Neural Networks' Application for Comparative Study of Academic Performance Considering Two Diversified Instructional Methodologies

Hassan Mustafa[1], and Fadhel Ben Tourkia[2]

***Abstract*—**This paper presents a realistic and fairly interdisciplinary approach to perform comparative analysis and evaluation of academic performance of two applicable educational packages (modules). Both have considered as diversified instructional methodologies with effective utilization of visual and auditory multisensory (multimedia) teaching for two different topics taught to children with average age about 11 years old. By more details, one of these topics concerned with learning "How to solve long division problem?". That has carried out by sequential processes: Divide, Multiply, Subtract, Bring Down, and repeat (if necessary). However, the second is associated with the critical instructional issue of "how to teach/learn reading?" Both adopted modules have carefully designed in order to develop two multimedia educational packages to be applicable for both above adopted topics at children's classrooms. Interestingly, obtained results proved to have significant improved distinction for the applied multisensory methodology (experimental groups) versus the classical one (control groups). That improvement has been clearly observed not only regarding average (mean) values of academic achievement, but also considering coefficient of variation which improvement results in more consistency of the statistical distribution of academic achievement's values. Furthermore, both multisensory designed modules proved to be in well agreement likewise the Artificial Neural Network (ANN) associative memories theory, cognitive multimedia, and classical conditioning.

Keywords—Associative memory, Computer Assisted Learning, Multimedia educational packages, Neural Networks Modeling.

I. Introduction

A growing community represents the field of learning sciences internationally. Many experts now recognize that conventional ways of conceiving knowledge, educational systems and technology-mediated learning are facing increasing challenges in this time of rapid technological and social changes. Since beginning of last decade, Artificial Neural Networks (ANN^{S}) models have adopted to investigate systematically mysteries of human brain, the most complex biological neural system, [1]. Additionally, modeling of human brain functions considered as recent interdisciplinary evaluation trend by educationalists in learning science incorporated Nero-physiology, psychology, and cognitive science, [2]. This piece of research adopts the conceptual approach of ANN^{s} models inspired by functioning of highly specialized biological neurons based on the organization the brain's structures/substructures. In the context of functions of biological neurons, overwhelming majority of neurobiologists' research efforts has recently revealed findings about common increasingly sophisticated role adopted by Artificial Neural Networks (ANN^{s}). This role applied commonly for systematic realistic modeling of interdisciplinary disciplines incorporating neuroscience, education, and cognitive sciences. During the nineteenth of last century, technologies of computer, Information, and mobile devices play an essential role in how individuals work, live, play, and, more importantly, learn. Furthermore, this decade (1990-2000) is called decade of the brain as announcement in 1989 WHITE HOUSE REPORT in U.S.A. [3]. Over the past quarter century, there has been much concern about the state of science, technology, engineering, and mathematics (STEM) education in U.S. schools and its effect on the future of U.S. competitiveness in a global marketplace [4].

Recently, evolutionary computer based trend has been adopted by educationalists while interacting in practical educational field (classrooms) with their learners (children). Consequently, educational organizations of all sizes — even the smallest schools and businesses — rely on recent interdisciplinary technological trend for supporting them in performing more efficient and effective operation via improvement of academic achievement [5]. The rest of this paper organized in four main sections as follows. A generalized overview of interactive learning/teaching model based on ANN^{S} presented at the second section. At the two third and fourth sections, adopted educational topics' issues have described briefly: each has concerned with one of adopted topics. An overview of the educational topic issue named "How to solve long division problem?" introduced at third section. Furthermore, obtained academic achievement results of a control group have statistically compared versus an experimental group in a classroom. Similarly, the fourth section presents a statistical

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comparative evaluation of obtained results for the other educational topic issue namely: "how to teach/learn reading language?" .Finally, some interesting conclusive remarks given at the last fifth section.

