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ARTIFICIAL NEURAL NETWORK-BASED LEARNING ANALYTICS TECHNIQUE FOR EMPLOYABILITY AND SELF- SUSTENANCE

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ABSTRACT
The growing global rate of unemployment buttresses the quest for functional and all-inclusive education as canvassed by the Sustainable Development Goal 4 (SDG 4). Employability of graduates and entrepreneurial skills for self-sustenance can be fostered through Learning Analytics (LA) - a pedagogical paradigm that inculcates data analytics and team work skills in learners. LA measures the learning process by collecting learning-related data, analyzing same, and reporting trends to stakeholders for adaptive learning solutions that improve learning experience and learning outcomes. Though there are many data science techniques for enhancing LA, artificial neural network stands out as a highly predictive data mining tool and machine learning technique. An Artificial Neural Network-based Learning Analytics (ANN-based LA) system uses regression analysis, pattern recognition, and predictive analytics to elicit robust information from learner's data for informed decision making by education stakeholders. However, there are open issues confronting ANN-based LA systems such as system quality issues, prolonged time of training neural network, and the huge memory space requirements. This paper proposes an n-tier layered software architecture for tackling the quality indicator concerns while hoping that upcoming researchers will resolve the others. This way, ANN-based LA will be repositioned for delivering functional education that promotes graduate employment through the impartation of industry-relevant skills like data analytics and team work.

Keywords: Artificial Neural Network, Employability, Entrepreneurship, Learner-related Data, Learning Analytics, Sustainable Development Goal 4..

1.0 INTRODUCTION

According to the learning analytics community, Learning Analytics (LA) is the measurement, collection, analysis, and reporting of data about learners and their contexts for purposes of understanding and optimizing learning and the environments in which it occurs [1]. Siemens [2] defines LA as the use of intelligent data, learner-produced data, and analysis models to discover information and social connections and to predict and advise on learning. In Chatti et al. [3], the authors opine that LA is the development of methods that harness educational data sets to support the learning process while Hoel and Chen [4] mildly suggest that LA is technology-enhanced learning.

LA deploys data as a framework for measuring and enhancing learning. To facilitate functional education, it integrates social, pedagogical and technical aspects of learning for robust human capital development. As outlined in the Sustainable Development Goal 4 (SDG 4), education is pivotal to the attainment of sustainable development and the Sustainable Development Goals (SDGs) [5,6].

There is a link between quality education and economic growth and the education value chain is critical to sustainable development [7,8]. Besides empowering citizens with writing and reading skills, education builds problem solving skills in people whose competencies, knowledge, and skills are required for the actualization of the SDGs. To further underscore the role of education in sustainable development, the United Nations advised all nations to commit a minimum of 26% of national budget to the sector [8].

LA by its processes and strategies imparts data analytics skills in students. As [9] and [10] observe, contemporary industry requires data analytics skills for competitiveness and global relevance. As a result, graduates with analytics skills are in high demand as they are perceived to be great contributors to organization's bottom line. Seeking employment apart, graduates with data analytics skills are known to be highly entrepreneurial thus promoting self-reliance.

Knowledge explosion has witnessed increased activities of learners on technology-enhanced pedagogical platforms such as e-learning, blended learning, massive online open courses (MOOC), and virtual learning. In tandem with the mandate of SDG 4, these technology-based learning paradigms are aimed at promoting inclusive, affordable, accessible, and quality education. The goal is to empower all citizens for meaningful contribution to sustainable development and the SDGs. To enrich learning experience and enhance learning outcomes, LA takes learning to a new height by harping on measuring learning and reporting on it to stakeholders using the humongous amount of learner-related data generated as they interact on online platforms. Reporting on learning patterns of students enables stakeholders in the education value chain such as counsellors, teachers, administrators, researchers, and government to adopt strategies for adaptive learning. Adaptive learning solutions as tailor-made solutions help to meet the specific learning needs of learners, hence enriching their learning experiences.

