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Correlational Analysis between Brain Dominances and Multiple Intelligences

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***Abstract*—**Aim of this research study is to investigate and establish the characteristics of brain dominances (BD) and multiple intelligences (MI). This experimentation has been conducted for the sample size of 552 undergraduate computer-engineering students. In addition, mathematical formulation has been established to exhibit the relation between thinking and intelligence, and its correlation has been analyzed. Correlation analysis has been statistically measured using Pearson's coefficient. Analysis of the results proves that there is a strong relational existence between thinking and intelligence. This research is carried to improve the didactic methods in engineering learning and also to improve e-learning strategies.

***Keywords*—**Thinking style assessment, correlational analysis, mathematical model, data analysis, dynamic equilibrium.

I. Introduction

COGNITIVE-contextual theories are supportive to explore the way that cognitive processes functions in various contexts. Thinking is an action of the decision-making process through mental images and concepts. Intelligence is an ability to understand complex things and acquire knowledge through their experiences. Reductionist and emergentist approaches provide contrasting views about the functioning of the brain. The former seeks basic elements and lower level explanations. Whereas, later seeks for the higher level organization of cognitive actions [1].

Emergentist view of intelligence theory starts with a Charles Spearman's general ability 'g' conceived as a leading part of the measurement of intelligence and mental energy [2]. Subsequently the final version of Thurstone's, 's' factor analysis of intelligence theory included both the general factor and seven specific factor(s) which includes word fluency, verbal comprehension, spatial visualization, number facility, associative memory, reasoning and perceptual speed [3]. In the heritage of contribution to intelligence theory, Robert Sternberg conceived Triarchic Intelligence Theory that includes analytic, creative and practical intelligences [4]. Howard, Earl Gardner supports Thurstone's notion and proposed Multiple Intelligence (MI) theory initially with seven intelligences, in the second edition having eight intelligences, in the third edition having nine intelligences and in the last edition ten intelligences. Finally, he argued that the packages included into intelligences are independent of one another [5]. In this research MI inventories having eight items have been adopted in this study.

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Piaget's theory recognizes two fundamental cognitive processes that work in somewhat reciprocal fashion. The first part is called assimilation, a process that involves link building with new information into an already existing cognitive structure. The second part emphasizes that there are four major periods involves in intellectual development such as, the sensorimotor period, pre-operational, concrete operational, formal operational and in this stage systematic way of thinking in all logical combinations are possible [6].

The argument of this study is that there is an existence of dynamic equilibrium between thinking and intelligence. Hypothetical model is proposed to illustrate the state of dynamic equilibrium. The latest ongoing research work has reaffirmed the link between cognitive thinking and neurosciences named Benziger Thinking Style Assessment (BTSA). This psychological instrument was developed by Katherine Benziger based on Carl Gustav Jung's typology [7]. Table I enlist the key functions and actions of four quadrants of brain, namely; Basal Left (BL), Basal Right (BR), Frontal Left (FL) and Frontal Right (FR). BTSA is a tool to understand the diverse thinking preferences of the 21st century students, to help them gear up their aspirations to learn and succeed in their lives. The prime objectives of this study are: (a) Identifying the brain dominances of the learner's (b) Identifying the multiple intelligences of the learner's (c) Applying correlational measure between brain dominances and the multiple intelligences.

II. Conceptual Framework

The underpinning relationship between cognitive process of thinking, learning, intelligences and knowledge is shown in Fig. 1. Moreover discussion has been made about the truth and beliefs pertaining to the cognitive structure.

Cognition could be defined as an acquisition of information (perception), selection of information (attention), representation of information (understanding) and retention of information (memory), and organizing of information (LTM storage) to guide, reasoning and coordination of motor outputs [8]. Cognitive structure is an internal organization of conscious and unconscious mental images, objects, associations, and concept. In the history of academics, many scholars have been worrying about formal educational environments that, it is better at selecting talent than developing it [9].

This research is one of the attempts to understand the learner's characteristics to implement a didactic model for learning management system.

