tools include specifically designed knowledge building tools, such as semantic networking tools and microworlds for moderating learning processors (Jonassen 1992).

24.2.2 *Cognitive Learning*

Figure 24.1 illustrates the cognitive model of learning.

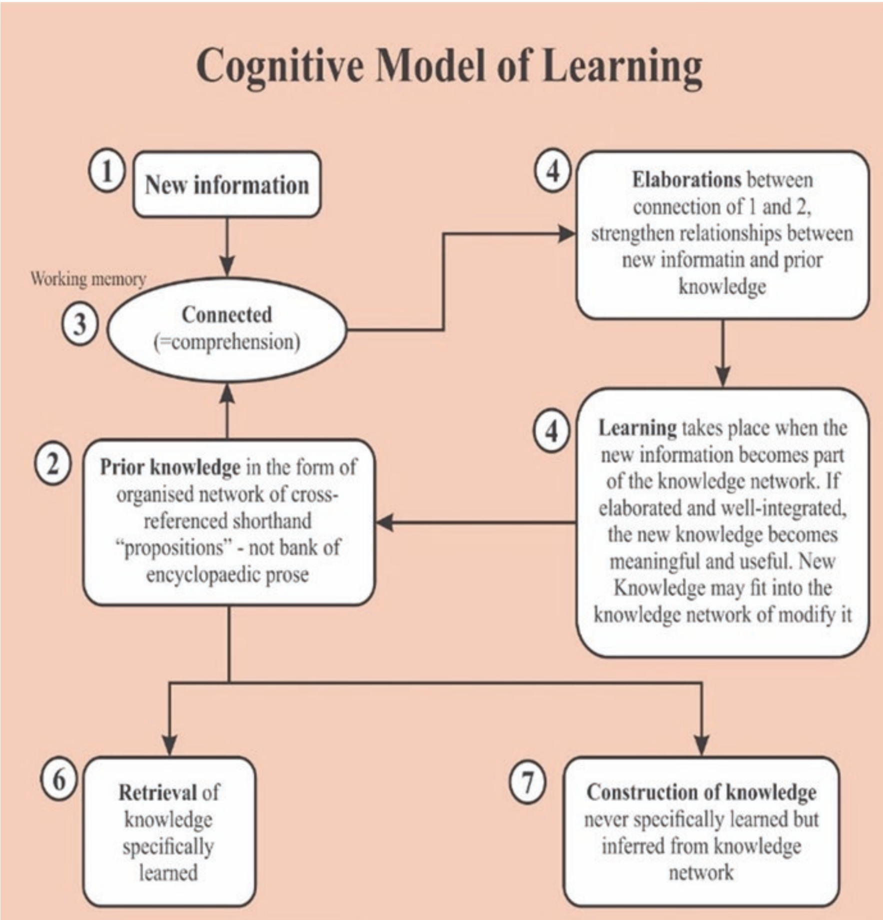

Fig. 24.1 Cognitive model of learning (Derry 1990, pp. 347–379)

Researchers have noted that various means of online education – interacting with content, with instructors, and among peers – scaffold the learning process and are adaptable to various environments of online learning. Diverse ways of presenting course content; frequent opportunities to learn actively; choice in manner of approaching and taking on course objectives; guidance and support from the instructor; various exercises; hands-on problems; bespoke control of learning; testing and feedback; and help screens. These are some of the concepts that are part and parcel of computer-based and online learning.

Online education may support specific ways of acquiring knowledge. On the one hand, a few researchers are trying to mimic traditional learning in the context of online education (which is less likely to lead to optimal results); on the other hand, there is a significant paradigm shift seen in the switch to online education as seen in the research done on faculty perceptions of student learning. Research by Dobrin (1999), for example, found that 85% of faculty who taught online courses reported their students' performance was similar to, or better than, what they found in brick-and-mortar classrooms. Early research on asynchronous online learning has demonstrated that students' ability to learn is determined by the structure and overall transparent communication of the material.

It is without a doubt that education is a good indicator of the quality of human life and success. Owing to this, factors, such as learners' interaction with their course content, student-teacher interactions, student-student interaction, and student-content interaction, have been the target of much research in the context of online learning.

Hilman et al. (1994), in relation to the concept of learners' interaction pertaining to distance education, found that new emerging technologies had temporarily created an additional type of interaction: learner-interface interaction. This is defined as the interaction between the student and the technology used in the implementation of the distance education process; in other words, it is the leaner-interface interaction. In this context, interface refers to the online medium through which a student interacts with their peers, instructors, and course content. One's use of the interface can either enhance or constrain the quantity and quality of the interactions. Therefore, it is necessary for interfaces to be appropriately designed in order to clarify knowledge structure or build knowledge through scaffolding.

One such example is at the University of Illinois Virtual Campus (IVC). Various resources welcome the student to the course material, such as a "Getting Started" orientation to the IVC interface, tips for academic success, career counselling, and other resources to enhance distance learning experience. Additionally, there are 40 IVC student support centres across the state that face-to-face, phone, and email support to students who wish to have a personal interaction. The vast availability and access to these services indicate the need to assist students in honing effective mental models of course interfaces with the notion of online interactions.

A promising area of investigation is the linking of learning concepts to things that go beyond the online class setting. In fact, various scholars believe that associating what we learn to the real world helps us develop thinking ideas beyond our thinking capabilities. There are, however, innovative studies that have delved into particular cognitive skills, hinting at certain affordances and constraint with online learning.

24.2.3 Cognitive Computing

Computer-based cognitive tools have been defined as intellectual partners in the learning process. They facilitate, engage, and augment the learning and teaching environment through a process principally based on cognitive psychology and cognitive computing. In recent decades, computers have moved from routine data-based learning to semantic learning which introduces knowledge-based inferences in the learning process. The recent advances are closely coupled with the huge progresses that have happened in artificial intelligence, expert systems, deep learning, and semantic learning.

We will give a very brief introduction to cognitive computing before we go into our main topic of cognitive tools and cognitive learning.

Cognitive computing is a complex subject based on sophisticated mathematics and algorithms which tries to model the thinking process taking the human brain as the model. Our brain is an extremely complex cognitive computing unit which has hardly been understood. However, at the very basic level, we model the system as a neural network.

A neural network can be very simple defined as a computing unit which takes in multiple inputs, applies various filtering, weights, and calculates a probable output. The main factor that differentiates it from a routine computing unit is that it learns the probable outcomes from known cases or behaviour patterns that is hidden in the input set and continuously feeds back its intermediate output into its intermediate states and refines the learning outcome in multiple layers and stages to come up with predictions which have the least error in terms of the expected result. This generates unknown patterns and meaning and introduces semantics into routine data analysis, and this is the fundamental departure from traditional data processing. Cognitive tools are utilities based on this power of semantics and work collaboratively with a human thinker to produce results which enrich our thinking and learning process.

24.2.4 Teaching the New Generational Paradigm

Public schools tend to place strict restrictions on Internet use. The intention for this, although good, however fails to bridge the gaps between Millennial experience and the world of technology (Considine et al. 2009). As far as an education crisis is concerned, what needs to be addressed is the average student perception that school is unnecessary and fuels boredom (Prensky 2008). Millennials, being different from the generations before, think differently than boomer generation. Hence, Millennials crave interaction and highly value collaborating with their peers. With the various audio/video chat platforms out there, communication among peers has never been easier, and access to a wide range of learning options and education services offered by universities and colleges (Koeller 2012). Technologies like Kindles and iPads, and the applications therein, offer another world of laying down instructions – a strategy necessary to have students value learning. What also needs to be considered is the deteriorated attention span among Millennials, which can be strengthened by tools and the diverse ways they can present course material. The only caveat is that these tools do not provide an opportunity for their users to reflect on the plethora of information they are exposed to (Koeller 2012). Hence, there is a need to use these technologies in conjunction with traditional teaching methods.

Regarding practical application, today's technology, with its various methods of presenting content, could help design a well-organized and efficacious learning environment, curriculums, and experiences that could intensify the learning experience. In today's environment, teachers assume that students have the basic knowledge and skills needed to use advanced technology. Therefore, learning and teaching at its best is a collaborative effort between students and teachers (Tomei 2005). Technology use must scaffold upon the previous versions of Bloom's taxonomy, not overpower it.

24.3 Bloom's Taxonomy in the Context of Online Learning

Bloom's taxonomy was introduced in 1956 under the leadership of psychologist Dr. Benjamin Bloom, and the taxonomy for the cognitive domain was revised in 2000. Bloom's taxonomy refers to promoting higher forms of thinking in education such as analysing and evaluating, rather than remembering facts, meaning that it is one of the classification systems used to expound and differentiate between the various different levels of human cognition – thinking, learning, and understanding. This assists in obtaining quantifiable results in student outcome, which further helps in creating the necessary classroom assessment techniques for the class.

Bloom's taxonomy was revised and updated to keep up with the new generations of technology-driven students. Andrew Churches (2009) came up with Bloom's digital taxonomy to create a podium to apply technology in the classroom setting. Many online and distance education programmes have adopted Bloom's digital taxonomy as a cognitive tool to evaluate students' learning process enhanced by technology. Over the years, a number of changes were made to two-dimensional framework of Bloom's taxonomy addressing the knowledge and cognitive processes (Krathwohl 2002).

Nowadays, many changes are found in the use of languages. In the past decades, the emergence of new technological verbs such as googling to describe the communication tools has become apparent on various websites. Technology's main intention is to serve as an instructional material for teachers to facilitate the learning process. According to Sir Ken Robinson, "Education is not only a preparation for

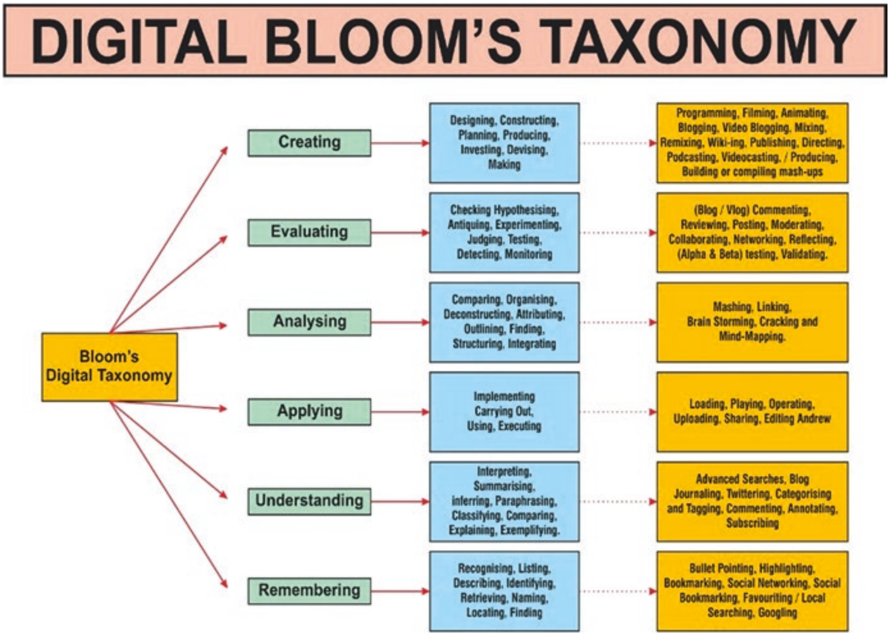

Fig. 24.2 Bloom's digital taxonomy (Churches 2009)

future but it is also about helping individuals engage with the current scenarios" (Robinson 2011).