To measure learning by understanding patterns in the huge learning-related data, LA relies on data science techniques such as data mining, knowledge discovery in databases (KDD), data warehouse, statistics, and machine learning [11]. One of the data science techniques renowned as a highly predictive data mining tool and machine learning technique is artificial neural network [12]. Reports in the literature suggest that an artificial neural network-based learning analytics (ANN-based LA) is useful for predicting student performance [13], classifying learning styles of students [14], and categorizing students including drop-outs [15]. These services are meant to offer advisory to education stakeholders for informed strategic interventionist measures for optimal learning outcomes [16].

LA systems and techniques guide students as they transit from education to employment and equally promote acquisition of analytics skills for employability [9]. For instance, the implementation of online educational systems like learning management systems (LMS) aids the building of employable skills (teamwork and analytics) as research studies have confirmed that LMS scales up students' sense of community just as it facilitates student engagement and success and supports learning communities. As a result, many universities have integrated LMS as a core enterprise component [17]. Advocates

of student progression are equally of the view that implementing LA tools like machine learning is invaluable in predicting learning outcomes just as it promotes teamwork skills.

Nevertheless, there are challenges confronting ANN-based LA which need to be tackled [18]. There are broadly three: system quality issues like interoperability, scalability, security, privacy, among others; prolonged time of training neural networks; and memory space requirements of neural network systems. To address the system quality issues, this paper proposes a multi-tier layered architecture with mechanisms that respond to identified issues.

The remainder of this article is arranged as follows: Section 2 concentrates on literature review; Section 3 outlines methodology; the implication of ANN-based LA for quality education and sustainable development is discussed in Section 4; in Section 5, factors responsible for the failure rate of prediction are discussed; Section 6 highlights areas that require further research; lastly, the work is concluded in Section 7.

2.0 LITERATURE REVIEW

2.1 Context of Learning Analytics

Learning analytics (LA) refers to the measurement, collection, analysis and reporting of data about learners and their contexts with a view to understanding and enhancing learning and the learning environments [1]. Organizations are desirous of making sense of the growth of their operational data. This is particularly so with respect to teaching, knowledge, and learning. Learning-related data is created as learners access learning materials, create new content, take examinations, and interact with colleagues and peers. So far, corporations and learning institutions have not fully utilized this data created by learners. With growing cost of education, institutions increasingly want to be competitive by reducing costs and increasing efficiency. Analytics is key to achieving this objective as LA provides platform for viewing and planning for changes at different layers of granularity such as institutional, departmental and course levels with evidence of cost saving and promotion of student retention and progression [17]. On the other hand, corporations are experiencing mounting pressure for higher productivity and competitiveness. To achieve these bottom lines, serious inputs into organizational capacity building are required from both informal learning and the work place. Through measuring, analyzing and reporting employees learning activities, LA can play vital role in enhancing their development.

Social interactions and information flow can also be harnessed to foster insights into effectiveness of organization in an enterprise setting. It also enhances organization's capacity to tackle new challenges or adapt to unexpected scenarios.

Also, since learning and knowledge work has extended from the boundaries of formal institutions to the workplace, many cloud-based platforms hosting the activities of individuals will offer analytics services.

Knowledge development and analysis have been boosted by advances in data mining, the semantic web, knowledge modeling and representation, analytics, and open data. In the nascent field of LA, the technical complexity shows paradigm shift from learning in terms of education, informal learning, and work place learning to social, networked learning. There is need to integrate the technical, social and pedagogical domains so as to guarantee that interventions and organizational systems will effectively serve the needs of all stakeholders.

2.2 Artificial Neural Network

Given a set of student data with input variables x1, x2, x3,.., xn and multi-class output variable y (y1, y2, y3...yn), artificial neural network commences the process of learning hidden and useful patterns in each

tuple with an activation function as shown in Figure 1 and mathematically defined as:

Output of neuron (y) = x1.w1 + x2.w2 +…+ xn.wn Eq. (1)

where w1, w2,..,wn are connection weights

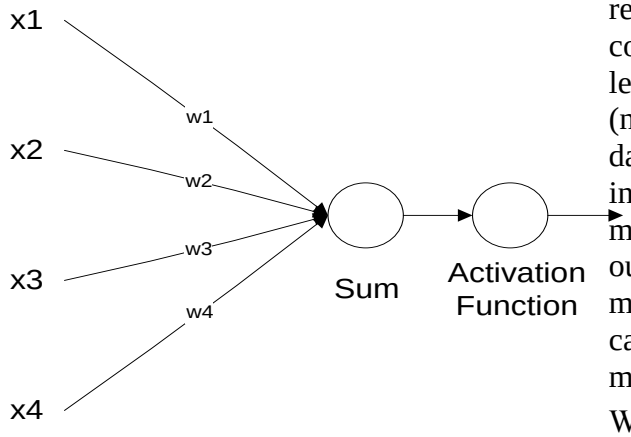

Figure 1: Artificial neuron structure showing learning process

The activation function trains the neuron to understand non-linearity of real live student data since neuron by its nature is linear. Also, the activation function ensures that real valued input data are converted into probabilistic output data.

Prior to the commencement of the learning process, regression analysis is performed on the data to map inputs to output. The logistic regression of the student data is shown in Figure 2.

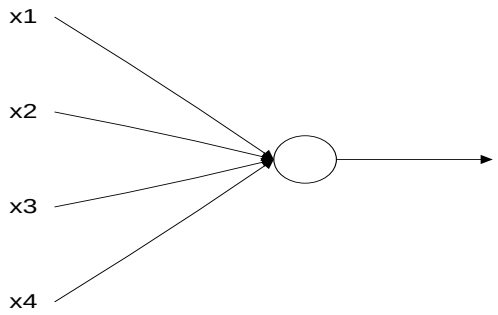

Figure 2: Logistic regression of students' data

In the event the network (or neuron) output (ŷ) differs from the data (or expected) output, an error occurs. This is called the cost or loss function. The neural network will continuously adjust its parameters like synaptic weight and learning rate until a zero error or an error size within the limit of tolerance is attained. Once this milestone is reached, the network is assumed to have correctly classify this instance of the data and learnt sufficiently its pattern. The machine (network) then moves to the next instance of data for similar pattern recognition. When all instances have been correctly classified, the machine is stable enough to start predicting outcome from future inputs. This metaheuristic iterative learning process is called the Perceptron Learning rule and mathematically denoted as:

$W_{new} = W_{old} + \eta * \delta * X$ Eq. (2)

where $\delta = Y - \hat{Y}$

Y = expected output

$\hat{Y}$ = network output

Wnew = new weight

Wold = old weight

η = learning rate

δ = error (cost or loss function)

X = inputs

Since obtaining an optimal solution (i.e. solution with the least cost function) involves iterative refinements with progressive reduction in gradient until an acceptable error size is attained, the learning process can be defined as a matrix of gradients as follows:

$$\frac{\partial y}{\partial x} = \begin{bmatrix} \frac{\partial y1}{\partial x1} & \frac{\partial y1}{\partial x2} & \frac{\partial y1}{\partial x3} \cdots & \frac{\partial y1}{\partial xn} \\ \frac{\partial y2}{\partial x1} & \frac{\partial y2}{\partial x2} & \frac{\partial y2}{\partial x3} \cdots & \frac{\partial y2}{\partial xn} \\ \frac{\partial ym}{\partial x1} & \frac{\partial ym}{\partial x2} & \frac{\partial ym}{\partial x3} \cdots & \frac{\partial ym}{\partial xn} \end{bmatrix} = 0$$

At the point where $\frac{\partial y}{\partial x}$ =0, the above Jacobian matrix becomes a Jacobi and the

machine is considered to have sufficiently learnt and can then be deployed for predictive analytics.

2.3 Open Issues of Artificial Neural Network-based Learning Analytics

Artificial Neural Network-based Learning Analytics (ANN-based LA) involves enhancing the learning experience and learning outcome in both educational institutions and enterprises using neural network to elicit information from learner-related data [18]. ANN is a high-end predictive data mining tool and machine learning technique [12] suitable for fostering learning and knowledge work is both formal and informal learning settings. It relies on regression analysis, pattern recognition, and predictive analytics to avail education stakeholders with credible and robust information for decision making [14]. Hence, learning enthusiasts such as students, teachers, administrators, researchers, and government are empowered with unbiased and non-prejudicial knowledge generated from the humongous learner-related data for purposes of designing strategic interventionist measures and adaptive learning solutions. In this sense, learning experience will be enhanced and education made functional in line with SDG 4 [6].

