ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 11, May 2014

On Realistically Optimal Evaluation and Analysis of Software Learning Packages' Performance Using Neural Networks

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Abstract*— This paper addresses a challenging problem concerned basically with realistic optimal computer-based educational simulations. More specifically, it searches for an optimally designed computational tool(s), such as software learning package(s), applied to teaching a specified curriculum in classroom. Herein, quantitative evaluation as well as statistical analysis of the learning environment nature have been considered for optimal learning systems' performance. Recently, this learning issue has gained significance due to the integration of information technology into educational/instructional practical operations. Accordingly, two learning parameters -that are candidates to measure effectiveness and efficiency of such packages- are elected to support the optimal selection of a relevant software learning package SWLP. These parameters -after establishing how to measure results and performance of the learning process- are: the output learning level, which evaluates obtained educational achievement, and time response considered in fulfillment of a pre-assigned educational achievement/learning level. Artificial Neural Networks (ANNs) modeling is adopted for the simulation of a realistic practical learning processes' performance, as well as software learning packages' evaluation and testing. Additionally, herein an Artificial Neural Network (ANN) model is presented. Which is based on guided-error correction learning (learning with a teacher). Therefore, it is used as a realistic simulating tool aiming at quantitative/statistical evaluation of the learning process under investigation. Consequently, presented ANN model considered both students' individual differences as well as SWLPs employed as virtual teacher in a computer course curriculum. Two learning parameters are considered during the running of the presented model. Namely, learning convergence (response) time, and secondly, the achievement (output) learning level (amplitude) response. It is worthy to note that obtained simulation results were well supported by the case study results that have been recently published.

***Index Terms*— Educational simulations, Neural Network Modeling, Computer Assisted Learning, Learning Performance Evaluation.**

I. INTRODUCTION

Generally, educationalists have been recently interesting in searching for optimal model for software learning packages designed as computationally assisting learning tools [1][2]. By the end of last decade, it is announced that modeling and simulation is breaking out from traditional areas of use (e.g., aviation and research) and emerging as an increasingly important tool for education and training [3]. Therefore, this paper addresses a challenging educational issue which basically concerned with optimality of realistic computer-based educational simulation [4]. Specifically, it searches for optimal designed computational tool (a software learning package) applicable for teaching some specific curriculum in a classroom. Herein, quantitative evaluation as well as statistical analysis have presented for learning environmental effect on two distinguished learning parameters that are relevant to select optimal learning systems' performance. Each of two parameters is adopted to support optimal selectivity of a relevant software learning package (SWLP).Both are candidates for measuring effectiveness and efficiency of learning packages under consideration. While performing the learning process, measured relevant parameters are: obtained outcome learning level (educational output achievement), and time response considered in fulfillment of a pre-assigned educational achievement/learning level (convergence learning time).Due to excessive progress in applicable information and computational intelligence technologies at fields of education and computer sciences, both learning parameters have become more significantly integrated with educational / instructional field operations in classrooms [5]. Recently Artificial Neural Networks (ANNs) modeling is adopted for the simulation of a realistically practical learning processes' performance, as well as software learning packages' evaluation and testing [6]. Additionally, adopted (ANN) model which presented herein is based on supervised guided-error correction learning (learning with a teacher).

Consequently, it is relevant to consider such model as a realistic simulating tool aiming to introduce quantitative and statistical evaluation of the learning process under investigation. Therefore, running of presented ANN model takes into account both students' individual differences as well as SWLPs which employed for virtual teaching of basic computer course curriculum, in addition to teaching one selected mathematical topic. Both introduced learning parameters have been statistically analyzed and evaluated during running the adopted ANN model similarly to that published at [6]. Therefore, for any arbitrary student's time response (convergence learning time) differs in accordance

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
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with their individual differences. More precisely, In the case of an overcrowded classroom, not all children are equal. There are some students who may need more help than others [7]. Consequently, they have to contribute tuning with larger number of neurons as given recently at [8]. Therein, this differences presented by the effect of Neurons' number on percentage degree of lesson focusing which analogously to getting tuning status in resonance circuit [8]. Finally, it is noticeable by the end of this paper that obtained simulation results were well supported by some case studies' results published recently [1][9][10].

