On Teaching Quality Improvement of a Mathematical Topic Using Artificial Neural Networks Modeling (With a Case Study)

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Abstract
This paper inspired by simulation by Artificial Neural Networks (ANNs) applied recently for evaluation of phonics methodology to teach children "how to read". A novel approach for teaching a mathematical topic using a computer aided learning (CAL) package applied at educational field (a children classroom). Interesting practical results obtained after field application of suggested CAL package with and without associated teacher's voice. Presented study highly recommends application of a novel teaching trend based on behaviorism and individuals' learning styles. That is to improve quality of children mathematical learning performance.
Keywords: Artificial Neural Networks, Learning Performance Evaluation, Computer Aided Learning, Long Division Process, Associative Memory.

1. Introduction

It is announced (in U.S.A.) that last decade (1990-2000) named as Decade of the brain [1]. Accordingly, neural network theorists as well as neurobiologists and educationalists have focused their attention on making interdisciplinary contributions to investigate essential brain functions (learning and memory). Recently, Artificial Neural Networks (ANNs) combined with neuroscience considered as an interdisciplinary research direction for optimal teaching children methodology how to read. This direction motivated by a great debate given at, [2] as researches at fields of psychology and linguistic were continuously cooperating in searching for optimal methodology which supported by educational field results. Nevertheless, during last decade phonics methodology is replaced –at many schools in U.S.A.- by other guided reading methods that performed by literature based activities [3] . More recently, promising field results are obtained [4] that support optimality of phonics methodology for solving learning/teaching issue "how to read?" [5-6]. Additionally, recent mathematical modeling for phonics methodology has been presented in details, [7]. Herein, this optimal approach adopted for improving teaching/ learning performance of a mathematical topic to children of about 11 years age. The suggested mathematical topic is teaching children algorithmic process for performing long division. Specifically for two arbitrary integer numbers chosen in a random manner (each composed of some number of digits). By detail, adopted principal algorithm for applied Computer Aided Learning (CAL) package consisted of five steps follows. Divide, Multiply, Subtract, Bring Down, and repeat (if necessary), [8]. For more details about recent view concerned with the effect of information technology computer (ITC) on mathematical education, it is advised referring to, [9]. The rest of this paper is organized as follows. At next section, a basic interactive educational model is presented with a generalized block diagram. Obtained results after application of suggested CAL package at the case study at next third section, in addition obtained simulation results. At the last forth section some interesting conclusions in addition to suggestions for future work are presented. Finally, an Appendix is given for simplified flow chart of adopted CAL package.

2. Basic Leaning/Teaching Model

Generally, practical performing of learning process - from neurophysiologic P.O.V. - utilises two basic and essential cognitive functions. Both functions are required to perform efficiently learning / teaching interactive process in accordance with behaviourism, [10-12], as follows. Firstly, pattern classification/recognition function based on visual/audible interactive signals stimulated by CAL packages. Secondly, associative memory function is used which is originally based on classical conditioning motivated by Hebbian learning rule. Referring to Fig.1 shown in below, the illustrated teaching model is well qualified to perform simulation of above mentioned brain functions. Inputs to the neural network learning model at that Figure, are provided by environmental stimuli (unsupervised

learning).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) or by the teacher. Finally, the tutor plays a role in improving the input data (stimulating learning pattern), by reducing noise and redundancy of model pattern input. That is according to tutor's experience, he provides the model with clear data by maximizing its signal to noise ratio. However, that is not our case which is based upon unsupervised Hebbian self-organized (autonomous) learning, [13-14]. Details of mathematical formulation describing memory association between auditory and visual signals are given at,[7].

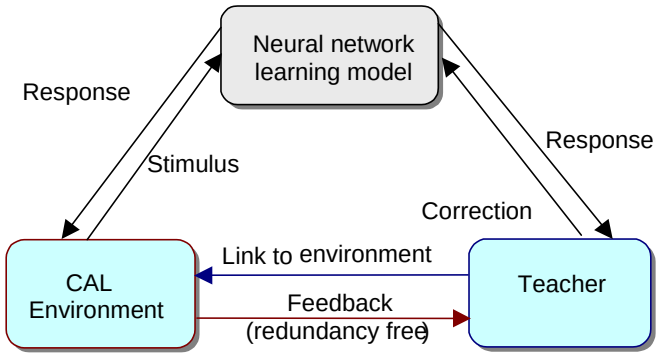

Fig.1: Illustrates a general view for interactive educational process, adapted from [6].

3. Results

The results obtained after performing practical experimental work in classroom (case study) is shown at next subsection 3.1. Additionally, at subsection 3.2 realistic simulation results are introduced. Interestingly, it is clear that both obtained results (practical and simulation) are well in agreement and supporting each other.