II. GGENERALIZED INTERACTIVE LEARNING /TEACHING MODEL

This section presents by its two subsections (A&B) respectively: details for basic realistic ANN modeling of interactive learning processes. In addition to mathematical formulation of natural brain learning phenomenoProcess

A. Simplified Overview for Interactive Learning Process

This section presents a suggested ANN model simulating realistically how learning to read could be performed. The adopted model considers the associative memory function originated brain working memory. By more details, the objective of associative function implies that children must code written words and letters; this code is called orthographic word-form. The reading goal is carried out by association (translation) of orthographic word-from code into a spoken word (phonological word-form code) [8]. In other words, the visually recognized written (code) pattern should be transferred and pronounced in accordance with its associated code as correspondingly correlated auditory code pattern which has been stored previously into working memory[9].

The extremely composite biological structure of Human brain results in everyday observed behavioral learning brain processes (functions). Specifically, at the educational field, it is observable that learning process performed by human brain is affected with a simple Neuronal performance mechanism [10].

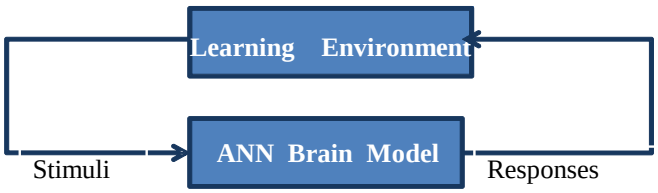

Figure 1. A generalized schematic diagram of an ANN brain model interacts with learning environment considering input stimuli and outputs response signals.

At the educational field, such learning processes generally performed in agreement with the neuronal self-organized learning principle. This learning principle could be modeled relevantly by the interactive relation among input stimuli and output responses signals. That is shown schematically by a diagram structure at Figure 1. This diagram decomposed into two level brain neural networks model concerned by autonomous learning by interaction with learning environment [11].

At Figure 1, an interactive learning model through stimulating signals is well qualified in performing realistic simulation for evaluating learner's performance. That Figure, illustrates inputs to the neural network learning model which provided by stimuli unsupervised learning environment [6].The correction signal for the case of learning with a teacher is given by responses outputs of the model will be evaluated by either the environmental conditions (unsupervised learning) [7] or by the instructor. The instructor plays a role in improving the input data (stimulating learning pattern), by reducing noise and redundancy of learning model pattern input [8]. In accordance with instructor's experience, he provides illustrated model with clear data by maximizing learning environment signal to noise ratio [7].

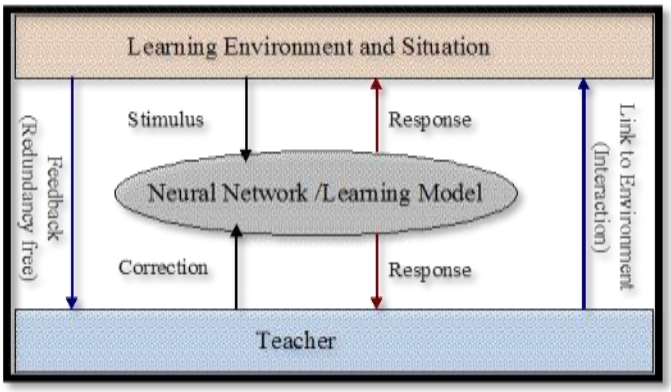

Fig. 2. A simplified diagram for an interactive learning process.

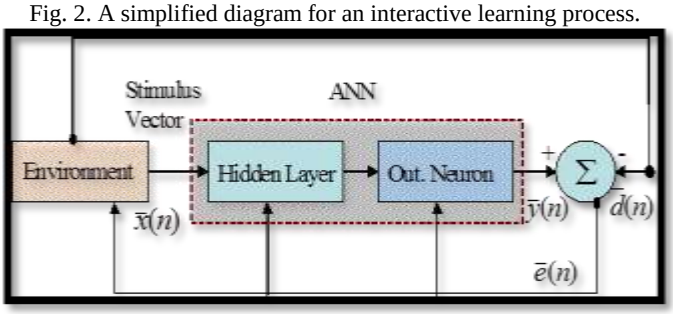

Fig. 2. Generalized ANN block diagram simulating two diverse learning paradigms adapted from [1].