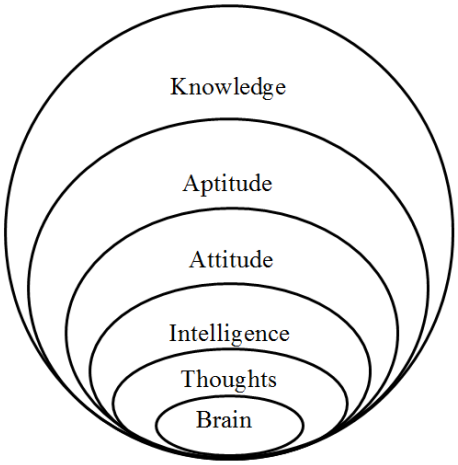

Fig. 1 Association map between cognitive process and knowledge

TABLE I
FEATURES AND CATEGORIES OF OPERATIVE BRAIN LOBES

Brain Dominance	Features
Basel Left (BL)	Stable foundations and Routine, Seeks order, processes, procedures, systems, Sensing is dominant, realistic, grounded, practical
Basel Right (BR)	Peaceful, Seeks feelings, harmony, spirituality, emotional, subjective, takes things personally, closeness with people
Frontal Right (FR)	Adoption and Internal Imaging, Seek meaning, expresses through images and metaphors, Intuition is dominant, uses hunches and speculations, Expressiveness
Frontal Left (FL)	Direction and Decision-making, Seek clarity, criteria, standards, objective measures, benchmarks, Thinking is dominant, analytical, logical, objective, critical

TABLE II
MULTIPLE INTELLIGENCES AND ITS FEATURES

Multiple Intelligences	Features
Verbal-Linguistic (VLI)	Verbal Skills, Ability to read and communicate either orally or in writing
Logical-Mathematical (LMI)	The capacity to discern logical and numerical patterns, Problem solving, Comfortable with the signs, symbols, abstract and mathematical concepts
Musical (MI)	Sensitivity to the sounds, Capacity to pick rhythm and tone
Bodily-Kinesthetic (BKI)	Handle object skillfully, Ability to control one's body movement,
Visio-Spatial (VSI)	Sensitive to images and videos, Capacity to perceive and create mental images
Intrapersonal (IAI)	The capacity to be self-aware, To discern in tune with inner feelings, values, beliefs, and thinking processes
Interpersonal (IEI)	Ability to work and collaborate with others, Respond appropriately to the moods of others
Naturalistic (NI)	Ability to understand the environment, the ability to categorize plants, animals and other objects in nature

Human memory is neither a single entity nor a phenomenon that occurs in a single area of the brain. The architecture of the brain's memory can be organized into (a) Sensory Buffer Memory (SBM) (b) Short-Term Memory (STM) (c) Long-Term Memory (LTM) and (d) Action Buffer Memory (ABM). The functional model of the brain illustrating the intercommunication among all the four memory systems and thinking engine of the brain is discussed in [10]. Functional model of the brain illustrates the intercommunication among all the four memories of the brain and the thinking process of the brain [11].

Thinking is an internal brain process triggered by a range of stimuli, both internal and external. Effective thinkers can spontaneously create internal stimuli to promote deeper thinking. Intelligence is usually defined as the cognitive or mental capacity of an individual. Intelligence and smart thinking usually collaborate with one another to work on empirical information. When thought is processed by intelligence, the resultant product could be said as knowledge. Thinking happens in STM and ABM and the final inferences are stored into LTM through the higher cognitive processes of inferences namely, logical deduction, logical induction, logical abduction, analogy, and modeling. A simple mapping function associated among all the four memories of the brain may be represented as follows:

Perception (SBM) ((Fuzzy Intersection, Model) (Thinking (STM, ABM) → (Model of Inferences) → Intelligence (LTM)

Understanding is the process of attributing meaning to sensory inputs. A set of visual signals representing an external scene would create a corresponding concept-model in our mind. Modeling Field Theory (MFT) [12] is used in the concept-model representation, relationship establishment with existing concept-models, search, retrieval and organization into LTM. This is reinforced by an auditory-linguistic input that, give an identity and meaning. As the sensory signals grow in number and quality, the concept-model grows stronger. These inputs are processed in hierarchically ascendant layers, until a level of satisfaction is reached to identify the object/concept. As cognition grows in sophistication, so it does the higher level of understanding. Brain searches the model to link with an existing knowledge in a combinatorial explosion to fetch and search the concept-model from a high dimensional vector space of data stored in LTM inherently.