Figure 24.2 represents Bloom's digital taxonomy.

24.4 Evolving Information and Communications Technologies as Cognitive Tools for Learning and Teaching

Evolving technologies are becoming increasingly important in the learning environment. Academicians have done extensive research on cognitive improvement with the development and application of new technologies in the educational field.

In higher education sector, use of mobile technologies is continuously increasing even though it is not widely accepted by the faculties and institutions. Especially countries where laptop and other computer devices are not affordable to many. Although evolving technology is a boon to teachers, it also poses challenges of accommodating successfully in the teaching and learning environment. It is necessary to have a pedagogical framework that integrates technology as cognitive tools in the context of a genuine learning environment. Supporting student learning by means of web technologies and analysing their progress necessitates this pedagogical framework. Well-planned learning, with the support of evolving technologies, can aid students in becoming more self-directed learners. Technology can simplify the complex learning process when designed and implemented successfully in a learning environment. Evolving technologies serve as important cognitive tools for learners and teachers.

One way students can be made responsible for their learning is through the process of scaffolding during a vital task, as opposed to directly instructing them on less vital activities. Surprisingly, however, student-centred learning environments, although they have garnered recent attention, tend to put a cognitive burden on the learner. Recent research shows that scaffolding student-centred learning can be done by cognitive tools in such environments. Major research work has been done to design and apply cognitive tools in these environments.

Figure 24.3 illustrates a conceptual framework with functional cognitive tool classifications (seeking and presentation of information, organization, integration, and generation of knowledge.

Assimilating the evolving technologies into the instructional design is the biggest challenge which can alienate the cohort of learners; a number of them required training to use these technologies, while others face a disconnect with these technologies owing to not using them in their day-to-day life. That being said, the personal use of mobile technologies, despite the skills of various levels of learners, is rising due to trends in social networking and opportunities in web publishing (Edmunds et al. 2012). This has the potential to effectively train a generation of learners to use new technology in education and has a synergy with the cognitive comprehension and emerging technology adoption. Success lies in this much needed integration and synergy.

It is increasingly imperative to initiate the engagement of evolving technologies in teacher education in preparation for a future of classrooms with autonomous learners who seek engagement, connectivity, and relevance (McLoughlin and Lee 2010). (MacDonald (2009)) It is negligent to presume that novice teachers will have information and communication knowledge when they start their teaching career; rather, focus on well-programmed training to assimilate and familiarize the teachers with evolving technologies in education, so that teachers feel comfortable to use the technologies in classroom setting effectively. Additionally, the author noted that inexperienced teachers were willing and more comfortable with using technologies in their classrooms but also desired formal support in training with pedagogical uses of ICTs.

As per the research, it is pertinent to provide the training on how to use the available technologies to the novices in the teaching arena, rather than assuming that they will learn on their own. It is also too risky to assume the inexperienced teachers seldom use available technologies in the classrooms. It is found that inexperienced teachers more often use ICTs in the classroom settings. However, that being said, it's important to train them and provide formalize support in learning on pedagogical uses of ICTs.

The authors Herrington and Parker (2013) investigated the use of evolving technologies as cognitive tools as problem-solving tools within a genuine academic setting. This study investigated on three main areas. The author used design-based

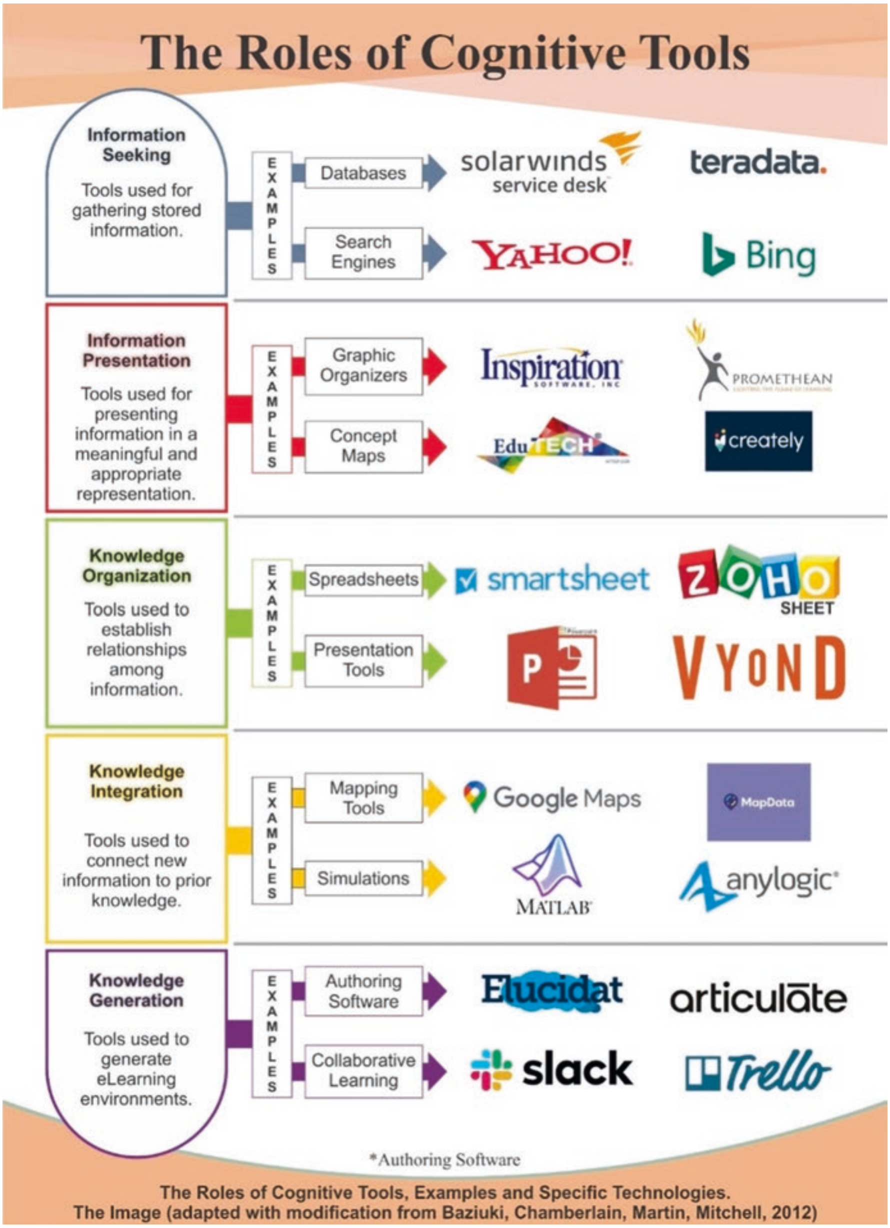

Fig. 24.3 Five roles of cognitive tools with specific examples. (Adapted from Bazluki et al. 2012)

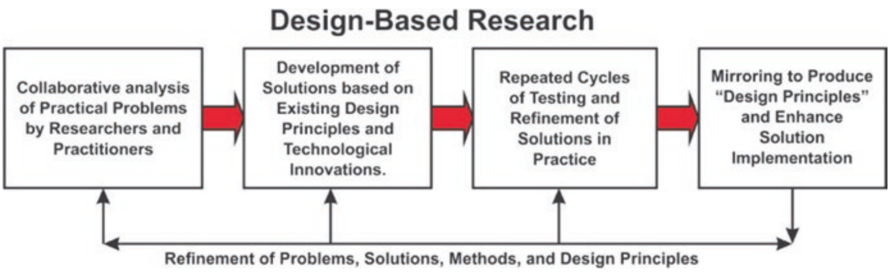

Fig. 24.4 Design-based research. (Diagram adapted from Reeves 2006)

research approach to probe the use of evolving technologies as a cognitive tool in academic setting. This study comprises of four broad repeated phases, as illustrated in Fig. 24.3 (Reeves 2006) (Fig. 24.4).

The initial phase of the study included an exploration of the problem and a literature review followed up with consultation with practitioners to explore the nature and extent of the problem of emerging technologies and their effective use in teacher education. The next phase was the solution design phase, where the students created genuine product using a variety of cognitive tools as a purpose of designing and learning. In the third phase, the designed product was tested on a target population. Investigators collected the data through surveys, discussion forums, email correspondence, transcripts of chats and discussion forums, blogs, websites, examination transcripts, etc. The researchers also collected the qualitative data through open-ended survey questions. In the fourth phase, design principles were compared with the data based on the learning experience with the target population, and the model is improved accordingly.

The unit inspired students to engage in self-regulated learning, adapt in researching, collaborate, and reflect on their learnings and adaptations to the dynamic ICT scene in schools and societies. After the completion of the general research, students were asked to write an academic essay on their findings, with the aid of bibliography referencing tools (like EndNote). Students published their works onto an online platform which allowed them to put in their collaborative efforts more easily. The study revealed a range of student attitudes towards their approach to technology ranging from eagerness and confidence to more antagonistic and gloomy responses going as far as fear of technology (Beckers et al. 2008).

Research revealed that some students felt extremely comfortable and confident using technologies as compared to others. Many students also expressed fear of lack of understanding of technologies. Students also showed aversion using mobile devices as pedagogical tools as it is banned in many schools. Some students felt uncomfortable as they saw paying huge tuition fee is waste if they have to learn by themselves. They should be taught in the classroom rather than self-learning. Few other students felt that they need more direct instructions so that they don't have to spend hours researching content. In conclusion, the analysis of qualitative data revealed use of cognitive tools, evolving technologies, makes students take responsibility and become independent learners than directed learners and helped in getting better score in the experiment.

24.4.1 Language Proficiency and Communication Skill Improvement via Technology-Enhanced Blended Classroom in Socio-economically Deprived Students: A Case Study

Implementing effective technology in a classroom setting to enhance student learning is a challenge, especially in socio-economically disadvantaged schools in developing countries. Children born in this technological era are more exposed to technology and digital media than previous generations. Hence, it is important to understand and consider how differently young children learn and communicate and how to implement the newest technological tools in a classroom setting.

These exposures of children from low-income families to technology are more critical considering the significant discrepancies in their socio-economic status and limited exposure and experience in using technology and digital media for learning.

All children in our case study had lower socio-economic status, and most of them had more disadvantages due to this status and did not have access to computers or the Internet at home or educated parents to guide them. Parents engaged less and less with their children's education due to low socio-economic status as well as due to the level of their education, because of their work schedules, limited financial resources, unfamiliarity with the education system, language barrier, and different cultural values. Self-confidence and self-regulation are core attributes we wanted to develop in these students along with effective communication skill improvement in English language.

Our main goal in using technology-enhanced classroom and digital content along with a blended learning module into the classroom was to increase students' engagement while working independently to achieve meaningful and responsible learning strategies.

St. Francis Xavier Higher Primary School is a Kannada-medium school, located at Chikka Kammanahalli, Bengaluru, India. Most students who come to this school are from low socio-economic backgrounds. Students at this school lack basic communication skills in English; as a result, when they move on to an English-medium high school, they have a very hard time in understanding the curriculum as well as communicating with teachers and with each other. They lag behind in their academics due to the fact they cannot understand much in English. Therefore, VESS Educational Services stepped in to help the students. VESS Educational Services conducted English language proficiency and communication skill courses for students from the first to tenth grades during the academic year 08/2019–03/2020, for a period of 8 months, twice a week, with each class lasting up to 45 min. VESS Educational Services offered English language proficiency and communication skill course A blended learning module with online content to 900 students ranging from the first standard to tenth grades.