B. Mathematical Formulae of Natural Learning Phenomenon

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The generalized simulation of two diverse learning paradigms is given at Fig. 2. Both paradigms are presented realistically: by interactive learning / teaching process, as well as other self-organized (autonomous) learning. By some details, firstly is concerned with classical (supervised by tutor) learning observed at our classrooms (face to face tutoring). Accordingly, this paradigm proceeds interactively via bidirectional communication process between teacher and his learner (s).However, secondly other learning paradigm performs self-organized (autonomously unsupervised) tutoring process. Referring to above Fig. 2, the error vector $\bar{e}(n)$ at any time instant (n) observed during learning processes is given by:

$$\bar{e}(n) = \bar{y}(n) - \bar{d}(n) \quad (1)$$

Where $\bar{e}(n)$ is the error-correcting signal that is controlling adaptively the learning process, and $\bar{y}(n)$ is the output signal of the model. $\bar{d}(n)$ is the desired numeric value(s). Moreover, the following four equations deduced:

$$V_k(n) = X_j(n) W_{kj}^T(n) \quad (2)$$

$$Y_k(n) = \varphi(V_k(n)) = (1 - e^{-\lambda V_k(n)}) / (1 + e^{-\lambda V_k(n)}) \quad (3)$$

$$e_k(n) = |d_k(n) - y_k(n)| \quad (4)$$

$$W_{kj}(n+1) = W_{kj}(n) + \Delta W_{kj}(n) \quad (5)$$

Where X is input vector and W is the weight vector. φ is the activation function. Y is the output. e_k is the error value and d_k is the desired output. Note that $\Delta W_{kj}(n)$ is the dynamical change of weight vector value. Above four equations are commonly applied for both learning paradigms: supervised (interactive learning with a tutor), and unsupervised (learning though student's self-study). The dynamical changes of weight vector value specifically for supervised phase given by:

$$\Delta W_{kj}(n) = \eta e_k(n) X_j(n) \quad (6)$$

Where η is the learning rate value during the learning process for both learning paradigms. However, for unsupervised paradigm, dynamical change of weight vector value igiven by:

$$\Delta W_{kj}(n) = \eta Y_k(n) X_j(n) \quad (7)$$

Noting that $e_k(n)$ in (6) is substituted by $y_k(n)$ at any arbitrary time instant (n) during the learning process.

III. DESCRIPTION OF THE FIRST EDUCATIONAL TOPIC

This section concerned with performing both of diversified instructional methodologies while teaching / learning the mathematical topic "How to solve long division problem?" [13][14].That specific mathematical topic solved via sequential processes as: Divide, Multiply, Subtract, Bring Down, and repeat (if necessary) [14] [15]. A simplified flowchart for a computer-teaching program given at Figure 3. It presents teaching of long division that announced to be the focus of intense arguments in the world of mathematical education [16]. Herein a special attention paid to some research studies in education show that use of recent educational technology can help student to improve their academic achievements on considering Artificial Neural Networks (ANN^S) modeling [16][17][18].