However, there are open issues of ANN-based LA that need to be addressed if this learning paradigm and pedagogy must continue to facilitate quality, affordable, and accessible education. The open problems are broadly three: system quality issues of interoperability, security, privacy, ethics, affordability and accessibility [16]; the prolonged time of training neural network [19]; and the huge memory space requirements of neural network [20]. Although research advances have been made in resolving these issues, upcoming researchers have a vista of opportunity to make further impact.

As a contribution, this paper outlines an n-tier layered software architecture for handling the system quality indicator concerns with a view to protecting learners' data, making learning analytics systems (and by extension, education) affordable, and ensuring accessibility to online materials through interoperable platforms.

2.4 Related Works

Previous works related to artificial neural network, learning analytics, and Sustainable Development Goal 4 (SDG 4) are explained as follows: In [13], research efforts were made to advance the efficiency of ANN-based LA in the computationally-intensive task of predicting the performance of students attending an e-learning course and classifying them. For best-fit mapping of student data, the researcher experimented with two models of ANN – multilayer perceptron and radial basis function. To increase the computational speed, the author optimized the neural networks architecture by decreasing the number of neurons used in both multilayer network and radial basis function network. This effort to advance the course of ANN-based LA yielded positive results as evidenced in the improved performance of the predictors underscored by low error rates. Clearly, research efforts were made to reduce the time it takes to train a network which can range from minutes to days particularly when huge and complex data are involved. Despite improving the computational speed of ANN, the focus of the study was not on the link between learning analytics and functional, affordable education.

Macfadyen and Dawson [17] and a few others reviewed literature and outlined reasons why LA as a pedagogical approach may not support institutional plan. The quest by educational institutions to enhance student retention through adaptive learning and promote student progression through impartation of data analytics/team work skills could be impaired by the challenges of LA. Apart from sensitizing on existing challenges and their impacts, the work neither addressed system quality issues nor

neural network challenges of training time and memory requirements of ANN-based LA.

The authors in [14] used ANN to identify learning styles with a view to customizing learning for high performance, learning satisfaction, and reducing the time required for learning. They opined that adaptive learning systems offer personalized content to students taking into cognizance their learning styles. Though questionnaires can be used to identify students' learning styles, the authors hinted that the approach has several demerits. To overcome these challenges, research has been carried out on automatic approaches that can identify learning styles. Since this line of research is still at infancy coupled with the fact that current approaches need significant improvement before their effective use in adaptive systems, the authors succumbed to using ANN to identify students' learning styles. The study evaluated the ANN approach using data from 75 students and it was discovered that it outperformed other approaches in terms of accuracy of identify learning styles. With accurate learning style identification, quality academic advice could be offered students by way of adaptive systems or by informed teachers who know precisely their students' learning styles. The authors concluded that such informed academic advising leads to greater learning satisfaction, higher performance, and reduced learning time. Despite focusing on enriching learning experience using ANN, the focus was not on using education to foster employability and entrepreneurial skills through data analytics and team work.

In [21], LA in higher education was x-rayed from the angles of methods, benefits, and challenges. The authors stressed that the learning environment and learning outcome can be enhanced using learner-related data and online educational systems. They observed that student retention, student progression and cost saving are benefits of LA. LA facilitates student progression through the impartation of industry relevant skills such as data analytics and team work as learning activities are measured and students engage in communal approach to learning. The study offers educational stakeholders insight into LA's methods, benefits, and challenges so as to be guided in applying LA efficiently and effectively. The ultimate goal is to enhance teaching and learning in higher institutions. Nonetheless, it did not address either system quality issues or the neural network issues of prolonged training time and huge memory requirements of ANN-based LA.

Authors in [22] used the legal instrument of general data protection law (General Data, 2016) to develop a framework (DELICATE checklist) for addressing the ethical and privacy concerns of LA. The learner has right to self-determination and thus the use of his data for enhancing learning and other socio-economic needs through research and development should be with his consent. As data is harvested during learning, the checklist ensures its appropriate use even in the development of strategic interventionist measures for adaptive learning without breaching privacy and ethical codes. However, the work only addressed some aspects of non-functional requirements (quality issues) of ANN-based LA systems. It equally failed to address issues of prolonged network training time and huge memory requirements of ANN.