We installed technology-enhanced classrooms/AV (audio-visual-equipped) rooms or utilized computed labs and installed network connections. Each class comprised an average of 40 students. The course was conducted over a period of 8 months, twice a week, with each class lasting up to 45 min. Initial pre-test was administered to measure reading, writing, listening speaking, and presentation skills. Over the period of 8 months, we used VESS online content blended with classroom teachers. The content was designed specially to enhance reading writing, speaking, and listening abilities and to build the confidence to communicate in English. Students were encouraged with role-plays, individual presentation, writing script, and group plays and group presentations. The online content was enriched with audio-visual interactive-type learning, reflective learning, and movie reviews, and scenario-based learning, technology-enhanced nonverbal communication skills, exercises, and tests were administered periodically to measure the improvement. At the end of the course, post-test was administered. The table shows pre-test and post-test results for the first to tenth grades by the end of eighth month.

Use of technology can transform the way the teaching and learning is done. Although computers have become the most important technological tools in most educational settings, there are still many problems with successful implementation of technology. One such problem is lack of training to teachers, availability of resources needed to effectively implement these technologies, lack of access to computers, supporting services and software and Internet connection are the main problems in rural as well as socio-economically disadvantaged schools. Obviously, without the correct amount of resources, it would be difficult for educators to effectively implement the technologies within the pedagogy. It is essential to equip teachers and schools with the right kind of technology both software and hardware needed to achieve their technological and instructional goals along with transmission of information and communications technology which is Internet connection. In developing countries, it is hard to have a good Internet connection without interruption. The ongoing technical support and administrative support are required to manage the technology. Above all teachers who also come from low socio-economic background need to be provided with ongoing training on use of technological tools. Finally, we believe that using an effective, technology-enhanced curriculum will foster low-income children's interest in learning.

24.5 Improvement in English Language Proficiency and Communication Skill After Using

24.5.1 Technology-Enhanced Content (Table 24.1)

24.6 Use of ICT in Higher Education

Cortese (2003) commented that it's unthinkable to deliver the quality teaching-learning in higher education without assimilating information and communications technology (ICT).

University professors considering the contributions of ICT to honing the learning abilities and skills of their students is one way to approach this challenge. The perception about using the information and communications technology is another factor that will limit how they make use of available cognitive and ICT tools in the classroom. A group of researchers designed a quantitative research in which 345 university professors from various departments of a Spanish university participated.

The results demonstrated that the professors recognized not only the potential of the ICTs but the positive effects they have on learning and developing important skills for the twenty-first century. The effects were observed in fields such as critical thinking, collaboration, communication, and other teaching and learning skills. Karamti (2016) notes that ICT has had a greater impact in the field of education, especially higher education. Cortese (2003) notes that the digital transformation of different universities opens new learning environments and the capability of

Table 24.1 Case study on technology-enhanced learning in socio-economically disadvantaged schools

Grade	Assessment areas	Pre-test (average)	Score in percentage	Post- test (average)	Score in percentage	Boost in self-confidence level
1st to 10th	Reading, writing, listening, speaking, and presentation skills	% of students		% of students		No confidence, low, medium, and high
		10% of students	Above 80%	30% of students	Above 80%	Medium to high
		30% of students	Above 50%	50% of students	Above 50%	Low to medium
		60% of students	Below 50%	20% of students	Below 50%	No confidence to noticeable increase in the confidence

professors to provide students with necessary knowledge and skills for life. However, the expectations around the impact of ICTs in the field of education have been less than satisfactory; in fact, it has not been as effective as predicted (Sahito and Vaisanen 2017). The inefficiency of ICTs is to be put on the shoulders of professors and their attitudes towards using them in the academic setting (Cubeles and Riu 2018).

One particularly important thing to consider is the training level of teachers in various organizations. It has been found that the digital skill profile of teachers varies widely from departments to departments and university to university. There are people at both end of the spectrum with a uniform distribution throughout. However, the challenge is that particularly the finding is more skewed towards a lack of experience and skill than a noted expertise. The problem is that the teachers are in general familiar with computers, but effectively using them and the broader set of tools to make education delivery more effective is highly lacking. The developed world is obviously much ahead in this, but as the economy, infrastructure, and investment vary highly across the globe, a uniform result is an impossibility to achieve. However, that shouldn't stop us from appreciating the fact that ICT is a part and parcel of education and integrating education and technology along with cognitive tools is a fundamental requirement in this changed world. Area-Moreira et al. (2016) found out in one case study that often professors have been maintaining a conventional type of educational culture with limited use of ICTs in most areas. The potential offered by ICTs is enormous, and from a practical point of view, it is important to understand that the acquiring and implementing of ICT skills in higher education is paramount, which permits adopting of technology science and innovation into higher education. However, the hurdles in the process are very clear, it's definite that we should adopt ICT in teaching and learning, but finding out a resolution for all the issues that are hindering this effort is not easy, and it will require a combined effort of the government, scientist, educationist, teachers, students, and the society (Gudmundsdottir and Hatlevic (2018). It is certain that to achieve the most optimal digital skills such as strategies and knowledge, capabilities, and attitudes, it is extremely important to train the professors in higher education setting (Spante et al. 2018). As pointed out by Shum and Crick (2012), developed nations are way ahead in this, and they have successfully integrated ICT in their teaching and learning process. The other nations have to learn from their experience and mistakes and seriously take up the process of this integration as early as possible. Higher education institutions are in a transformation process in learning-teaching processes, so students could obtain enough skills and abilities to function well in an uncertain and complex society. The twenty-first-century skills such as "critical thinking", "collaboration", and "creativity and imagination" are more important than ever for continued and successful integration into the mainstream society. Digital tools guarantying to provide these skills on an inclusive and equal access to education approach.

It is acknowledged and noted that more significant learning value is associated with integration of ICT in academic process (Jääskelä et al. 2017). However, as discussed earlier, this integration has not been welcomed very much by the academic community in all parts of the globe. Many professors are reluctant to use technological and cognitive tools in profession task. Main reason could be the lack of adequate training finical burden require these advance tools and fear of technology. Due to this reason, university professors have a hard time integrating ICT tools in their academic practice which in turn hinders the professional success of their students.

A study done by Bas et al. (2016) and Pandolfini (2016) tries to find out how university professors think about assimilating ICTs in everyday classroom teaching and the contribution of ICTs towards the development of knowledge skill set that is required for the twenty-first-century workforce. A prominent finding of this study is that the use of ICTs in university classroom setting has the greater possibility of enriching creativity critical thinking analytical evaluation and interpersonal skills; it also promotes collaborative learning in an educational setting. In conclusion, all the studies do suggest that integration of ICT in the teaching-learning process is mostly beneficial and has a huge impact to offer. There are issues in doing a tight integration, but we have to try to go towards that goal, and only time will tell how successful we will be.

24.7 Artificial Intelligence (AI) as a Cognitive Tool

Artificial intelligence (AI) has been successfully used as a cognitive tool in higher education settings. Robotics is one such field where AI is extensively used. Using robotics as a cognitive tool in the educational realm makes it an excellent tool for learning and decision-making.

Owing to the developments, Alimisis (2013) and Xia and Zhong (2018) reported that robotics has gained importance in the education field as a cognitive tool. Most of the modern education institutions have shown interest in implementing robotics as an evolving technological tool. The robotics has the potential to change both higher education and K-12. Robotics has taken educational technology to new level mostly in science and technological courses including it constantly evolving hardware and software tools have further augmented the curiosity and necessity to adopt emerging AI-aided technologies. Considering the applications of AI and robotics in science and technology, for example, space exploration and medical sciences, it is crucial to assimilate robotics STEM (science, technology, engineering, and mathematics) (Lindsay 2020; Zhong and Xia 2020). Robotics has paved a path for developing optimal tools in autistic students for kids who often find communicating with other students or people intimidating and confusing as compared other students who can pick up verbal and nonverbal cues easily. Scientists have developed a robot called NAO robot which has been shown to help kids with autism to learn social and communication cues as well as different educational lessons.

According to Eguchi (2012), implementing robotics education in learning environment is entertaining and attractive as it provides the hands-on training and it also stimulates students' cognitive skills and curiosity. Author Benitti (2012) noted adopting AI and robotics in education contributes to the development of skill sets such as creative thinking, decision-making, problem-solving, collaborative, and communication skills. Implementing robotics in STEM education improves students' problem-solving and creative thinking ability. It also makes learning as a fun field activity. Robotics increase positive attitude and motivate students to learn and advance in education and become innovative (Karim et al. 2015).

In one case study of robotics interaction (Uzun 2020), the author investigated the use of robotics as cognitive tools instead of technological products in a traditional teaching environment. The results of this experiment were noteworthy and showed that students are more adept at interacting with robots, they learn better in a cognitive environment, and the simplification brought about by including robotics in the learning process was having a very high impact.

Educational robotics is a progressive field and is ever-changing and rapidly progressing. We need to be in sync with the developments that are happening. To utilize the benefits fully (Uzun 2020). Robotics have undergone huge change in recent times, and the changes are huge and have touched every aspect of the subject. The new scope and utility that have emerged are very ripe for adoption in the educational domain, and it is expected that research and adoption in this domain will continue at a steady pace for years to come and will be hugely beneficial to the students.

24.7.1 AI and ICTs in Biomedical Learning and Teaching

Advances in biomedical research with the aid of cognitive tools such as information and communications technology have brought revolutionary change in theoretical and methodological teaching and learning. Significant improvement in cognitive performance and mastering of science has been observed due to application of cognitive tools in research and pedagogical learning in biomedicine and engineering courses. This mastering of science helped people to discover and improve a wide range with other technologies such as devices, bioprinting, and surgical robots that used to improve human health.

Medicine is a complex, multifaceted, challenging field. The link between cognitive science and the biomedical field can be explored and validated by the support of information technologies such as the processes of decision-making and problem-solving using technological tools. ICTs are used in comprehending the information to deliver Internet-based healthcare and the implementation of collaborative tools and biomedical technologies in our healthcare environment. By the way, researchers suggest some of the phenomenal knowledge gained in biomedical technologies such as 3D bioprinting, surgical robots, and 3D imaging which makes it easier to understand the conceptual basis of informatics and in the clinical practices.

Recent advances in biomedical informatics and biomedical technologies have been taken into the next level such as clearly explaining the disease pathways, human-on-a-chip technology, and computer modelling that has elevated the understanding of human body and faster development of medical treatments, reducing cost and animal use. In addition to this, researchers have reported that cognitive tools such as computer-based learning and technology application in the classroom have enabled better understanding of curriculum and hands-on learning approaches in undergraduates, graduates, as well as high school students.

24.7.2 Information and Computer Technology in Medical Education

Information technology is used in a profound way in most of the educational areas including medicine and healthcare discipline. Information technology, along with software and hardware with storage, retrieval, sharing, and use of information in health and biomedicine, data, and knowledge, has greatly helped in the decision-making and delivery of healthcare.

Information technology has augmented and facilitated student learning experiences and solving problems to the specific scenarios. It is implemented in many areas such as nursing, clinical care, dentistry, pharmacy, public health, occupational therapy, and (bio)medical research.

