Kennedy Andrew Thomas
Joseph Varghese Kureethara
Siddhartha Bhattacharyya *Editors*

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Editors
Kennedy Andrew Thomas
Centre for Education Beyond Curriculum
Christ University
Bengaluru, Karnataka, India

Joseph Varghese Kureethara
Department of Mathematics
Christ University
Bengaluru, Karnataka, India

Siddhartha Bhattacharyya
Rajnagar Mahavidyalaya
Birbhum, West Bengal, India

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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

Kennedy Andrew Thomas
Joseph Varghese Kureethara
Siddhartha Bhattacharyya

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About the Editors

Kennedy Andrew Thomas is the director of the Centre for Education Beyond Curriculum (CEDBEC) and professor of education in the School of Education at Christ University, Bangalore, India. He obtained his Doctor of Philosophy, Master of Education, and Bachelor of Education degrees from from Bangalore University, Bangalore and Master of Arts degree in Psychology from Annamalai University, Annamalainagar, India. He has published research articles in international and national journals, and authored and edited books/chapters of reputable nature. He is a resource person in fields of research, education, and technology, and has delivered multiple sessions and organized numerous national and international seminars every year under the CEDBEC, Christ University, Bangalore. He is a research supervisor for doctoral scholars, and doctoral/MPhil researches have been completed under his guidance. Dr. Thomas is an active member of multiple professional associations for the cause of research and education.

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.

G. N. M. Dixit (✉)
SMS Foundation, Mentor, Aundh, Pune, Maharashtra, India
e-mail: gnmdixit@gmail.com; gnmdixit@smspimar.org

K. A. Thomas
School of Education, Centre for Education Beyond Curriculum (CEDBEC), CHRIST (Deemed to be University), Bengaluru, Karnataka, India
e-mail: kennedy.andrew@christuniversity.in

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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).

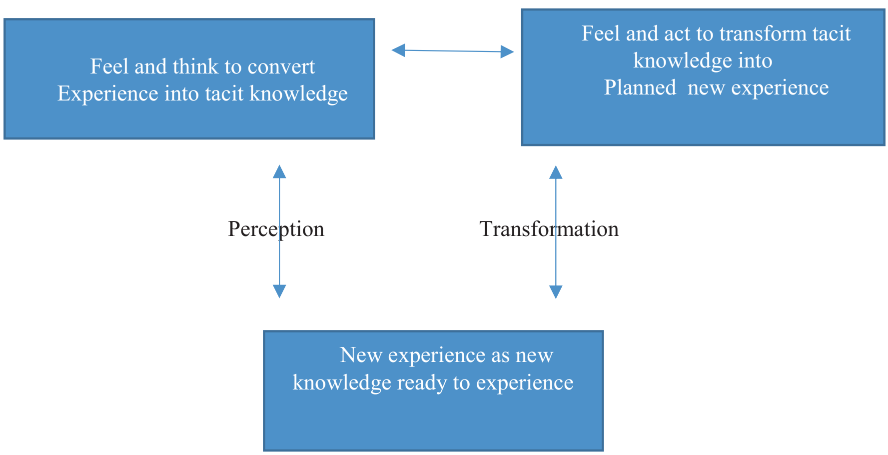

Fig. 1.1 Experiential learning engine to conceptual framework

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