The rest of this paper is organized as follows. The basic of teaching /learning modeling and its relation with ANN learning paradigms is presented at second section which constitutes of two subsections (A&B). At subsection A a general view for interactive educational process is presented. However, ANN Modeling of natural learning phenomenon is introduced at subsection B At the third and fourth sections, comparison between obtained learning performance results versus obtained simulation results are presented. At the third and fourth sections, two comparisons have introduced for considering two measurable relevant learning parameters: time response requested in fulfillment of a pre-assigned educational achievement / learning level (convergence learning time), in addition to obtained learning achievement level (educational output outcome) respectively. An interesting mapping of time response results into learning outcomes is presented at the fifth section. At the sixth section, some conclusive remarks are finally introduced by the end of this paper.

II. GENERAL VIEW FOR INTERACTIVE EDUCATIONAL PROCESS

In this section, two figures (1 & 2) have been depicted in below. Both figures illustrate the interdisciplinary approach which concerned with measuring learning performance phenomenon using ANN. More detailed illustrations of both figures are given at the two subsections (*A & B*) respectively as follows.

A. General View for Interactive Educational Process

At Figure 1, an interactive teaching model through stimulating signals (by SWL packages) is well qualified in performing simulation for evaluation of student's learning performance. At this Figure, inputs to the neural network learning model are provided by environmental stimuli (unsupervised learning) [11].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) [12] 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 [13]. In accordance with instructor's experience, he provides illustrated model with clear data by maximizing learning environment signal to noise ratio [13] [14].

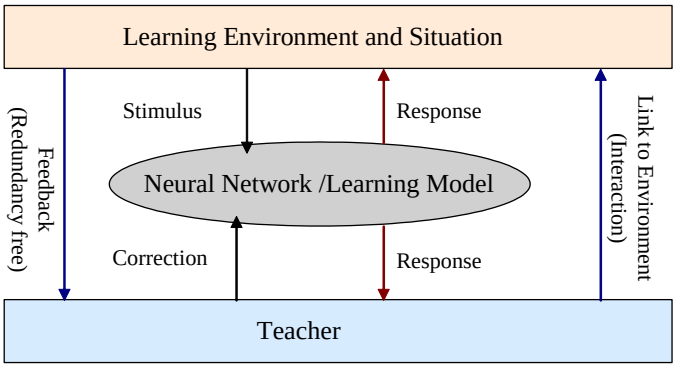

Fig. 1. Simplified view for interactive educational process.

B. ANN Modeling of Natural Learning Phenomenon

Figure 2 illustrates generalized simulation of two diverse learning paradigms. It presents realistically both paradigms: 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.

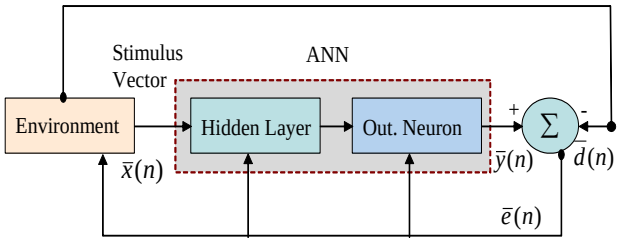

Fig. 2. Generalized ANN block diagram simulating two diverse learning paradigms adapted from [19].

The mathematical formulation of the Generalized ANN Learning / Teaching Model given at Figure 2 is given as follows. The error vector at any time instant (n) observed during learning processes is given by:

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

Referring to above Fig.1; following four equations are deduced:

$$V_k(n)=X_j(n)W^T_{kj}(n) \qquad (2)$$

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

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
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the model with clear data by maximizing its signal to noise ratio. However, that is not our case which is based upon unsupervised learning.