Author Dr. Sunil Kumar Joshi (2010) noted that with the development in IT, there has been a substantial change in medical education all over the world. In today's world, the majority of the medical students are computer literate. Advanced education in the field of medicine has reported that medical illustration, computer simulations, computer-based curriculum, virtual patients, mobile devices, social media, and e-learning have evolved as pedagogical strategies in order to unveil an active learning process and to improve the quality of services that health professionals need. To enhance the knowledge applications, a number of advanced technologies have been adopted in the field of medical education including medical students using multimedia, audio-visual aids, computer based such as palmtops, personal digital assistants (PDA) and curriculum also being employed in medical education. Besides,

These days, the classroom instructions are completely directed by an online system with access to the Internet, which helps to obtain up-to-date information on different aspects of health and disease and to address with colleagues in different countries via net conferencing. Many online textbooks and various journals as *Nature*, NEJM, *The Lancet*, JAMA, and BMJ and online databases such as Hinari and PubMed have made it possible to access the latest information on new development in medicine also strengthening the comprehension, skill, and research development.

Computer-based teaching is a powerful tool in medical education. Interactive digital materials and simulations are used to study histopathology, anatomy, and heart sounds in medical and nursing schools. Computer-based technology is extensively used in medical education predominantly in studying the development of anatomical three-dimensional atlases of various internal organs using computed tomography and magnetic resonance imaging. Computer-based technology is helping students to visualize and understand the subject matter clearly.

24.8 Social Media Platform and Learning in Higher Education Settings

Social media platform is the biggest disruption that has happened in this century. We generally define social media as a digital application which provides content, allows user to generate content, and provides a platform for social interaction either in group settings or in private settings. Some of the famous ones are Facebook, Twitter, Tinder, Instagram, LinkedIn, and various others. The infrastructural base of social media is a desktop or a laptop computer or a handheld device like iPad or a mobile phone. Nowadays, predominantly social media is shifting to the mobile space and that has become the principal base for access and interaction.

Social media technology has been adopted very widely in academics in various forms but mostly as a mode of delivery and communication. A huge number of teachers and institutes have adopted social media, and platforms like YouTube have become like universities in terms of content. Also specialized platforms like edX, Coursera, Udacity, and MIT OCW have been set up as platforms for education delivery. They are getting integrated in the physical classroom, and the concept of blended classroom has become the new normal. Their success and adoption are so high and so popular; it is getting hotly debated whether they can replace university education. The question of whether they can supplement is already decided and accepted.

Some of the other social media giants such as Google, QQ, YouTube, Facebook, LinkedIn (e.g. LinkedIn), Instagram, and Tinder have been extensively used for teaching and learning. There has been an increase of students using social media as a learning platform over the past years, and this is predicted to rise. Mulyono and Suryoputro (2020) have observed students and teachers in Indonesia facilitating learning and teaching activities through the use of social media. Their study showed that 95% of 63 million Internet users use social medial and that according to the opinions of various teachers, there is a value in this when it comes to providing learning and instruction via video. A reported advantage for teachers is that they were able to analyse their students' performance and give feedback. All of this increased the students' desire for learning and gave them the opportunity to engage in their learning environments.

Embracing of social media has enabled the interaction among peers for sharing of learning resources. With the integration of mobile technology and mobile applications, students can now acquire the necessary skills and apply their knowledge to real-life situations. There is a high value on the use of social media as a cognitive tool due to student's ability to access course material despite place and time, thus enabling them to learn without limitations. In summary, the adoption of social media is valued for its ability to offer opportunities for the students to access the teaching and learning resources such as video, demonstration, and learning files, which allow students to grasp the learning materials.

24.9 Mobile Technology and Access to Learning

Researchers have found out that mobile technology has a very positive impact on access to education and resources. The technology has also advanced very rapidly, and it is now very capable of providing the infrastructure required for a successful integration of ICT and teaching learning process. In support of Herrington and Oliver (2000), Parker et al. (2013) reported that interest and motivation in learning are better fostered through the integration of mobile technology in the learning space.

Mobile technology has made access above specially for the people on move and in developing countries where affordability of other technological tools is an issue due to economy constraints.

24.10 Current Trend in the Application of Technology in Learning-Teaching

Commitment to exploring the opportunities to use cognitive tools such as advanced technology in a classroom setting is a promise to improve the quality of classroom instruction. For example, learning through audio-visual simulations of real-life scenarios enhances learning. Difficult courses become easier when computers are included in the classroom learning process. Access to computers helps students focus on the content being taught, as opposed to focusing on copying it from the board. Technology-enhanced classes can supplement/complement the textbooks and reduce use of papers.

The present trend is to focus on generation Z, which is confronting the challenges from multiple directions. Their educational experience needs to be enhanced and mapped to their way of thinking and experience. Adaption of technology in classrooms in large swaths will definitely improve their experience and will make education more affordable, useful, and relevant to them. Multiple new technologies like virtual reality, artificial intelligence, and cognitive computing have made the learning and teaching experience very encouraging and useful.

Using everything from block-chain networks to computer simulations, it has become inevitable for the educational institutions to adapt to forever-changing technological innovations. The demand scenario has also changed, and the employers and students both now demand a different type of educational offering and outcome. It is evident that adaption of technology at scale will definitely bring out the best in everyone and the process of learning and teaching will only benefit. The students coming out of the institutions will also be more prepared for the new world and new demand.

24.11 Technology-Enhanced Learning Tools

Real-time learning, live tutoring, using modern online learning platforms such as Google classroom, Facebook live streaming, WebEx sharing Blackboard, Skype, artificial intelligence, virtual classrooms, robotic teaching assistants, CDs, AV rooms, tablets loaded with educational apps, equipped with computers, instructor-led learning, online classes, VTR goggles are some of the tools effectively used in enhancing the learning experience.

Benefits of Technology-Enhanced Classrooms

- Individual learning is promoted.
- Promotes collaboration.
- Students get a rich learning experience.
- Hands-on experience to match employer's expectations.
- Benefits for teachers.
- Technology-enhanced classrooms facilitate and accelerate the learning process for all spectrum of learners be it visual, auditory, reading, writing, or kinaesthetic learner.

24.12 A Look at the Current Application of Technological Tools in Learning Science and Other Disciplines

Carl Zeiss microscope company uses integrated technology where the whole classroom can access the images while teachers have a control over what students can watch.

Georgia Tech built a virtual teaching assistant called Jill Watson on the IBM Watson supercomputer platform. This virtual teaching assistant answers scenarios and questions in various discussion forms along with real teaching assistants who moderate the discussions (John Marcose 2020).

Indus International School at Bangalore has introduced humanoid robot teaching assistants to interact with students in a classroom just like regular teachers would do.

Artificial intelligence is one of the school of educations where trainee teachers use simulated school children for teaching. In the University of Michigan, engineering students are using augmented reality track to test autonomous vehicles in simulated traffic.

The University of New Hampshire is using artificial intelligence for homework and examination grading. They have set up collaboration with Pearson testing for this. Bartleby Write is an AI writing tool developed by Barnes & Noble to correct grammar, punctuation, and spelling, also searches for plagiarism, and helps create citations (John Marcose 2020).

The students in Rensselaer Polytechnic Institute are using an artificial immersion lab to learn Mandarin via virtual setting. The students learn Mandarin Chinese by conversing with artificial intelligence avatars that can recognize speech but also their gestures and expressions, all against a computer-generated backdrop of Chinese shops, hotels, and sceneries.

Instructors and students face greater challenges in teaching methods ever since the inception of technology-enhanced learning (TEL). Technology is evolving incredibly fast as per the expectations of all stakeholders. Emerging technologies are revolutionizing the teaching and learning methodologies.

24.13 Challenges in Introducing Technology into the Classroom

Introducing technology into the classroom brings along with it a set of new challenges. The introduction is not fool-proof, and there is always a chance of adoption failure. This integration and adoption need to be a very well-planned project, and what we need to consider is that it is just like any other complex project with timelines, impact, rollout, and rollback. The project will have an execution time. The implementation cannot work on a very tight schedule as there is always a chance of rejection, and if it so happens that the teacher or the student or both are reluctant to adapt the change, then they have to think of a rollback or work on hybrid models or modifications. Also, technology is very fluid in nature and is ever-changing in both a short and a long period. There is always a risk of technology obsolescence or significant technology changes. This influences the procurement and setup decisions very profoundly.

Teaching in a classroom equipped with computers is a double-edged sword as it introduces scope for diversion. In a brick-and-mortar classroom, students generally engage in taking notes, doing discussions with teacher, etc., but once the student is in front of the computer, the necessity to engage in that manner rapidly decreases. Students may even decide to engage with teachers in non-real-time via message boards, mail, etc. The main problem is however that the students may get engaged in something else during the class via the Internet or even just through content stored in the computer. So, this span of attention and keeping attention is a big challenge, and it is not expected that the teacher will be monitoring everyone individually all the time to figure out who is doing what; rather, we can even say that the idea itself of doing that is impractical. So, teachers have to invent and adapt. Infrastructure is another big concern in providing an integrated experience. Setting up infrastructure for meaningful interaction and integration involves investment, budget, and continuous upkeep and monitoring. Maintaining a software and hardware infrastructure is a specialized function, and that will require hiring of external consultants or signing up for paid support services. So, a detailed budgetary planning on the part of the institution is a must before proceeding on the path of large-scale technology adaption and ICT integration with teaching and learning.

In summary, the effective use of technology has the potential to transform the student-teacher relationship at every level, and the benefit it shows and the impact it generates far outweigh the initial issues involved and the recurring investment that it requires.

24.14 COVID-19 and Educational Technology

COVID-19, the pandemic that is ravaging the world since last year-end, has created a strategic disruption in online education. Earlier, brick-and-mortar was the principal mode of education, and online education was a secondary delivery mode with questionable mainstream adoption. However, this pandemic has changed the scenario completely and made online education the principal mode of delivery. Educational institutes, students, and teachers all over the globe have shifted rapidly to the online mode, and it has been a great success. This has turned out be a large-scale real-time laboratory or case study for adoption of technology in education and use of cognitive tools to supplement and enrich education. Various extensive studies have been done (Basilaia and Kvavadze 2020; Demuyakor 2020; Bao 2020), and the results are all very positive. They have shown problems and issues, but they have also shown solutions, and the future looks to be bright. We do not discuss extensively about this topic which has become an independent subject of enquiry with huge amount of research content and case studies developed consistently. The reader is encouraged to follow up with the literature to see the ideas expressed in this chapter in real-time scenario.

24.15 Conclusion

In this chapter, we have extensively studied the various advantages and pitfalls of adopting technology to enhance the cognitive abilities in education at all levels with an emphasis on higher education. We clearly see that there is a huge scope although there are problems and issues to resolve with the large-scale adoption of information technologies; however, that being said, the trend is very promising across nations. We expect that technology and cognitive thinking will get more deeply integrated in the educational framework. It's not a question of one system replacing the other, but the success lies in a blended approach, and we think that the future lies in a blended education delivery mode which will completely change the present scenario. The entire landscape of learning-teaching environment is going to change significantly and drastically over the years honing the skill sets required for twenty-first-century workforce.

References

Alimisis, D. (2013). Educational robotics: Open question and new challenges. *Themes in Science & Technology Education, 6*(1), 63–71.

Area, M., Hernández, V., & Sosa, J. J. (2016). Models of educational integration of ICTs in the classroom. *Comunicar Media Education Research Journal, 24*, 79–87.

Bao, W. (2020). *Human behaviour and emerging technologies*. Wiley Online Library.