The established relationship between the number of inputs-signals and number of concept-model is shown as follows:

$$N(\text{Retrieval of Concept-models from LTM}) = \frac{1}{N}(\text{Input Signals(SBM)})$$

When N (Input Signals (SBM)) = High, N (Concept-models (LTM)) = Low
When N (Input Signals (SBM)) = Low, N (Concept-models (LTM)) = High

Synaptic plasticity plays a vital role in memory and learning in the brain, stronger the input signals stronger the synaptic plasticity happens into LTM. Learning is defined as the process of forming connections between stimuli and responses in the view of behaviorists. Whereas, constructivists assume that all knowledge is constructed from previous knowledge to new knowledge.

Learning could be defined as a change in knowledge or perception, skills, behavior and/or attitudes. It is governed by several factors, such as an individual's existing knowledge, native intelligence, linguistic ability, aptitude, assimilative capacity, processing speed, biological factors, environmental and social conditions and so on. Fuzzy intersection of these all factors could measure the rate of learning. Categories of learning, different forms of learning, mechanism of learning, role of concepts and objects in learning, mathematical model of learning named Real-Time Process Algebra (RTPA) and Object Attribute Relational (OAR) algebra and algorithm for cognitive process of learning were discussed in [13].

Intelligence of human being has been derived ultimately from the characteristics of individual nerve cells, undoubtedly results from synergism. Intelligence might be defined as the ability to process information both qualitatively and quantitatively. Relative correlation between g and the measurement of multiple intelligences have been discussed in [14].

Knowledge could be defined as the sum of all information that a human being possesses at any point in time. Knowledge is sometimes viewed as a concrete manifestation of abstract intelligence, but it is actually the result of an interaction between intelligence (capacity to learn) and situation (opportunity to learn), so is more socially constructed than intelligence [15]. Relationship between intelligences and knowledge is said as, a crystallized intelligence, g(C) or the individual's store of knowledge about the nature of the world and learned operations which can be drawn through solving problems. Whereas, fluid intelligence g(F) is the ability to solve novel problems that depend relatively on stored knowledge as well as the ability to learn [16]. Thus, it may be postulated that intelligence is an explicit and measurable quotient of knowledge, whereas wisdom is the implicit and immeasurable quotient of knowledge.

III. Mathematical Framework

A. Hypothetical Model of Representing an Identical Reactions between Thinking and Intelligence

The challenge of representing the mechanism of brain is due to various factors such as, (a) Genetic and Biological Factors, (b) Chaos with Problems of Testing Models, Methods of Assessment and Multiple Invariance of Mechanisms Across Situations, (c) Noise, (d) Dynamic in nature, (e) Non-linear, (f) Stochastic, (g) Normative, (h) Multiple Modes of Behavior, (i) Incremental Change, (j) Environment Dependence, (k) Sequential Effect etc. However, numerous research activities happening in the last decades towards brain anatomy, educational psychology, and cognitive informatics. These investigations have brought today's calculating machine called 'computer and its intelligences'.

A phenomenological [17] model treats a brain as a "black box". In a simple dynamic equilibrium action, a relationship may be established between thinking and intelligence. In Dynamic Equilibrium, the participating entities are in a constant state of flux, reacting with each other to form new products, and then reacting again to return to their previous states. The state of constant change keeps repeating itself until an external stimulus is introduced to change the state of dynamic equilibrium.

$$T\ (Thinking) \rightleftharpoons I\ (Intelligence) \tag{1}$$

here, there are two reactions were considered: (a) the forward reaction, in which the thinking (T) process or action is converted into intelligence, and (b) the backward reaction, in which an intelligence (I) leads to thinking.

If both of the reactions are elementary level, then the rate of reaction is given by

$$\frac{d[T]}{dt} = -k_f\,[T]_t + k_b\,[I]_t \tag{2}$$

where, k_f - is the rate constant for the forward reaction; k_b - is the rate constant for the backward reaction. The square bracket denotes the concentration or aptitude towards learning. Amount of Learning is direct proportion to K * t Where K – Assimilation power of the learner; t – Amount of time actually spent.