3.1 Case Study Results

A learning style is a relatively stable and consistent set of strategies that an individual prefers to use when engaged in learning [15-16]. Herein, our practical application (case study) adopts one of these strategies namely acquiring learning information through two sensory organs (student eyes and ears). In other words, seen and heard (visual and audible) interactive signals are acquired by student's sensory organs either through his teacher or considering CAL packages (with or without teacher's voice). Practically, children are classified in three groups in according to their diverse learning styles (preferences).

The two tables (Table.1 & Table.2) given in below illustrate obtained practical results after performing three different learning experiments. At table.1, illustrated results are classified in accordance with different students' learning styles following three teaching methodologies. Firstly, the classical learning style is carried out by students-teacher interactive in the classroom. Secondly, learning is taken place using a suggested software learning package without teacher's voice association. The last experiment is carried out using CAL package that is associated with teacher's voice. This table gives children's achievements (obtained marks) considering that maximum mark is 100. The statistical analysis of all three experimental marking results is given in details at Table.2 shown in below.

Table.1: Illustrates students' marks after performing three educational experiments.

Classical Learning	**35**	**43**	**29**	**50**	**37**	**17**	**10**	**60**	**20**	**48**	**15**	**55**	**40**	**8**	**20**
CAL without Voice	**39**	**29**	**52**	**60**	**50**	**68**	**62**	**30**	**55**	**42**	**40**	**59**	**48**	**70**	**2**
CAL with Voice	**65**	**70**	**50**	**75**	**45**	**50**	**62**	**90**	**85**	**50**	**80**	**90**	**58**	**55**	**60**

Teaching Methodology	Students' average Achievement score (M)	Variance σ	Standard deviation $\sqrt{\sigma}$	Coefficient of variation $\rho = \sqrt{\sigma} / M$	Improvement of teaching Quality
Classical	32.46	265.32	16.28	0.50	-
CAL (without tutor's voice)	46.80	297.49	17.24	0.36	44.1%
CAL (with tutor's voice)	64.33	283.42	16.83	0.26	98.2%

Table.2: Illustrates statistical analysis of above obtained children's marks.

3.2 Simulation Results

The suggested ANN model adapted from realistic learning simulation model given at [6] with considering various learning rate values. It is worthy to note that learning rate value associated to CAL with teacher's voice proved to be higher than CAL without voice. Simulation curves at Fig.2 illustrate statistical comparison for two learning processes with two different learning rates. The lower learning rate ($\eta = 0.1$) may be relevant for simulating classical learning process. However, higher learning rate ($\eta = 0.5$) could be analogously considered to indicate (approximately) the case of CAL process applied without teacher's voice.

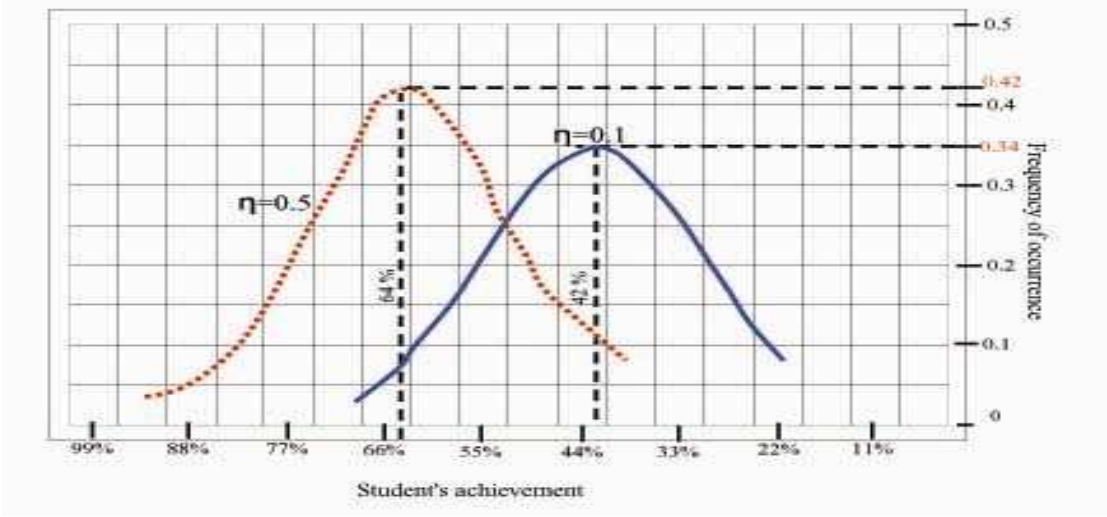

Fig.2 Illustrates Simulation results presented by statistical distribution for children's (students) achievements versus the frequency of occurrence for various achievements values, at different learning rate values ($\eta = 0.1$& $\eta = 0.5$).

Learning Rate value	Children's average Achievement score (M)	Variance σ	Standard deviation $\sqrt{\sigma}$	Coefficient of variation $\rho = \sqrt{\sigma} / M$	Improvement of teaching Quality
η=0.1	42	428.5	20.7	0.61	-
η=0.5	64	918.1	30.3	0.47	66%

Table 3: Illustration of simulation results for different learning rate values η.