Bas, G., Kubiatko, M., & Sünbül, A. M. (2016). Teachers' perceptions towards ICTs in teaching-learning process: Scale validity and reliability study. *Computers in Human Behavior, 61*, 176–185. Elsevier Ltd.

Basilaia, G., & Kvavadze, D. (2020). Transition to online education in schools during a SARS-CoV-2 coronavirus (COVID-19) pandemic in Georgia. *Pedagogical Research, 5*(4).

Bazluki, Chamberlain, Martin, Mitchell (2012). Department of Educational Psychology and Instructional Technology, University of Georgia, in Brent Robertson, Laura Elliot, Donna Washington.

Beckers, J., Schmidt, H., & Wicherts, J. (2008). Computer anxiety in daily life: Old history? In E. Loos, L. Haddon, & E. Mante-Meije (Eds.), *The social dynamics of information and communication technology* (pp. 13–23). Burlington, VT: Ashgate.

Benam, K. H., et al. (2019). Exploring new technologies in biomedical research. *Drug Discovery Today, 24*(6), 1242–1247.

Benitti, F. B. V. (2012). Exploring the educational potential of robotics in schools: A systematic review. *Computers & Education, 58*(3), 978–988. Elsevier Ltd.

Bloom, B. (1956). *Taxonomy of educational objectives: The classification of educational goals*. London: Longman.

Chen, M., Herrere, F., & Hwang, K. (2018). Cognitive computing: Architecture, technologies and intelligent applications, *Computer Science*. IEEE Access, 6.

Churches, A. (2009). *Bloom's digital taxonomy*. Amazon: e Book.

Clark, S., & Lee, L. (2019). Technology enhanced classroom in low-income children's mathematical content learning: A case study international journal of information and education technology. *International Journal of Information and Education., 9*(1), 66–69.

Considine, D., Horton, J., & Moorman, G. (2009). Teaching and reaching the millennial generation through media literacy. *Journal of Adolescent & Adult Literacy, 52*(6), 471–481.

Cortese, A. D. (2003). The critical role of higher education in creating a sustainable future. *Planning for Higher Education., 31*(3), 15–22.

Cubeles, A., & Riu, D. (2018). The effective integration of ICTs in universities: The role of knowledge and academic experience of professors. *Technology, Pedagogy & Education., 27*(3), 339–349.

Demuyakor, J. (2020). Coronavirus (COVID-19) and online learning in higher institutions of education: A survey of the perceptions of Ghanaian international students in China. *Online Journal of Communication and Media Technologies, 10*(3).

Derry, S. (1990). *Cognitive model of learning*. http://www.longleaf.net/grow/strategicreader/StratModel.html Accessed 15 Sept 2010.

Dobrin, J. (1999). Who's teaching online? *ITPE News, 2*(12), 6–7.

Edmunds, R., Thorpe, M., & Conole, G. (2012). Student attitudes towards and use of ICT in course study, work and social activity: A technology acceptance model approach. *British Journal of Educational Technology, 43*(1), 71–84.

Eguchi, A. (2012). What is educational robotics? Theories behind it and practical implementation. *Computers & Education, 58*, 978–988.

Gudivada, V. N. (2016). Cognitive computing: Concepts, architectures, systems, and applications. *Handbook of Statistics, 35*, 3–38.

Gudmundsdottir, G. B., & Hatlevic, O. E. (2018). Newly qualified teachers' professional digital competence: Implications for teacher education. *European Journal of Teacher Education., 41*(2), 214–231.

Gutierrez-Garcia, J. O., & López-Neri, E. (2015). Cognitive computing: A brief survey and open research challenges. *3rd International Conference on Applied Computing and Information Technology/2nd International Conference on Computational Science and Intelligence*, pp. 328–333.

Herrington, J., & Oliver, R. (2000). An instrumental design framework for authentic learning environments. *Educational Technology Research and Development, 48*, 23–48.

Herrington, J., & Parker, J. (2013). Emerging technologies as cognitive tools for authentic learning. *British Journal of Educational Technology, 44*(4), 607–615.

Hillman, D. C., Willis, D. J., & Gunawardena, C. N. (1994). Learner-interface interaction in distance education: An extension of contemporary models and strategies for practitioners. *The American Journal of Distance Education, 8*(2), 30–42.

Iiyoshi, T., Hannafin, M. J., & Wang, F. (2005). Cognitive tools and student-centred learning: Rethinking tools, functions and applications. *Educational Media International, 42*(4), 281–296.

Jääskelä, P., Häkkinen, P., & Rasku-Puttonen, H. (2017). Teacher beliefs regarding learning, pedagogy, and the use of technology in higher education. *Journal of Research on Technology in Education., 49*(3), 198–211.

John Marcose. (2020). http://www.nytimes.com/2020/02/20/education/learning/education-technology.html

Jonassen, D. H. (1992). What are cognitive tools? In P. A. M. Kommers, D. H. Jonassen, J. T. Mayes, & A. Ferreira (Eds.), *Cognitive tools for learning* (NATO ASI series (Series F: Computer and systems sciences)) (Vol. 81). Berlin/Heidelberg: Springer.

Joshi, S. (2010). Use of information technology in medical education. *Webmed Central Medical Education, 1*(9), 1–7.

Karamti, C. (2016). Measuring the impact of ICT on academic performance: Evidence from higher education in Tunisia. *Journal of Research on Technology in Education, 48*, 322–337.

Karim, M. E., Lemaignan, S., & Mondada, F. (2015). *A review: Can robots reshape K-12 STEM education? Computer Science*. IEEE International Workshop on Advanced Robotics and its Social Impacts. IEEE, pp. 1–8.

Kelly III, E. J. (2015). *Computing, cognition and the future of knowing: How humans and machines are forging a new age of understanding*. Computing Research: IBM Research and Solution, USA.

Koeller, M. (2012). From Baby boomers to generation Y Millennials: Ideas on how Professors might structure classes for this media conscious generation. *Journal of Higher Education Theory and Practice, 12*(1), 77–82. North American Business Press.

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory Into Practice, 41*(4), 212–218.

Lindsay, S. (2020). Exploring skills gained through a robotics program for youth with disabilities. *OTJR: Occupation, Participation and Health, 40*(1), 57–63.

MacDonald, R. (2009). Supporting learner-centred ICT integration: The influence of collaborative and needs-based professional development. *Journal of Technology and Teacher Education, 17*(3), 315–348. Society for Information Technology & Teacher Education, Waynesville, NC USA.

McLoughlin, C. E., & Lee, M. J. W. (2010). Personalised and self-regulated learning in the Web 2.0 era: International exemplars of innovative pedagogy using social software. *Australasian Journal of Educational Technology, 26*(1), 28–34.

Mulyono, H., & Suryoputro, G. (2020). The use of social media platform to promote authentic learning environment in higher education setting. *Science for Education, 10*(2), 104–123.

Pandolfini, V. (2016). Exploring the impact of ICTs in education: Controversies and challenges. *Italian Journal of Sociology of Education, 8*(2), 28–53.

Parker, J., Maor, D., & Herrington, J. (2013). Authentic online learning: Aligning learners needs, pedagogy and technology. *Issues in Educational Research, 23*(2), 227–241.

Prensky, M. (2008). *Young minds, fast times: The twenty-first-century digital learner*. Retrieved November 15, 2011.

Reeves, T. C. (2006). Design research from a technology perspective. In J. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational design research* (pp. 52–66). New York: Routledge.

Robinson, K. (2011, March 4). *Out of our minds: Learning to be creative (2nd ed.). Chichester: Wiley.*

Sahito, Z., & Vaisanen, P. (2017). Effect of ICT skills on the job satisfaction of teacher educators: Evidence from the universities of the Sindh Province of Pakistan. *International Journal of Higher Education, 6*(4), 122–136.

Shum, S. B., & Crick, R. (2012). Learning dispositions and transferable competencies: Pedagogy, modelling and learning analytics. In *Proceedings 2nd international conference on Learning Analytics & Knowledge* (pp. 1–10). Vancouver/New York: ACM Press.

Spante, M., Hashemi, S. S., Lundin, M., & Algers, A. (2018). Digital competence and digital literacy in higher education research: Systematic review of concept use. Cogent education, Information & Communications Technology in education. *Review Article, 5*, 1–21.

Tomei, L.A. (2005). Taxonomy for the education domain. Information science, Hershey. 835-838.

Uzun, A. (2020). Using educational robotics as a cognitive tool for ICT teachers in an authentic learning environment. International education studies. *Canadian Centre of Science and Education, 13*(4), 27–40.

Xia, L., & Zhong, B. (2018). A systematic review on teaching and learning robotics content knowledge in K-12. *Computers & Education, 127*, 267–282.

Zhong, B., & Xia, L. (2020). A systematic review on exploring the potential of educational robotics in mathematics education. *International Journal of Science and Mathematics Education., 18*(5), 79–101.

Chapter 25
Revisiting Cognition and Information Technologies Through a COVID-19 Lens

Susan Crichton

25.1 Introduction

In 2000, colleagues from the University of Sydney and I co-authored a book chapter entitled *Communications and Networking in Education*, ironically also published by Springer. That chapter was my first academic publication, following the awarding of my doctoral degree which focused on fostering social interaction and deep learning in virtual learning environments. What united the authors in that publication was an appreciation of the additional cognitive load that integrating technology (information and communications technology – ICT) had on educators and their students.

The timing of that 2000 writing was significant as ICT was increasingly beginning to be used to support remote and distant education programs. It is important to remember that prior to this time, correspondence, or distance education, was primarily offered through paper-based packages of content and materials sent through the mail and supported by radio (https://www.australian-children.com/school-of-the-air) or telephone interactions. The 1990s–2010 were the hay days of online/virtual learning, especially in North America and Australia. The Internet was stabling and becoming ubiquitous by the mid-1990s, and universities and K-12 schools were reconceptualizing their correspondence and distance learning practices, developing best practices for online learning and blended learning. During this period, telecommunications infrastructures were maturing, and multimedia content could finally be added to the rather meager online text content. Additional content could be found on fledging Internet sites using search engines such as Netscape and Mosaic, names now lost in a world now dominated by Google, Explorer, and Safari.

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In our 2000 chapter, we stated:

> New, dynamic, virtual learning environments are presenting opportunities for more diverse types of learning and cognitive social activity than have been previously available in formal educational settings. Some consequences of our understanding of how learning occurs include newly recognized forms of learning, how these can be nurtured, and how this new knowledge can be applied to the design of virtual social contexts that encourage new approaches to learning and thinking. (Gibbons et al. 2000, p. 2)

We went on to suggest that both the settings and environments could be designed in ways that would leverage cognitive development that added neural placidity and foster active and social learning.

Now, 20 years later, it feels timely to review that previous publication in light of the pressures and the opportunities provided by COVID-19. This global pandemic has impacted all levels of education with the conclusion of the 2019–2020 academic year in North America and followed by the opening of the 2020–2021 term[1]. For many of us in higher education, the need to respond quickly to the impact that the closure of our physical campuses had on teaching and learning was enormous. Within weeks in March 2020, institutions closed their physical campuses, and their faculty had to quickly pivot their practices to online, distant, and remote learning in an attempt to save the academic year. One of the more shocking things that arose during that time period was the fact that many educators and academics had no idea of the rich history of online learning. Many stated that they had to invent ways to connect with students as the physical campuses closed and students and faculty were required to work from their homes. It was as though "remote learning," as governments and the media called it, was something new and untested, despite its long history.