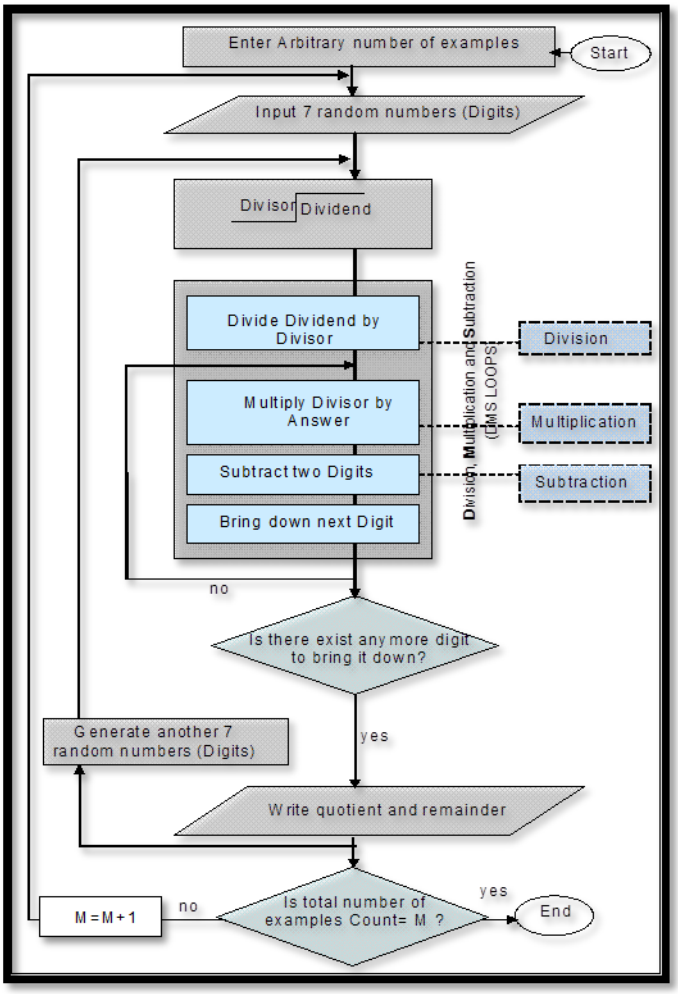

Figure 3. A simplified macro-level flowchart describing briefly algorithmic steps for the suggested CAL package.

Briefly, the introduced work inspired by a strong belief that interdisciplinary combining of (ANN^S) modeling with observed challenging phenomenal educational issues for their investigational study, analysis, and evaluation. Furthermore, the overwhelming majority of neuroscientists have adopted the concept which suggests that huge number of neurons in addition to their synaptic interconnections constituting the central nervous system with its synaptic connectivity performing dominant roles for learning processes in mammals besides human [19][20]. More specifically, this motivation is supported by what revealed by National Institutes of Health (NIH) in USA that children in elementary school, may be qualified to learn "basic building blocks" of cognition and that after about 11 years of age, children take these building blocks and use them [21][22]. Interesting results revealed in valuable in sequential steps. The obtained results declare the significant distinction of multisensory instructional methodology as follows.

A. Tabulated results

Teaching Methodology	Children's average (Mapped) Score [%	Variance σ	Standard deviation $\sqrt{\sigma}$	Coefficient of variation $\rho=\sqrt{\sigma}/M$
Classical	35.733	465.26	21.57	0.60
CAL (with tutor's voice)	71.267	473.5	21.76	0.31

Table.1: Illustrates statistical analysis of above obtained learners' achievement outcome.

B. Graphical results

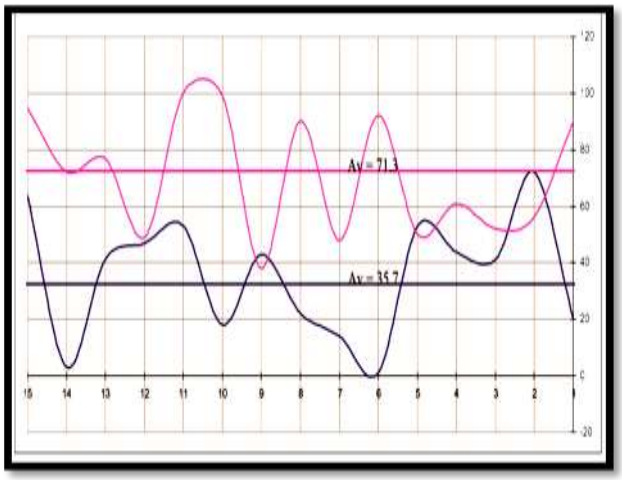

Fig. 4 Illustrates graphical Comparison for Classical Learning versus multisensory module (associated with tutor's voice) considering children's academic achievement

VI. DESCRIPTION OF THE SECOND EDUCATIONAL TOPIC

In the context of teaching children how to read, individually, intrinsic different number a set of highly specialized neurons at the corresponding visual brain area contribute to the perceived sight (seen) signal is in direct proportionality with the correctness of identified depicted / printed images. These images represent the orthographic word-from has to be transferred subsequently into a spoken word (phonological word-form) during reading process. Furthermore, individual intrinsic characteristics of such highly specialized neurons (in visual brain area) influence directly on the correctness of identified images associated with orthographic word-from.