The work by [18] offers sufficient evidence that learning and LA are not the exclusive preserves of schools and higher education. They are relevant in workplaces for sustained growth and development. The authors explored the use of artificial intelligence, specifically ANN, for the development of various domains of business administration. They opined that artificial intelligence tentacles such as deep learning, neural networks and machine learning have enhanced progress in academic research and fostered applications of learning systems in various domains. Hence, the various fields of endeavour have experienced improved business activities and firm development.

They specifically made mention of retail industry, finance, enterprise management and manufacturing industry as benefitting domains. The authors concluded that despite existing challenges, accelerated development of artificial intelligence will scale up its impact on more fields. Though the study did not unveil specific challenges confronting ANN-based LA, it opined that the challenges have slowed the pace of ANN-based LA development, including its use as a tool for fostering functional education through the impartation of work-ready skills.

Authors in [5] posit that the need for a more sustainable world informed the decision of the United Nations members to set up the 17 Sustainable Development Goals (SDGs). In the course of formulating this global policy instrument, education was positioned as the rallying point for promoting sustainable development. The authors demonstrated the significance of adopting interdisciplinary approach to education for sustainable development. The paper opined that multiple disciplines and sectors are required to deliver on the agenda of the SDGs. The role of sustainability education is to tailor teaching to students' backgrounds just as LA aims at enriching learning experience and outcomes by fashioning out adaptive learning solutions based on information mined from learners' data. However, the study failed to discuss how ANN-based LA can impact the actualization of the SDGs let alone discussing the challenges of the pedagogy.

In summary, none of the above studies focused on using ANN-based LA for enhancing the SDG 4 vision of quality, affordable, and functional education that guarantees employability and entrepreneurial skills and actualization of other SDGs. This present study proposes a software architecture that addresses the system indicator concerns of ANN-based LA systems with a view to enriching learning experience and enhancing learning outcome. Another objective is to make education affordable and accessible to all as promoted by SDG 4 [6].

3.0 METHODOLOGY

The SDG 4 canvasses quality education that encompasses promoting lifelong learning opportunities and inclusive and equitable quality education for all. Therefore, a learning pedagogy such as ANN-based LA that empowers learners with requisite data analytics and team work skills for employability and entrepreneurship through learning activities that are measured should be prioritized. Nonetheless, the challenges confronting this learning paradigm should be addressed for better educational service delivery. Prominent among these problems are system quality issues such as scalability, interoperability, privacy, ethics, affordability, accessibility, and security. In response, this paper proposes an n-tier layered architecture for ANN-based LA systems with mechanisms that address these challenges.

It is worth mentioning that previous research efforts have alleviated quality indicator concerns like interoperability, privacy and ethics, and data ownership and sharing [25,26]. Also, receiving attention of researchers are issues of socially equitable learning experience [27], which covers quality indicators like accessibility, affordability, availability and portability. Since education is a social service, other researches examined inclusiveness, advocating that LA systems, techniques and tools should be deployed in a fashion that guarantees inclusive education. Learners' mobility, data security, and system scalability are other concerns also receiving attention in the literature though to a lesser extent. Security and scalability concerns are thorny issues that need particular attention for LA to deliver on its perceived benefits.

Prior to designing the ANN-based LA system in furtherance of research efforts to tackle system quality issues, requirements were gathered and analyzed. The system was

designed using Unified Modeling Language. Nonetheless, implementation is yet to be done.

3.1 Requirements for Artificial Neural Network-Based Learning Analytics (ANN-based LA) System

The proposed Artificial Neural Network-based Learning Analytics (ANN-based LA) System is conceived as an integrated framework that facilitates diverse functionalities that are critical in the sphere of quality education and production of robust human capital. The essence is to offer support for learning and knowledge work, avail affordable and inclusive education to all in line with SDG 4, and empower graduates with employability and entrepreneurial skills such as data analytics and team work skills. The ANN-based LA system will offer functionalities like Enquiries, Regression Analysis, Pattern Recognition, and Predictive Analytics. It will offer analytics services at different layers of granularity such as Student, Teacher, Administrator, and Government Official based on the learning pattern of these stakeholders as shown in Figure 3.