As I write this chapter some 6 months after the initial impact of COVID-19 was felt, it is timely to consider what we know about online teaching and learning and how we might consider COVID as a provocation to draw from previous best practices while incorporating the promise and potential of our current technology affordances – infrastructure, hardware, and software. This chapter shares research into the field of online learning and a case study of actual practice developed at the University of British Columbia's Okanagan Campus (UBC Okanagan). UBC is a post-secondary institution which offers a range of undergraduate and graduate programs and is consistently globally ranked in the top 35 of public universities (https://www.ubc.ca/). UBC has two campuses: the largest and oldest is in Vancouver, British Columbia, Canada, and the second campus is located in Kelowna, British Columbia (https://www.ubc.ca/our-campuses/okanagan/). UBC's main campus in Vancouver enrolls approximately 54,000 students; UBC Okanagan hosts 9,120 students.

[1] Please note, at the time of this publication, the 2020–2021 academic year had just started in North America and the majority of post-secondary institutions in Canada were offering courses exclusively online.

25.2 Background to the Learning Design Intern (LDI) Program: A Case Study

This chapter situates the research from our 2000 work within the current context of the University of British Columbia's Okanagan Campus (UBC Okanagan), sharing a campus-wide initiative, the Learning Design Intern (LDI) program. The LDI program was developed quickly in May 2020 as (1) a way of helping faculty members re-purpose their traditional courses for blended delivery and (2) a way of responding to how could UBC transition its courses online for the new academic year while ensuring academic integrity and rigor.

In mid-March 2020, the UBC President and Provosts' Offices on both campuses recognized the need for changed instructional practices and learning opportunities in order to (1) address the challenges of COVID-19 and (2) to comply with the orders from both the national and provincial public health officers. Each campus approached the challenges in slightly different ways. UBC Okanagan developed a Transition Support Framework in April 2020. That framework is illustrated in Fig. 25.1.

Specific budget considerations for the Transition Support Framework included:

- Learning Technology Rover Program – administrator and students
- Learning Design Internet Program – administrator and graduate students
- Blended Learning Teaching Assistants – administrator and undergraduate and graduate students
- Student Technology Bursary Program – one-time student support to purchase technology, based on need
- Increased site licenses for software to support blended learning
- Learning Design Consultant – consultant with blended learning expertise – short-term contract

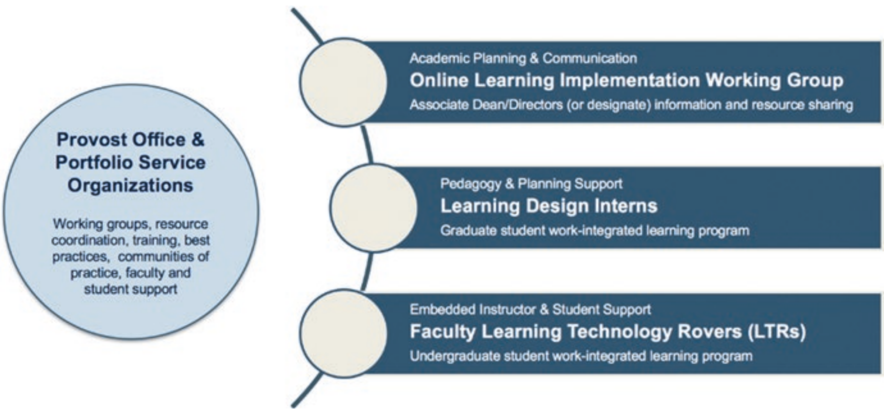


Fig. 25.1 Transition Support Framework: April 2020

The LDI program was developed to provide graduate students with intensive training in the fundamentals of learning design for blended learning delivery. The Provost's Office felt faculty needed direct supports to help them redesign learning rather than merely to move existing courses and transition instructional practices online. A workshop was followed by a work experience in which the LDIs were partnered with faculty members in their disciplines and, together, they worked to design existing courses for blended delivery in advance of the 2020 Winter Term. The LDIs receive ongoing training and mentorship throughout their work experience. Specific components of the LDI program included the following:

- Materials and resources for the immersive workshop for the graduate students selected for the LDI program.
- Supportive, just-in-time seminars provided throughout the program; these included DYI video tutorials, seminars with needed subject matter experts, etc.
- Companion website (https://provost.ok.ubc.ca/initiatives/learning-services/learning-design-2/ldi-program-components/) which was developed to be an ongoing repository for resources and materials as well as work developed by the LDIs during the program.

A detailed explanation of the LDI program components can be found at https://provost.ok.ubc.ca/initiatives/online-transition/learning-design-2/ldi-program-components/.

The LDI program hired 22 graduate students (masters and doctoral level) from a range of disciplines and provided them with a 15-h workshop facilitated across 5 days. They were supported for the next 3 months by Technology Rovers and a Program Manager. The Technology Rovers were students who had received training in the learning management system (CANVAS) used at UBC Okanagan and other relevant software tools and applications essential to supporting to blended course delivery. The Project Manager was a senior administrator with experience in Student Services. Her role in the LDI program was to draw on her previous expertise and support the LDIs as they worked with their faculty partners and to keep the program on schedule.

Blended learning was used by UBC as the instructional approach to address the challenges presented by COVID-19 and the closing of physical access to the university campuses for traditional face-to-face instruction. The term blended learning is used throughout this chapter, recognizing the dated nature of the term *virtual* learning which was used in the original 2000 chapter. "Blended learning emerges from an understanding of the relative strengths of face-to-face and online learning. This opens a wide range of possibilities for redesign that goes beyond enhancing the traditional classroom lecture" (Garrison and Vaughan 2007). Shortly after the traditional campus learning was replaced by "remote" or online learning immediately following Canada's recognition of the global pandemic, UBC began development of a Guiding Principles (2020) document to support faculties. That document recommended that faculties "… *[e]*xplore ways to adapt both your course design and delivery to take advantage of the flexibility made possible by online learning while cultivating a strong, inclusive, online learning community." The LDI program further defined the UBC recommendation and suggested that instructors and course designers consider blending learning opportunities by embracing the range of variables that they can/could *control* in terms of place, time, and specific learning experiences. The LDI program stressed that a blended learning approach helps to create a learning environment that considers learning along a continuum of practice – from fully face-to-face to completely online. The LDI program encouraged instructors and course designers to think of various ways that labs, simulations, tutorials, and assessment could be done and match those with the goals of specific courses or programs.

Because of the urgency required to support faculty in the transition to blended approaches, the Provost's Office hired a consultant to lead the design, development, and implementation of the LDI program. The author of this chapter was the consultant. I had worked at UBC Okanagan prior to my retirement. During my UBC employment, I became a tenured faculty member in the School of Education and eventually its Associate Dean. Prior to coming to UBC Okanagan, I had been a tenured faculty member at the University of Calgary, Calgary, Alberta, Canada. My research agenda focused on blended learning, and I had developed and co-instructed the first Teacher Education course in Canada that intentionally prepared pre-service teachers to teach in blended learning environments. My familiarity with UBC Okanagan's infrastructure and academic structures allowed me privileged access to colleagues and provided me with insights into the potential challenges that the pivoting online due to COIVD-19 would present.

My first task was to design the content for the LDI workshop. As a learning designer, I appreciated and worked within the constraints provided by the Provost's Office. These constraints included:

- The Provost's Office would hire the graduate students who would be part of the first LDI cohort.
- The Provost's Office would select the faculty members who would work in partnership with the first LDI cohort.
- The duration of the LDI contract consisted of 3 months, which included training, supports, and course redesign.
- The LDI program content needed to align closely with and support the UBC Guiding Principles for Fall 2020 Course Adaptation (https://ctlt-act-2020.sites.olt.ubc.ca/files/2020/06/Developing-guiding-principles-for-fall-instruction.pdf) which was primarily a policy document.
- The LDI training workshop would focus on learning design rather than traditional instructional design, which signaled, from the Provost's Office, the importance that was being placed on the learners and their specific needs during with unprecedented time.
- The LDI workshops would be 15 h in duration, offered over 5 days. The LDIs were required, per their contract, to attend all the sessions and participate fully in the learning activities.

- Following the workshop, the LDIs would work under the direction of the LDI Manager, whose role it was to act as Project Manager and ensure each LDI had a faculty partner and the course redesign efforts were as successful as possible.
- All assets of the LDI program (i.e., templates, training materials, etc.) would be owned by the Provost's Office and licensed under Creative Commons Licensing. The materials would be housed on a website hosted by the Provost's Office and managed by UBC Library Services (https://provost.ok.ubc.ca/initiatives/learning-services/learning-design-2/).

Research and practice informed the blended learning design principles for the LDI program. These included sharing theory and practice about the following key concepts:

- Defining blended learning
- Positioning blended learning on a continuum of practice
- Principles of learning and teaching
- Discussion of student needs – especially for remote learning
- Design principles – givens, constraints, and chunking content
- Use of templates and resources
- Introduction to assessment options
- Introduction to project management

I felt this was critical as we could not assume that the LDIs or all of their faculty partners deeply understood these concepts and their impact on learning. By developing a common understanding, using similar resources, and working collaboratively, we hoped the LDIs and their faculty partners would form a community of practice (Wenger 1998) that would sustain the work beyond the initial cohort.

I designed the content for the LDI workshop, drawing on my experience with blended learning. I developed an Implementation Plan that organized the flow of the content to be presented; the tasks that the LDI would do to show their competency; the presentations the Project Manager would need to prepare for her presentations; and the resources needed. I used this Implementation Plan as a framework for initial design discussions with colleagues at UBC Okanagan who held expertise in blended learning. We were able to iterate quickly workshop ideas and needs on the Implementation Plan and manage issues of copyright for the resources in a timely manner prior to moving the workshop content into the learning management tool – CANVAS. As the development of this content was quickly done, I stressed to the Project Manager and technology support people that iterations of the materials would happen regularly, and consequently, initially, little time or effort was put into branding and formatting. The Library Services colleague was invaluable in terms of securing needed copyright and acceptable use permissions.

I worked closely with the LDI Project Manager, helping her to prepare and eventually present her daily presentations based on the Implementation Plan. To guide the development of the presentations, I designed a simple framework that provided a model good blended learning practices and offered a predictable pattern of learning for both the Project Manager, who was new to blended learning, and LDIs themselves. It felt to us that modeling the model of good blended learning was essential as few if any of the LDI participants had experienced it themselves, previously. The format consisted of:

- Questions arising from the previous day
- Introduction of the new concepts for the day
- Development of a lexicon of terms needed for UBC Okanagan's implementation of blended learning
- Presentation 1 – Big idea and key concept and presentation of relevant resources, templates, etc.
- Task 1 or more – Learning activities that would allow the LDIs to make meaning of presentation
- Presentation 2 – Big idea and key concept
- Task 2 or more – Learning activities that would allow the LDIs to make meaning of presentation
- Additional presentations and tasks
- Closing remarks
- Reminder of tasks needing completion prior to tomorrow's class
- Reminder of the resources provided in the presentations

After completing the workshop, the Project Manager met regularly with each LDI and once a week with all the LDIs to ensure timelines and program intentions were being met. As word got out about the success of the program, additional faculty members who were not part of the initial LDI cohort asked if they could receive the LDI training. Due to scheduling and the fact that the start of the academic year was to commence in 2 weeks, the Provost's Office decided to develop the LDI Companion Website as a way of sharing the learning and the resources. The website followed the structure of the LDI workshops and attempts to offer a summary of the content that was covered and access to the templates and the resources. The structure of the website was based on a three-step process for course redesign for blended Learning.