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

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

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

Where: X……. input vector, W…….weight vector, φ……. is the activation function,
y……. is the output, e_k……. the error value, and d_k…… is the desired output.
Noting that $\Delta W_{kj}(n)$ 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 students' self-study).
The dynamical changes of weight vector value specifically for supervised phase is given by equation:

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

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

$$\Delta W_{kj}(n)=\eta\, y_k(n)\, x_j(n) \quad (7)$$

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

III. ANALYSIS OF LEARNERS' RESPONSE TIME A CASE STUDY

Performance evaluation of computer based Educational systems are adopted mainly by using two measurable learning parameters. Namely, both measured parameters -on the average values- are learning convergence (response) time and learners' achievements (outcomes). This section is dedicated for presentation, analysis, and evaluation of learning convergence (response) time in two subsections (A & B) as follows.

A. Effect of SWL packages' application on Learners' response time

Herein, error correcting learning paradigm ANN model introduced in the above section 2.Where it is adopted to simulate the learning principle under supervision with a teacher in nature learning processes observed to converge to some output response time value (s) after some number of training cycles. For any case this number observed to differ in a diverse manner following different learning abilities of learners (individual differences). The application of SWL packages results in improvement of learners' response time as shown at Fig.3.

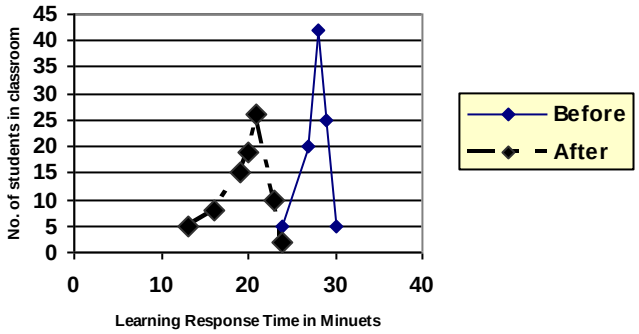

Fig 3: illustrates the effect of applied a SWL package on learner's response (learning convergence) time, before and after application of adopted SWLP (adapted from [1]).

B. Simulation Results of Time Response versus Different Learning Rate Values η

Referring to Fig.4, it is noticeable that statistical variations for number of occurrences observed to have approximately bell shape performance versus different values of learning response time (iteration cycles). In other words, the resulting values distribution having a bell form shape seemed to be similar to Gaussian (normal) distribution. Referring to above obtained output results, values corresponding to the learning rate values (0.4, 0.3, 0.2, and 0.1), are given respectively, as (13, 17, 27, 55) cycles on the average for learning convergence (response) time. Conclusively, convergence time (number of training cycles) is inversely proportional to the corresponding learning rate values.

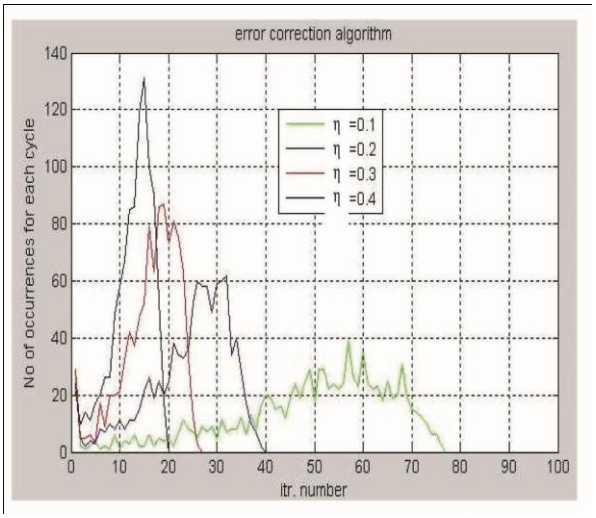

FIG. 4. ILLUSTRATES THE STATISTICAL DISTRIBUTION OF LEARNING CONVERGENCE TIME FOR DIFFERENT LEARNING RATE VALUES (η)

The relative graphical illustration for measured values of iteration cycles (response time) versus the number of occurrences (for each iteration cycles number) is depicted. Moreover at figure 5, the instantaneous time response values

ISSN: 2277-3754
ISO 9001:2008 Certified
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have been declared for two learning rate value (0.1 and 0.5) considering different samples of learners' groups.. However at figure 6, an illustration of the statistical distribution for the relation between two learning rate value parameters (0.1 and 0.5) and learning response (convergence) time is given.