If only T is present at the beginning, time t=0, with a learning aptitude $[T]_0$, the sum of the two learning concentrations, $[T]_0$ and $[I]_0$, at time t, will be equal to $[T]_0$.

$$[T]_t = k_f * [T]_{t-1} \tag{3}$$

$$[I]_t = k_b * [I]_{t-1} \tag{4}$$

$$\frac{d[T]}{dt} = k_f * [T]_t + k_b([T]_t - [T]_0) \tag{5}$$

The solution to the differential equation (6) is

$$[T]_t = \frac{k_b + k_f\, e^{t(k_b + k_f)}}{k_b + k_f}\,[T]_0 \tag{6}$$

Grows exponentially with respect to time only when continuum with thinking learning and concentration.

$$[I]_t = \frac{k_b + k_f\, e^{-t(k_b + k_f)\,t}}{k_b + k_f}\,[T]_0 \tag{7}$$

Loss of information occurs when there is no precision and recall or due to physical or mental illness.

Let t approach infinity, that is, $t \to \infty$, in (6) and (7).

As time tends towards infinity, the learning concentrations $[T]_t \rightarrow \infty$ and $[I]_t$ tend towards constant values at some point of time due to the limit of one's information processing rate and biological limitations. Hicklin envisaged that existence of dynamic equilibrium between information acquisition and loss [18].

$$[T]_\infty = \frac{k_b}{k_b + k_f}\,[T]_0 \tag{8}$$

$$[I]_\infty = \frac{k_f}{k_b + k_f}\,[T]_0 \tag{9}$$

In practice, change of learning concentration is not

measurable after certain period due to the nonlinear dynamics of psychological phenomena. Therefore, we attempt to infer based on trial and error from the overall behavior of the human. Since the learning, concentration does not change thereafter; they are, by definition, equilibrium concentrations.

Now, the equilibrium constant for the reaction is defined as,

$$K = \frac{[I]_{eq}}{[T]_{eq}} \quad (10)$$

It follows that,

$$K = \frac{k_f}{k_b} \quad (11)$$

In general, there will be more than one forward reaction and more than one backward reaction. The overall equilibrium constant is related to the rate constants of the elementary reactions.

$$K = \left(\frac{k_f}{k_b}\right)_1 \times \left(\frac{k_f}{k_b}\right)_2 \times \left(\frac{k_f}{k_b}\right)_3 \times \ldots \quad (12)$$

IV. Materials and Methods Used in Empirical Investigations

A. Survey Goal

The prime objective of this research study is to set the relationship between brain dominances and multiple intelligences.

B. Survey Sample

The targeted sample of this study was drawn chiefly from computer science and engineering based on non-probability sampling type and convenience sampling method.

C. Questionnaire Design

There are two types of cohort panel study has been conducted within a span of six months. Retrospective study is to learn the historical background of the educational psychology. The prospective study is to identify the possible inventories to be utilized in the research. Benziger Thinking Style inventory has been administered for brain dominance identification having 80 items with binary answer. Gardner's Multiple Intelligences assessment has been administered for intelligence identification having 80 items with multiple choices. To empower the participant's responses questionnaire layout has been provided in bi-lingual along with an instructional page and navigational path.

D. Conduction of Survey

Sample size of 100 has been considered for the initial phase of the cross-sectional pilot survey. Consequently, a computer-assisted survey method was adopted using the open source educational software named MOODLE [19]. Design of digital questionnaire has been done using 'Notepad' text editor. To upload the questionnaire into LMS 'GIFT' file format has been used. In order to collate the data, additional efforts were taken in developing the software.

A survey has been carried out with sufficient amount of explanations to the targeted audiences. Even then unavoidable errors have been induced in the responses due to random sampling nature and the cognitive biases of respondents.

TABLE III
Hypothetical Association between Thinking and Intelligence

Brain Dominances/ Intelligences	Dominant Intelligence I	Dominant Intelligence II
Basal Left (BL)	Intrapersonal (IAI)	Naturalistic (NI)
Basal Right (BR)	Musical (MI)	Interpersonal (IEI)
Frontal Right (FR)	Visio-Spatial (VSI)	Bodily-Kinesthetic (BKI)
Frontal Left (FL)	Logical-Mathematical (LMI)	Verbal-Linguistic (VLI)

E. Formulation of Hypothesis

The Tables I and II enlist the traits of BD and MI respectively. Hypothetically established relationship between brain dominances and multiple intelligences has been shown in Table III.

V. Design of Algorithm

A. Data Pre-Processing Algorithms

In this section there are two algorithms have been used in identifying individual's brain dominances and multiple intelligences.