- Step 1: Become Familiar with Blended Learning
    - Step 1.1: What Is Being Blended?
    - Step 1.2: Place and Time
    - Step 1.3: The Role of Time
    - Step 1.4: The Role of Technology
    - Step 1.5: Selecting Technologies for Learning
    - Step 1.6: Accommodating the Reality of Access
- Step 2: Reimaging Course Structure and Delivery
    - Step 2.1: Chunking a Course
    - Step 2.2: Reviewing the Syllabus
    - Step 2.3: Templating and Writing

- Step 3: Considering the Learner and Their Learning
  - Step 3.1: Student Experience Survey Findings
  - Step 3.2: Backward Design
  - Step 3.3: Evidence-Based Assessment
  - Step 3.4: Assessment Issues
  - Step 3.5: The Final Check
  - Step 3.6: Readings and Resources

The LDI program was conceptualized and designed and the initial workshop delivered within 1 month. Therefore, it seemed critical that a program review be conducted immediately, before a second cohort was planned.

Going forward, UBC Okanagan refined its Support Framework to include departments and groups on campus who impact student learning: UBCSUO – the Provost Office; Students' Union; Associate Vice-President Students; UBC Information Technology Department; and the Centre for Teaching, Learning and Technology in Vancouver (Fig. 25.2).

25.3 Program Review Process

Recognizing that the LDI program was developed in haste, despite its attention to best practices and research in the field of blended learning, it was agreed that the program should undergo a review following the initial offering, in June–August 2020. The review was commissioned by the Provost's Office, and the findings are

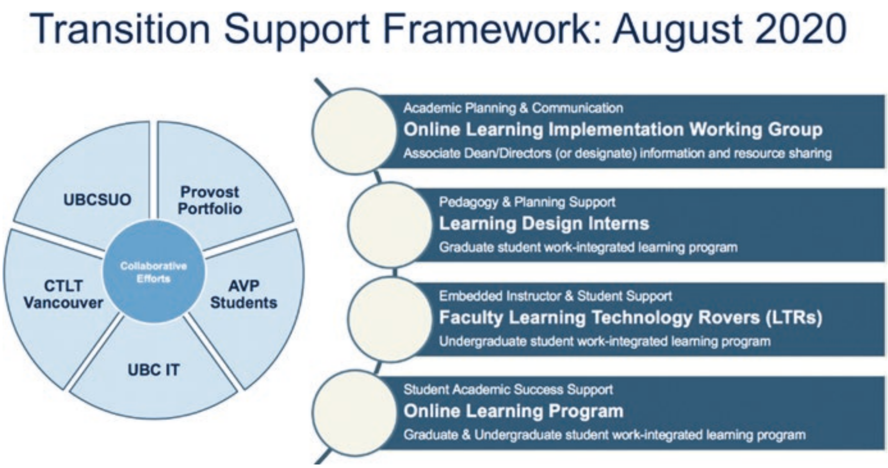


Fig. 25.2 Transition Support Framework: August 2020

shared later in this chapter – Initial Findings from Program Review October 2020. It was decided to conduct a program review rather than a formal research study as results were needed quickly to inform the next cycle of LDI program offerings and to recognize the numerous pressures of potential participants. It was felt that seeking informed consent, conducting interviews, etc. would unnecessarily take valuable time away from the graduate students and faculty who were already stressed by COVID demands, teaching schedules, and other tasks that were requiring modified approaches due to the pandemic. It was also feared that due the time constraints of the new semester, faculty and graduate students would be reluctant or unable to participate in a more formal study.

Data for the review was gathered from a survey of both the graduate students in the program and their faculty partners. Additional data was gained from data analytics of website access and downloads. This data source was viewed as important as faculty and the LDIs had asked for the development of the companion website as a repository for workshop resources. The LDI Program Facilitator/Administrator was also consulted, and her report to her boss informed the LDI program review.

Findings shared in the LDI case study are discussed using a variety of thematic analysis approaches to explore the dynamics of learning in technology-enabled contexts such as through those created using a blended learning instructional strategy. The findings from those perspectives suggest there is an important relationship among the intentions of the institution and the instructional design and teaching practices of faculty and their graduate assistants. Further, they suggest a strong positive relationship between the personal agency (i.e., faculty and graduate students) concerning (1) how they thought about integrating technology, (2) changes in their personal teaching philosophies and how the use of technology might impact that, and (3) their comfort in embracing and coping with the challenges imposed on faculty by outside forces, such as the COVID-19 pandemic.

Social constructivists remind us that our thinking about technology integration suggests that we cannot separate what we know from the context in which we learned it. Our personal knowledge is dependently constructed with our socio-historical settings. How we use and come to understand new information and ways of working suggest that cognition is plastic – moldable and shaped by external pressures and learning opportunities (Gibbons et al. 2000, p. 4). Gibbons et al. suggest the "the plasticity of cortical function at the level of neuronal groupings and consider perception as an active and creative act. Socio-cultural theorists (Luria 1971; Vygotsky 1978; Crawford 1996)" recognizing the need to encourage active learning and social engagement.

The challenge that Gibbons et al. found was to find ways in which they could "investigate individual difference constructs within situated human activity frameworks that entertain the dynamic relationship between learner and context."

25.4 Revisiting the Literature

Gibbons et al. (2000, p. 5) state "to better realise the new opportunities offered by technology we need to develop more reflexive theoretical accounts of learners acting in contexts of practice …[and] focus on the development of the research object of cognitive style as a lens for studying the interaction between learner and context."

This suggestion encourages researchers to explore the notion of *situated interventionism* which aims to create "new forms of practices" (Engestrom and Cole 1997, p. 308) by changing the setting of problem to be solved. In the context of the case study shared in this chapter, researchers needed to study both the problem of practice (i.e., pivoting learning environments and offering traditionally presented face-to-face courses in a blended learning format) and the faculty members' comfort and understanding of blended learning affordances and the technologies that enabled them.

The transition from traditional learning environments to blended learning environments creates both cognitive and tangible artifacts that reflect the required collaboration among members within the organization and the socially distributed nature of knowledge translated and dissemination. Throughout the case presented in this chapter, faculty members and graduate students had access to a range of cognitive supports created just in time to support them as they moved their courses into a blended learning environment. Analysis of the use of those resources and their efficacy is reported later in this chapter.

One of the intentions of the LDI workshops and supports was to create a community of practice that could support each other and share resources and best practices. That intention was central to the design of learning environments used in the LDI program, recognizing that collaboration fosters social engagement and peer engagement as well as providing an intellectual stimulus that encourages higher-order thinking and deeper, personalized learning. In this way, it is proposed to facilitate attempts to address Rogers and Rutherford's challenge to "develop a means of choreographing the flow of activity through individuals and technology" (Gibbons et al. 2000, p. 4).

From my previous work in virtual and blended learning environments, I knew that before supporting changed practices for faculty and students, institutions have to encourage, share, foster, and support innovative educational practices which in turn can support knowledge-building and encourage more active participation in the educational experience. However, while the introduction to innovations in pedagogy and the technologies that might support it can enable shifts in teaching, these two elements cannot ensure it or make it happen. The temptation to rely on traditional instruction which typically is still found in most educational institutions is strong and widely encouraged despite the clear evidence that it rarely reflects the structure of the rich learning environments that support deep learning and support knowledge-building.

Recognizing this connection, the organizers of the LDI program developed a learning support model drawing on the understanding of the components inherent in the literature of learning organizations, intentional learning, and action research. The LDI program drew from three attributes of an organization for learning: personal mastery (individual activity), social interaction (collaboration), and systems thinking (holistic understanding). The LDI design recognized the need to foster critical and creative understanding of the innovations as well as provide for faculty and LDIs to foster higher-order thinking about the changes before incorporating them into their instructional practices.

Further, research (Gibbons et al. 2000) suggests there is a relationship between a person's personal agency and their adoption of changed practice. Further, they noted that "within the university setting, personal agency was clearly used in two opposing ways:

- to resist changes associated with ICT;
- to enhance communication, cooperation and the use of ICT in research and administration (p. 10)."

This finding from 2000 was determined to still be valid in 2020. In the case study shared in this chapter, there were faculty members who were opposed to significantly modifying their course delivery for blended learning, stating they say no reason to make changes, stating their resistance to a changed pedagogical approach and a belief that the pandemic would simply go away. Additionally, it was discovered that many of the participants in the LDI case study were primarily consumers of social media and digital content and few actually produce or create content using productivity software. While Prensky (2001) coined the term Digital Natives to suggest that young people have with advanced skills, abilities, and dispositions toward technology, that construct has been highly critiqued as being too simplistic and ignoring the more complex use of technology beyond simple consumption of social media. Bax (2011) stated the term, Digital Natives, essentially ignores essential elements of the nature of learning and good pedagogy that Prensky's Digital Immigrants (faculty members and older adults) have. Further, the case study presented in this chapter discovered that few of the graduate students in the LDI program had the skills required to create and produce digital content and design learning within a learning management environment.

25.5 Initial Findings

The initial findings from the LDI program review suggest Wenger's assertions remain true. Informal learning, in the form of workshops, facilitated supports, and access to relevant, curated content (i.e., the LDI Companion Website), did influence and impact changes in practice. With peer and timely supports, faculty and LDIs were able to learn new ways of working and apply those ways to creatively and constructively change their course designs and instructional strategies as illustrated in the next section.

Table 25.1 Components of the learning design intern program

	LDI workshops	LDI seminars	Companion website[a]
Description	Immersive learning experience for graduate students who will ultimately serve as Learning Design Interns (LDIs)	Just-in-time topical support for LDIs as they begin to work with their Faculty Course Authors	Companion guide to the LDI Workshop Overview
Purpose/ audience	Preparing graduate students to assist faculty in preparing their courses for BL	Technical and pedagogical supports as needed and as they arise from the initial work	Support for Faculty and LDIs as they prepare their courses for BL
Contents	• 5-day workshop • Seminar series • Handouts	• Demonstration of and tips for working with your faculty course author • Revisiting and revising your LDI templates • Getting the most out of Canvas • Handouts from the seminars	An introduction to blended learning in 3 steps: 1. Become familiar with blended learning 2. Reimagine course structure and delivery 3. Consider the learner and learning • Handouts, templates, curated web links
Facilitators	• LDI Instructor/Project Manager • LD Interns: 22 graduate students	• LDI Instructor/Project Manager • LTR Manager • Faculty and Staff as relevant	• LDI Instructor/ Project Manager • Graphic/web designer

[a]https://provost.ok.ubc.ca/initiatives/learning-services/learning-design-2/ldi-program-components

There were 22 graduate students hired into the first cohort of the LDI program. All the LDIs completed their contracts and redesigned at least one course with a faculty partner. As of August 30, 2020, the official culmination of the initial LDI cohort, 71 courses were redesigned for blended learning and uploaded to the university's learning management system. The 22 LDIs worked with total of 78 faculty members.

As previously illustrated on Table 25.1, the Learning Design Intern Program consisted of three components: the LDI Training, the LDI Seminars, and the Companion Website. Data informing the efficacy of these components was collected using surveys and data analytic tools.

Survey questions were developed for both the LDIs (graduate students) and their faculty partners. Each survey had closed questions that solicited Likert responses and open-ended questions for each question grouping. Responses to the open questions were analyzed thematically.