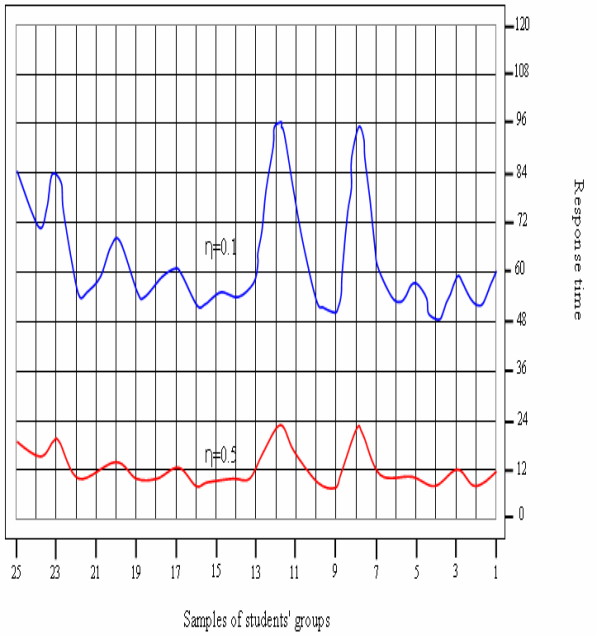


Fig 5: Illustrates the effect of learning rate parameter on the learning response (convergence) time for two different values 0.1& 0.5 presented by upper and lower curves respectively, adapted from [15].

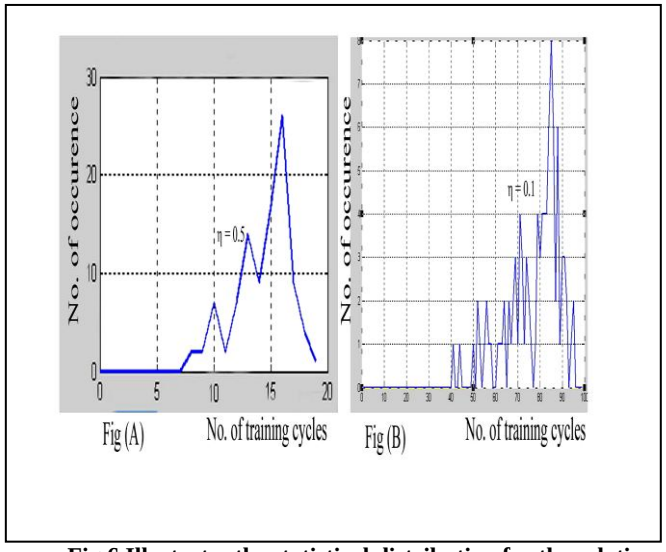
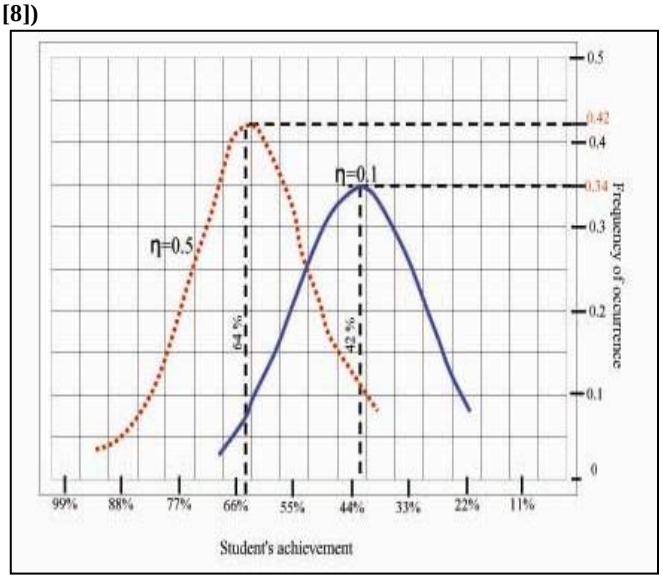


Fig.6 Illustrates the statistical distribution for the relation between two values of learning rate parameter and response (convergence) time at Fig (A)&Fig(B) corresponding to two different values of learning rates 0.5& 0.1 shown at Figure:5 respectively.