Algorithm: Pre-Processing

Step 1: Calculating the total score for each of the brain quadrants
{
BL = $\sum I_j$
BR = $\sum I_j$
FR = $\sum I_j$
FL = $\sum I_j$
{j → 1 to 20
}
Step 2: Calculating the total score for each element of MI
{
VLI = ∑ Scale value of the items 6, 8, 10, 15, 26, 36, 38, 58, 60 and 69
LMI = ∑ Scale value of the items 5, 11, 12, 19, 23, 33, 37, 46, 56 and 62
MI = ∑ Scale value of the items 2, 4, 14, 20, 28, 34, 45, 59, 74 and 76
BKI = ∑ Scale value of the items 3, 7, 16, 25, 39, 44, 48, 52, 54 and 61
VSI = ∑ Scale value of the items 24, 27, 30, 42, 47, 55, 57, 78, 68 and 70
IEI = ∑ Scale value of the items 21, 31, 41, 49, 53, 67, 71, 72, 75 and 79
IAI = ∑ Scale value of the items 1, 13, 18, 32, 40, 63, 65, 66, 77 and 80
NI = ∑ Scale value of the items 9, 17, 22, 29, 35, 43, 50, 51, 64 and 73
}

VI. Measures and Inferences

A. Demographic Analysis

Tables IV and V shows the number of instances for BD and MI respectively. Table VI shows the correlation measures between the four quadrants of the brain and eight multiple intelligences. Hypothetically established pair matches between BD and MI results are found to be positive. Hypothesis validation has been illustrated in Table VII. Basal brain dominances and frontal left show a partial correlation effect. Although the numbers of instances are lesser for frontal right results were obtained with the highest correlation.

TABLE IV
DEMOGRAPHIC ANALYSIS OF BD

BD	BL	BR	FR	FL
Count	164	283	49	56
%	29.7	51.3	8.9	10.1

TABLE V
DEMOGRAPHIC ANALYSIS OF MI

MI	VLI	LMI	MI	BKI	VSI	IEI	IAI	NI
Count	66	101	33	55	130	69	46	52
%	12.0	18.3	6.0	10.0	23.6	12.5	8.3	9.4

TABLE VI
CORRELATION COEFFICIENTS BETWEEN BD VS MI

BD/MI	VLI	LMI	MI	BKI	VSI	IEI	IAI	NI
BL	0.16	0.23	0.07	0.10	0.09	0.15	0.17	0.20
BR	0.28	0.16	0.21	0.10	0.19	0.22	0.15	0.18
FR	0.24	0.16	0.18	0.24	0.33	0.22	0.14	0.26
FL	0.21	0.27	0.15	0.21	0.27	0.23	0.18	0.24

TABLE VII
HYPOTHESIS VALIDATION

Brain Dominances/ Intelligences	Expected Intelligence	Obtained Intelligence
Basal Left (BL)	IAI and NI	LMI and NI
Basal Right (BR)	IEI and MI	VLI and IEI
Frontal Right (FR)	BKI and VSI	BKI and VSI
Frontal Left (FL)	VLI and LMI	VSI and LMI

B. Implications for the Education

Factors that could affect learning are, biological, environmental, social, cultural, gender, genetic, economic, racial, family heritage, ethnographical, educational intervention, cognitive-enhancing pharmaceuticals, physical exercise, cognitive exercise, longitudinal study of intelligences, brain structure and functions, neural efficiency, brain size, fluid and crystal intelligence, stereotype threat, stress, heritability, power of working memory, self-regulation, N-back task, attention control training, working memory training improves the performance of students in academics etc., have been discussed in [20].

High level of stress hormones damages, specific areas of the brain, namely the neural circuitry and hippocampus are important for regulating attention, short-term memory, long-term memory and working memory. Factors like lack of micronutrients and the presence of environmental toxins, and synthetic food leads to poor intelligences [21].

VII. CONCLUSION

In this research study, an attempt has been made to illustrate a flow between thinking and intelligence through differential calculus. Moreover, an empirical investigation has been done to find the relationship between brain dominances and multiple intelligences. The final inference of this study shows that there is no specific relationship exists between thinking styles and multiple intelligences. This research is carried out in order to understand the psychological traits of learners, in order to fill up the gap between learning technology and pedagogy.

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