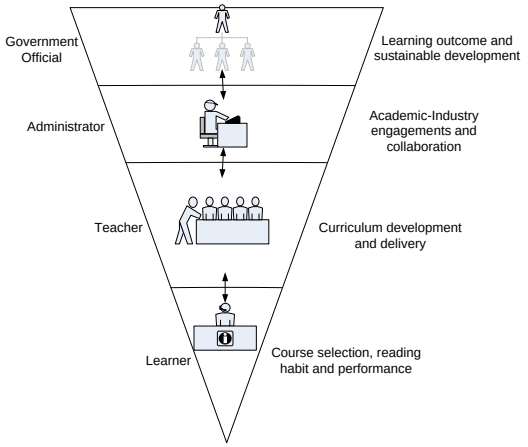

Figure 3: Layers of granularity of learning outcome (Source: Okewu and Daramola [16])

Examples of desired analytics outcomes include:

i. Learner – a student intending to graduate with a particular class of degree will query the ANN-based LA system for advice on parameters like required reading habit, and minimum performance at each level. To respond to such request, data such as student's current GPA, course of study, and current level have to be supplied.
ii. Teacher – the proposed system shall be able to advice teachers on curriculum development and delivery.
iii. Administrator – On querying the system, administrator shall be able to learn about employability and entrepreneurial skills required in the industry so as channel the institutions academic efforts in the direction of industry relevant skills.
iv. Government Official – the ANN-based LA system shall offer critical advisory services to government officials on institutions with comparative and competitive advantage in producing skilled manpower in various sectors such as health, education, and agriculture for sustainable development. For instance, in the event of national emergency such as disease outbreak, it will offer unbiased advice to government on institutions to fund for research that target such emergency. Sample inputs to the system will include patents, volume of publications, field of research, and research experience.

Both functional and non-functional requirements of the proposed ANN-based LA system were gathered using requirements engineering tools like observation and interview [29].

The user defined functional requirements include Enquiries, Regression Analysis Services, Clusterization Services, Classification Services, and Prediction Services presented as use cases in the Use

Case diagram in Figure 4. These services are also dominant machine learning tasks [30].

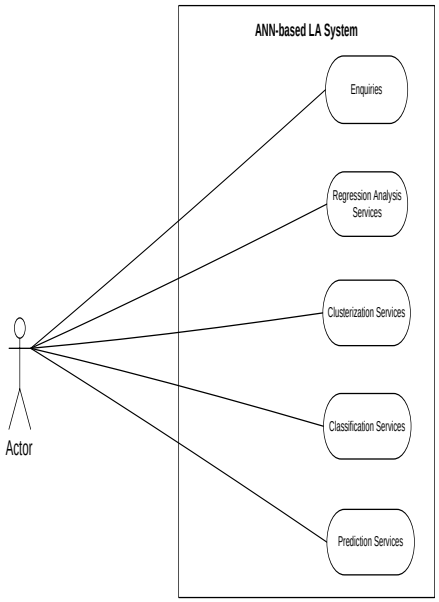

Figure 4: ANN-based LA Use Case diagram

The actor in this context is a stakeholder that seeks advice from the ANN-based LA system, who could be, but not restricted to, student, lecturer, educational administrator, or government official with constitutional oversight functions over educational institutions.

Examples of tasks performed by stakeholders on the proposed system which are also services denoted by the use cases in Fig. 2 are as follows:

Enquiries – for instance, the ANN-based LA system could provide stakeholders with information on student statistics in a discipline, in a school, or from a particular state.

Regression Analysis Services – for example, the system can provide information on subjects' combination for various courses for students seeking admission into tertiary institutions.

Clusterization Services – for example, the ANN-based LA system can advise students on subjects that can be accepted in lieu of others in an admission process.

Classification Services – the proposed system, for instance, can advise on student learning style classification which will guide the development of adaptive learning solutions.