IV. SIMULATION RESULTS OF LEARNERS' ACHIEVEMENTS (OUTCOMES)

Fig 7: Illustrates realistic simulation results obtained after running of an ANN model. The results presented by statistical distribution for samples of 1000 virtual students .The obtained achievements are presented versus the frequency of occurrence for various students' achievements (outcomes) values, at different learning rate values (η=0.1&η=0.5), (Adapted from [8])



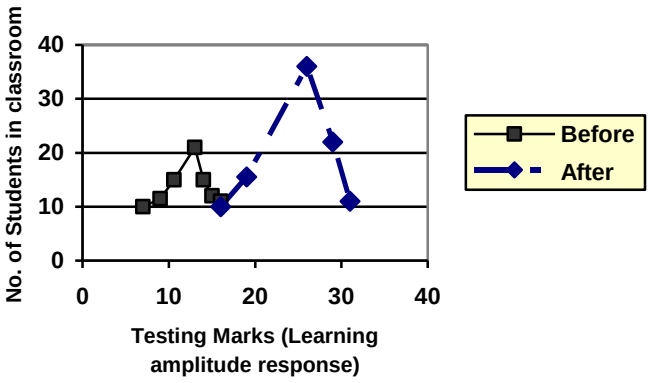


Fig 8: illustrates the effect of SWL package (before and after its application) on students' Learning achievements outcomes (adapted from [6]).

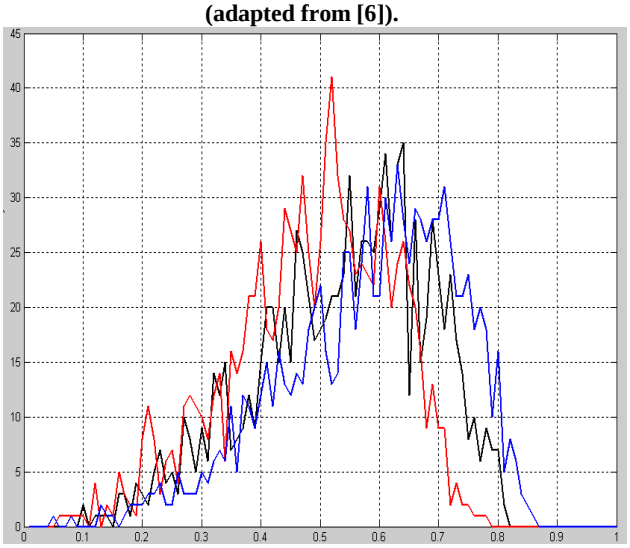


Fig 9. The three changes of learning rate values η (0.05, 0.3, and 0.5).

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
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V. RESULTS OF MAPPING LEARNER'S RESPONSE TIME INTO HIS LEARNING OUTCOMES

A learning style is a relatively stable and consistent set of strategies that an individual prefers to use when engaged in learning [16][17]. 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). After running of computer assessment program for both SWLP modules, obtained results are tabulated and graphically presented. 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 SWLP 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.3 shown in below. Moreover, obtained results are graphically illustrated at two figures (10 & 11). At Fig.10, graphical comparison of classical learning versus SWLP module (without tutor's voice) is presented. However, comparison of classical learning versus SWLP module (associated with tutor's voice) is shown at Fig.11. At both figures, it is sown that average value of classical virtual outcome is given by Av=35.7. However, after running of the other two SWLPs results in two values 58.8 and 71.3 for two modules (without tutor's voice) & (with tutor's voice) respectively.

Table.1: Illustrates children's time response after performing three educational experiments, so that all 15 children group might reach correctly achievement (solution) for assigned long division problems.