4. Conclusion

This paper comes to two interesting conclusive remarks given as follows:

- Evaluation of any CAL package quality is measured after statistical analysis of educational field results. So, above suggested strategy provides specialists in educational field with fair unbiased

judgment for any CAL package. That is by comparing statistical analysis of simulation results with natural analysis of individual differences obtained in by practice.

- After practical application of our suggested multimedia CAL package (case study), interesting results obtained considering diverse individuals' learning styles. Obtained results are depending only upon two cognitive sensory systems (visual and/or audible) while performing learning process.
- Consequently, by future application of virtual realty technique in learning process will add one more sensory system (tactile) contributing in learning process. So, adding of the third sensory (tactile system) means being more promising for giving more additive value for learning/teaching effectiveness. Finally, for future modification of suggested CAL package measurement of time learning parameter will be promising for more elaborate measurement of learning performance in practical educational field (classroom) application. This parameter is recommended for educational field practice, [17] as well as for recently suggested measuring of e-learning systems performance [18].

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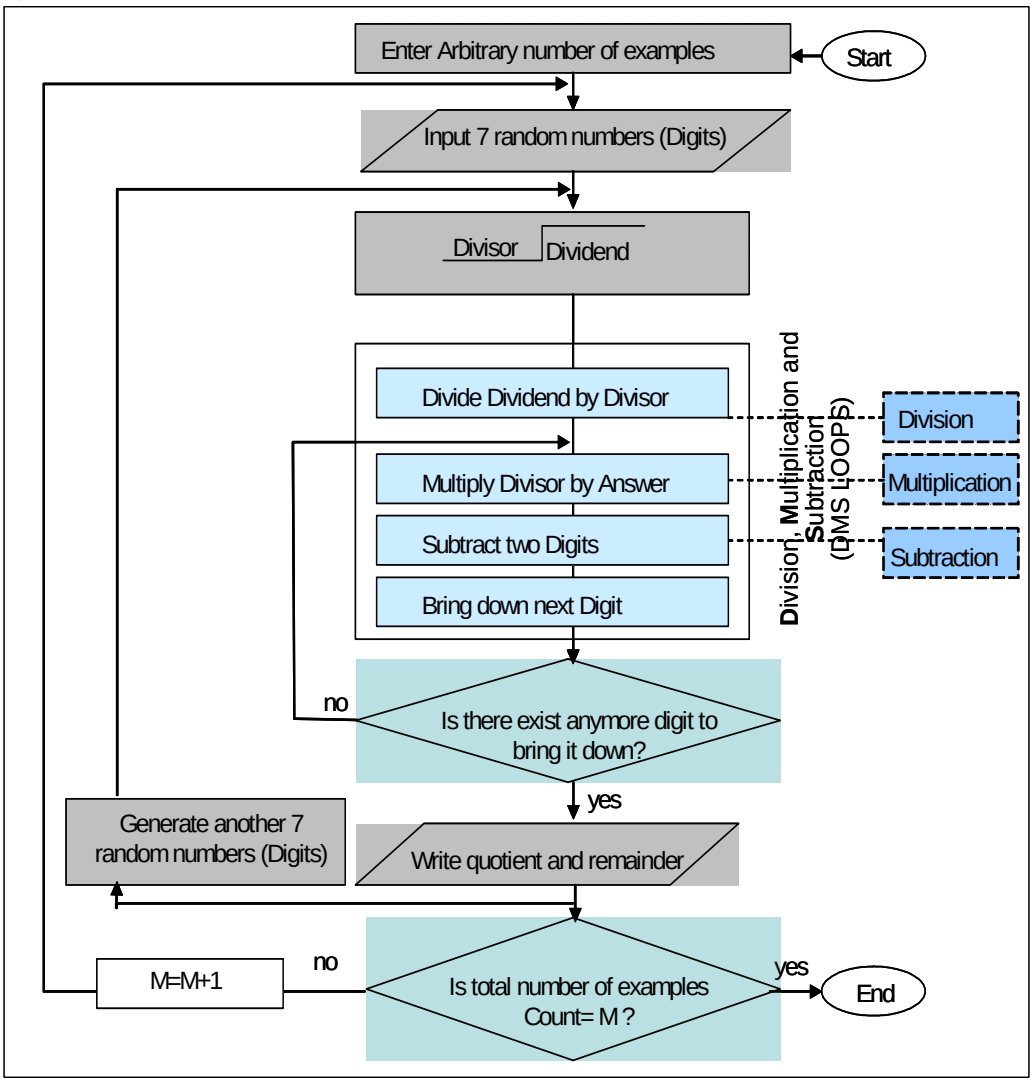
APPENDIX



The shown figure in the above illustrates a simplified macro-flowchart describing briefly algorithmic steps for CAL package designed under supervision of this manuscript's authors,(by Eng. Mohammed H. Kortam). That is according to above long division principles given at above reference [8].