The reading brain function is mainly concerned with carrying out the associative memory brain function originated working part of brain memory. The objective of associative function implies that children must code written words and letters; this code called orthographic word-form. Association (translation) of orthographic word-from code into a spoken word (phonological word-form code) carries out the reading goal [23]. In other words, the visually recognized written (code) pattern should be transferred and pronounced in accordance with its associated code as correspondingly correlated auditory code pattern which has been stored previously into working memory [24][25][26]. Referring to (Fig.5&Fig.6), suggested models obeys that concept as the two inputs I_1, I_2 represent sound (heard) stimulus which simulates *phonological word-form* and visual (sight) stimulus which simulates *orthographic word-from* respectively. The post-processed outputs O_1, O_2 are corresponded to reading and dictating (writing) processes respectively. It is worthy to note that in accordance with autonomous learning paradigm the suggested model obeys the original Hebbian learning rule [7]. As the children perform, thir reading tasks based on previously learned lessons former experienced acquired knowledge. Furthermore, the simulated reading process flows that model is analogously straightforward to the Pavlovian conditioning learning [27]. The input stimuli to the model considered either conditioned or unconditioned stimuli. Visual and audible signals developed for training (interchangeably) as model's inputs to obtain desired (post-processed) output model's responses. Moreover, the model obeys elaborate mathematical analysis for Pavlovian learning process [28]. Additionally, the model modified following general Hebbian algorithm (GHA) and correlation matrix memory [6] [24] [25]. The adopted model designed following simulation of the previously measured performance of classical conditioning experiments. The model design concept presented after the mathematical transformation of some biological hypotheses. In fact, these hypotheses derived according to cognitive/ behavioral tasks observed during the experimental learning process. It is noticed that in the below simple structure given at Fig.6, it drives an output response reading function (pronouncing) that is represented as O_1. However, the other output response represented as O_2 obtained when input sound considered as conditioned stimulus. Hence visual recognition as condition response of the heard letter/ word obtained as output O_2. In the context of neurobiology, the strength of response signal is dependent upon the transfer properties of the output motor neuron stimulating salivation gland. Lettered circles A, B, C, and D represent a neuron cell body. However, synaptic junctions Wij between neuron (I) and neuron (j) .The output signals released out from sensory sound and sight neurons A and C represented by y1 and y2 respectively denote lines connecting cell bodies. The output signals released out from sensory sound and sight neurons A and C are represented by y_1 and y_2 respectively.

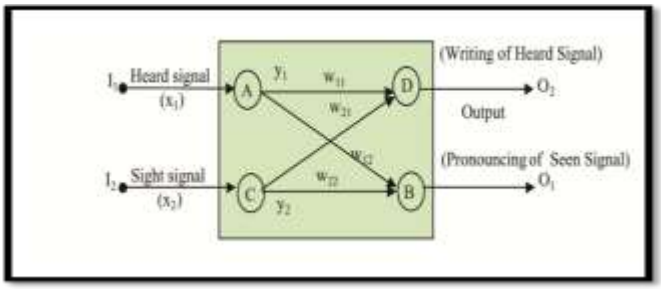

Fig.5. Generalized reading model which predented as pronouncing of some word (s) considering input stimuli and output responses.

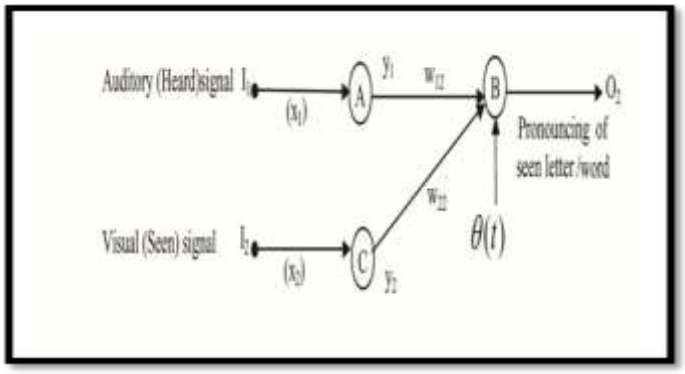

Fig. 6. The structure of the first model where reading process is expressed by conditioned response for seen letter/ word