Classical Learning (Sec.)	119	185	180	160	272	243	226	182	233	160	173	185	266	136
CAL without tutor's voice (Sec.)	112	96	177	155	158	117	147	181	182	139	200	181	101	167
CAL with tutor's voice (Sec.)	153	162	143	167	77	171	83	192	63	62	169	109	121	71

Table 2. Illustrates mapped children's time response (seconds) for the under test children into virtual achievement scores (outcomes)

Classical Learning (Marks)	20	72	41	44	53	1	14	22	43	18	53	47	41	3	64
CAL without tutor's voice (Marks)	80	76	83	45	55	54	73	59	43	43	63	34	43	81	50
CAL with tutor's voice (Marks)	90	56	52	61	50	92	48	90	38	99	100	49	77	72	95

Table.3: Illustrates statistical analysis of above obtained learners' achievement outcome.

Teaching Methodology	Children's average (Mapped) Score [%	Variance σ	Standard deviation $\sqrt{\sigma}$	Coefficient of variation $\rho = \sqrt{\sigma}/M$	Improvement of teaching Quality
Classical	35.733	465.26	21.57	0.60	-
CAL (without tutor's voice)	58.8	265.04	16.28	0.28	64.7
CAL (with tutor's voice)	71.267	473.5	21.76	0.31	99.7

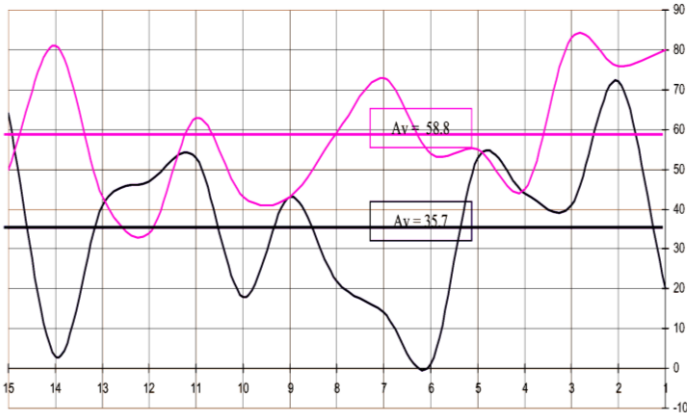

Fig. 10: Illustrates graphical comparison for classical learning versus SWLP module (without tutor's voice) considering virtual mapping of response time (number of training cycles) into children's outcomes.

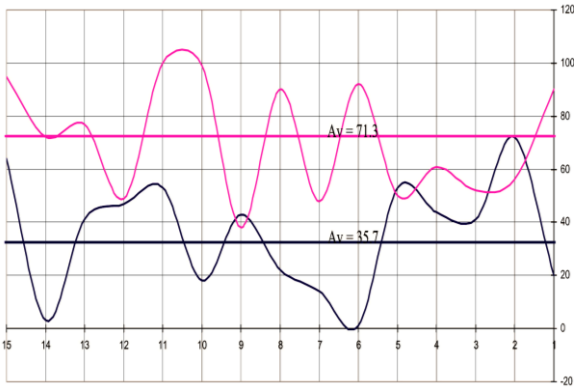

Fig 11: Illustrates graphical Comparison for Classical Learning versus SWLP module (associated with tutor's voice) considering virtual mapping of response time (number of training cycles) into children's outcomes.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
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VI. CONCLUSIONS

The following are some interesting conclusion remarks deduced after analysis of obtained realistic ANN simulation results:

- Students who might wish to attain better learning performance have to be more adaptive with his learning environment.
- ANN modeling is a realistic and relevant tool to obtain interesting results in the context of student's learning performance.
- Modification of learning systems performance quality obtained by the increase of learning rate value, which is expressed by the ratio between achievement level (testing mark) and the response learning time. This implies that learning rate could be considered as a modifying parameter contributes to both learning parameters (learning achievement outcome level and learning time response).
- After practical application of our two presented multimedia SWLPs (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.
- In future, more elaborate quantitative evaluation of individual differences phenomena expected .by incorporation of some internal intrinsic parameters such as gain factor parameter associated with neuronal activation function in adopted ANN model.
- More elaborate analytical study and evaluation is recommended for the effect of increasing neurons' number contributing to learning process on quality of learning performance.

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ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 11, May 2014

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