The survey questions were grouped consistent with the program framework:

- Familiarity with Blended Learning
- Re-imagining Course Structure and Delivery

- Considerations of the Learner and Their Learning
- Course Redesign

Because ethical consent was not required or requested for the program review, detailed findings from the data cannot be shared in this chapter. However, what is shared is the general impressions the findings have provided.

25.6 Student Responses

Unanimously, the students agreed that they had gained an adequate understanding of the potential and promise of blended learning. They reported they were able to describe and define blended learning to others and they felt the workshop had provide them with adequate supports, resources, and materials to work with their faculty partners. All recognized the program had been delivered quickly, and they stated they were grateful for the opportunity to have been part of the initial cohort. While the majority of respondents wished the workshop had lasted longer, they recognized that it had not been possible to do so in the first cohort. They stressed that in subsequent cohorts, extending the time period of the workshop across the duration of the contract would have made learning the material easier.

The majority of the students felt they had learned to redesigned a course effectively. They felt the templates and resources had been valuable. One recommendation they made was to provide more context-specific examples, and they suggested that the content they had developed in this first cohort would be valuable to subsequent cohorts and, therefore, should be archived and shared.

All the students stated they appreciated learning about learning. This finding was refreshing as it validated the program's decision to focus on learning design rather than instructional design and teaching effectiveness.

A delightful and unintended consequence of the LDI program was the statement from the students that they unanimously wanted to learn more about learning design and hoped to stay part of the program and work to redesign additional courses. Half of the student respondents noted they would be interested in pursuing a career in learning design. This enthusiasm for learning design has prompted the Provost's Office to consider developing a Certificate in Learning Design.

25.7 Faculty Responses

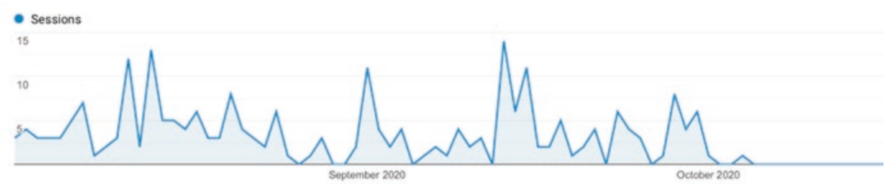
Faculty agreed that the LDIs had learned about blended learning and had gained an understanding of learning design. Faculty felt that working with an LDI would be enormously valuable for new faculty and instructors. However, for themselves, faculty reported they wished the LDIs had gained more technical skills working with the learning management system – CANVAS – than with redesigning courses.

Many of the faculty responses reflected a concern about course content ownership and delivery – areas some felt graduate students should not be assisting faculty with, even if the learning environment had been switched from traditional delivery to online. Only one faculty respondent had a negative view of the LDI program, and that individual's comments reflected a desire to stay with the status quo of teaching supports and traditional delivery – neither of which were possible due to COVID concerns. One comment that reflected the students' enthusiasm for learning design was that she/he saw benefit of the LDI program for faculty but more importantly saw benefit for graduate students who might eventually be teaching classes of their own.

25.8 Website Analytics

Data analytics was used to determine the usage of the website that was developed after the workshop. The LDIs and their faculty partners were told given the link to the website, and the Provost, in her regular newsletter, announced the launch of the website (https://provost.ok.ubc.ca/initiatives/online-transition/learning-design-2/). The website was created as a response from faculty to understand the materials that was covered in the LDI program and as a way to share this information with the broader UBC academic community (Fig. 25.3).

Specifically, analytics were able to report user search sequences, user time on individual pages, and download attempts for each resource. In Fig. 25.3, the term sessions refers to single visits to the website. Whether a *User* lands on one of the web pages and leaves a few seconds later or spends an hour reading every blog post on the site, it still counts as a single *Session*. If that *User* leaves and then comes back



Landing Page	Acquisition			Behavior			Conversions	
	Sessions	% New Sessions	New Users	Bounce Rate	Pages / Session	Avg. Session Duration	Goal Conversion Rate	Goal Completions
	232 % of Total: 3.60% (6,452)	46.98% Avg for View: 50.87% (-7.64%)	109 % of Total: 3.32% (3,282)	63.79% Avg for View: 47.92% (33.12%)	2.84 Avg for View: 1.92 (47.66%)	00:02:32 Avg for View: 00:03:00 (-15.48%)	0.00% Avg for View: 0.00% (0.00%)	0 % of Total: 0.00% (0)
1. /initiatives/learning-services/learning-design-2/	232 (100.00%)	46.98%	109 (100.00%)	63.79%	2.84	00:02:32	0.00%	0 (0.00%)

Fig. 25.3 Website usage

later, it would not count as a new *User* (see above), but it would count as a new *Session*. At this time, the downloads were not able to be recorded. The website will remain on the Provost's home page, and it is anticipated that the website will be maintained and updated with additional resources, exemplars, and content as the LDI program continues.

25.9 Conclusions

Based on the findings of the program review, the LDI program was successful. Plans are underway to refine the program, based on user feedback, and to continue to offer it to support quality learning and teaching across the campus. The website is available to anyone who would like access, and the resources are shareable, using Creative Commons Licensing.

Common themes that arose from the analysis of the data that are supported by the literature include:

1. The need importance of ensuring educational settings/learning environments support the diversity of contexts and learning styles that all learners bring to their studies. These findings confirm there is no one instructional design or strategy that attends students' needs. By focusing on learning rather than teaching, it appears learning environments can be more inclusive and nimbler to student needs, allowing good teaching to support learning.
2. The learning contexts in which students and instructors find themselves are socio-politically situated therefore need to be open to change and negotiation.
3. Cognition is flexible and developed within the context in which it is situated. Therefore, teaching strategies must follow learning needs – both students' needs and subject domain core knowledge.
4. Regardless of the learning environment, it is critical to create opportunities to foster the relationship between context and cognition and the related knowledge and capabilities if deep learning and change are desired.
5. COVID-19 and the need to quickly pivot to blended learning reminded members of the academic community that learning is continuous if one is required to adapt to novel situations such as the COVID-19 global pandemic. The status quo becomes quickly unworkable.

While no one would suggest that COVID-19 was a good thing, good things have come from the need to pivot quickly to blended learning. Faculty were required to re-think what constituted essential learning in their courses and how that learned would be experienced. Among the positive elements arising from the LDI program at UBC Okanagan, the Centre for Teaching and Learning (CTL) has a deeper understanding of the roles and responsibilities of its teaching assistants (TA). The LDIs identified the work of the TAs in their Learning Design Instructional Templates. Based on those templates, the CTL staff were better able to plan the TA Training for the upcoming year. Further, because the TA Training was redesigned, it gave the

CTL an opportunity to get a laddering opportunity for successful TAs to eventually become Learning Design Interns, thereby creating a continuity of supports, employment, and skill development for undergraduate and graduate students.

To support the work of the LDIs in preparing thoughtful and respectful courses that recognized the demands on students across the semester, UBC Okanagan developed a Course Workload Calculator Tool (https://ubcoapps.elearning.ubc.ca/). Development of this tool was focused on adapting an existing openly licensed, research-informed, online tool for estimating the expected time commitment of students within courses to include a broader set of learning activities.

By choosing to focus on learning rather than instruction, the LDI program made a bold move. This move appears consistent with the literature on cognition and the socially constructed nature of learning. While there has only been one cohort of the LDI program, early findings suggest the approach has been successful and worthy of further consideration and development.

References

Argryis, C. (1993). *Knowledge for action: A guide to overcoming barriers to organizational change*. San Francisco: Jossey-Bass Publishers.

Bax, S. (2011). Digital education: Beyond the wow factor' in digital education: Opportunities for social collaboration. In M. Thomas (Ed.), *Digital education*. New York: Palgrave Macmillan.

Brown, A. L. (1994). The advancement of learning. *Educational Researcher, 23*(8), 4–12.

Crawford, K. (1996). Vygoskian approaches to human development in the information era. *Educational Studies in Mathematics, 31*, 1–2.

Edelman, G. M., & Tononi, G. (1995). Neural Darwinism: The brain as a selectional system. In J. Cornwall (Ed.), *Nature's imagination*. Oxford: Oxford University Press.

Engestrom, Y., & Cole, M. (1997). Situated cognition in search of an agenda. In D. Kirshner & J. A. Whitson (Eds.), *Situated cognition: Social, semiotic and psychological perspectives*. Mahwah: Lawrence Erlbaum.

Engestrom, Y., & Middleton, D. (1996). *Cognition and communication at work*. Cambridge: Cambridge University Press.

Garrison, D., & Vaughan, N. (2007, October 19). *Blended learning in higher education: Framework, principles, and guidelines*. Wiley. https://onlinelibrary-wiley-com.ezproxy.library.ubc.ca/doi/book/10.1002/9781118269558

Gibbons, P., Crawford, K., Crichton, S., & Fitzgerald, R. (2000). Cognition and information technologies in context. In D. Watson & T. Downes (Eds.), *Communication and networking in education*. New York: Springer. Retrieved from https://www.researchgate.net/publication/259760405_Cognitive_development_in_ICT_contexts

Guiding principles for Fall 2020 course adaptions. (2020). Retrieved from https://ctlt-act-2020.sites.olt.ubc.ca/files/2020/06/Developing-guiding-principles-for-fall-instruction.pdf

Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT Press.

Kofman, F., & Senge, P. M. (1993). Communities of commitment: The heart of learning organizations. In S. Chawla & J. Renesch (Eds.), *Learning organizations: Developing cultures for tomorrow's workplace*. Portland: Productivity Press.

Lave, J. (1988). *Cognition in practice: Mind, mathematics, culture in everyday life*. New York: Cambridge University Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Melbourne: Cambridge University Press.

Leont'ev, A. (1981). *Problems of the development of the mind*. Moscow: Progress.
Luria, A. R. (1966). *Higher cortical functions in man*. New York: Basic Books.
Luria, A. R. (1971). Towards the problem of the historical nature of psychological processes. *International Journal of Psychology, 6*, 259–272.
Luria, A. R. (1973). *The working brain: An introduction to neuropsychology*. Middlesex: Penguin.
Luria, A. R. (1976). *Cognitive development*. Cambridge, MA: Harvard University.
Merleau-Ponty, M. (1962). *Phenomenology of perception*. Evanston: Northwestern University Press.
Nardi, B. (1996). Studying context. In B. Nardi (Ed.), *Context and consciousness*. Cambridge, MA: MIT Press.
Prensky, M. (2001). Digital natives, digital immigrants. *On the Horizon, 9*(5), 1–6.
Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. New York: Oxford University Press.
Scardemalia, M., & Bareiter, C. (1994). Computer support for knowledge building communities. *The Journal for Learning Sciences, 3*(3), 265–283.
Senge, P. M. (1990). *The fifth discipline: The art and practice of learning organizations*. Toronto: Currency and Doubleday.
Thompkins, P. K. (1993). *Organizational communication imperatives: Lessons of the space program*. Los Angeles: Roxbury Publishing Company.
Vygotsky, L. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.
Vygotsky, L. S. (1986). *Thought and language*. Cambridge, MA: The MIT Press.
Weir, S. (1992). *Electronic communities of learners: Fact or fiction* (Working paper 3-92). Cambridge, MA: TERC Communications.
Wenger, E. (1998). *Communities of practice*. Cambridge, MA: Cambridge University Press.

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