C. Graphical results

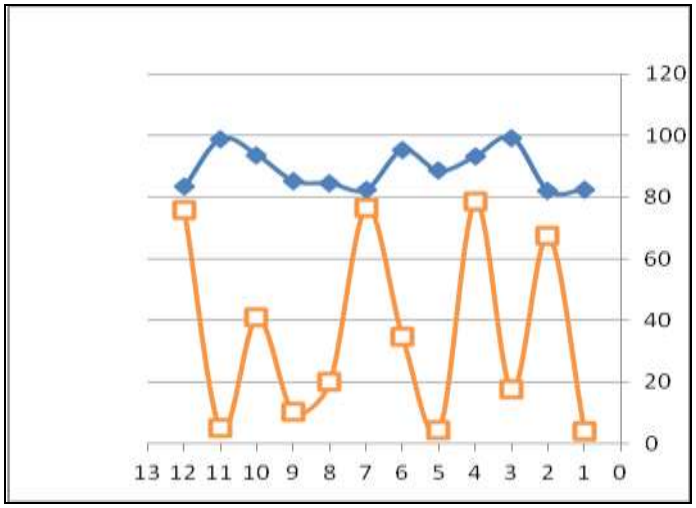

Fig.7 illustrates the obtained academic Achievement results for assessments of two applied **Classical (A)** and **Multisensory Computer Based (B)** instructional methodologies:

CONTROL GROUP (CLASSICAL METHODOLOGY)._____ (A)

EXPERIMENTAL GROUP (COMPUTER BASED METHODOLOGY). _____(B)

D. Tabulated results

TABLE.2 ILLUSTRATES STATISTICAL ANALYSIS OF ABOVE OBTAINED CASE STUDY RESULTS (ACADEMIC ACHIEVEMENT) OF THE CONTROL GROUP

Sum of total Students' outcomes score (Marks)	Mean of total Students' outcomes (Marks) M [%]	Variance σ	Standard deviation $\sqrt{\sigma}$	Coefficient of variation $\rho = \sqrt{\sigma} / M$
505.1	**36.08**	**812.82**	**28.51**	**0.79**

TABLE.3 ILLUSTRATES STATISTICAL ANALYSIS OF ABOVE OBTAINED CASE STUDY RESULTS (ACADEMIC ACHIEVEMENT) OF THE EXPERIMENTAL GROUP

Sum of total Students' outcomes score (Marks)	Mean of total Students' outcomes (Marks) M [%]	Variance σ	Standard deviation $\sqrt{\sigma}$	Coefficient of variation $\rho = \sqrt{\sigma} / M$
1249.8	89.27	6.58	**2.57**	**0.029**

V. CONCLUSIONS AND DISCUSSIONS

This piece of research comes to the following six interesting conclusion remarks:

- ANN modeling is a realistic and relevant tool to obtain interesting results in the context of student's learning performance.
- Herein, evaluation of academic achievement performance presented via statistical analysis approach that provides educationalists with unbiased fair judgment tool for quality for any of instructional methodologies. The comparative evaluation of statistical analysis results in clearly improvement has been not only regarding average M [%] (mean) values of academic achievement, but also considering coefficient of variation ρ which improvement results in more consistency of the statistical distribution of academic achievement's values
- This paper adopted two educational methodologies modules (applied for teaching a mathematical topic and Arabic language reading). One of these methodologies considers classical (conventional) instructional methodology. However, the other considered simultaneous visual and audible learning materials. Ir revealed dependency of learning / teaching effectiveness upon children's sensory cognitive systems. As shown at Tables (2&3)
- Detailed comparative assessments for presented Computer based module tutoring methodology versus conventional tutoring methodology resulted in superiority of learning performance quality (better academic achievement) after application of simultaneous visual and auditory materials. That's shown at the two figures (Fig.4& Fig. 7), they are concerned respectively with the mathematical topic of "How to solve long division problem?", and with the topic of "how to teach/learn reading language?".
- Interestingly, the above obtained results agree well with Lindstrom's findings that participants could only remember 20% of the total learning materials when they were presented with visual material only, 40% when they were presented with both visual and auditory material, and about 75% when the visual and auditory material were presented simultaneously [29].
- Finally, for future extension of presented research work, it is highly recommended to consider more elaborate

investigational analysis and evaluations for other behavioral learning phenomena observed at educational field (such as learning creativity, improvement of learning performance, learning styles,……etc.) using ANNs modeling. As consequence of all given in above, it is worthy to recommend realistic implementation of ANNs models , to be applicable for solving educational phenomena issues related to cognitive styles observed at educational phenomena and/or activities.

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