Prediction Services – For example, given new (or future) data such as reading habit, course of study, and current grade point average (GPA), the system will forecast possible graduation class of degree of a student based on historical data.

3.2 System and Software Design

The software architecture of the ANN-based LA system is shown in Figure 5. It is an n-tier layered architecture with presentation layer, services layer, and data layer [31], [32]. For learners to have access to other educative platforms for enhanced learning experience, the system is linked to third-party applications like emailing system, social media (Twitter, Facebook, GooglePlus, YouTube, instagram), and learning management systems. This means these platforms have to be interoperable with the ANN-based LA system for seamless communication. To interact with the system at the presentation layer, the user can use either mobile device such as smartphone or fixed device like desktop. The second layer (service layer) houses both web services and middleware. As indicated in the diagram, the web services compartment is made up of mechanisms such as Data Management, Search, Security, Regression Analysis, Pattern Recognition and Predictive Analytics. To respond to data-related system quality issues such as data security, policies for articulating data ownership and handling on the ANN-based LA system are outlined in the Data Management component. These policies guide the system in determining who owns a particular data, who can use data, and for what purpose data is used. In this way,

stakeholders/actors will not misuse learners-related data. Relatedly, guidelines for protecting privacies of users as well as ensuring ethical usage of data are spelt out in the Security component. It also verifies users through authentication information like username and password so that only authorized learners gain access into the system. The Search component facilitates enquiries from the ANN-based LA system. The data analysis components such as Regression Analysis, Pattern Recognition, and Predictive Analytics offers insight into hidden and useful patterns in the data. The Middleware segment comprises a group of middleware that fosters interoperability between the ANN-based LA system and all platforms and external systems that learners are using for facilitate learning and knowledge work. The middleware ensures machine-independent seamless flow of information between various heterogeneous systems and programs related to learning. For example, the Home Grown middleware are tailor-made applications that handle peculiar interoperability needs of the proposed system. The RPC/ORB (Request Procedure Call/Object Request Broker) concentrates on synchronous distributed applications while Pub/Sub (Publish/Subscribe) deals with real communication based on messaging. The Message Queuing fosters reliable communication based on messaging, and finally, the TP Monitors (Transaction Processing Monitors) middleware coordinates processes and critical transactions within the ANN-based LA system.

For affordability and reliability, the data layer is managed by a NoSQL technology, Hadoop MapReduce. It handles huge data storage and processing effectively and efficiently. As an open source component, its inclusion in a learning initiative like ANN-based LA system will ensure affordable and inclusive education as propagated by SDG 4 [33]. The layer also comprises of a number of databases (Administrative, Student, Staff, Research, Community Service, Finance) which provide the learning-related data that doubles as the training data for the neural network-based LA system.

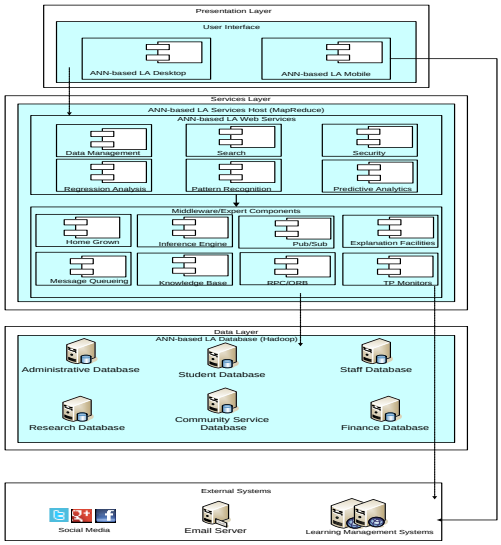

Figure 5: ANN-based LA n-tier Layered Architecture (Source: Okewu and Daramola [16])

In Figure 6 below, the neural network perspective of the ANN-based LA system is presented. Historical data on learners' activities are captured and fed into the system as training data. The system models the data as a neural network with emphasis on mapping inputs to output. Regression analysis by the system is performed to identify which set of input variables are responsible for given output in the learner-related data. After linking inputs to output, the training of the system commences with an activation function whose role includes training neurons to learn non-linear representation of real live data such as the learners' observational data. The activation function also ensures that real valued data are converted to probabilistic data in the neural network.

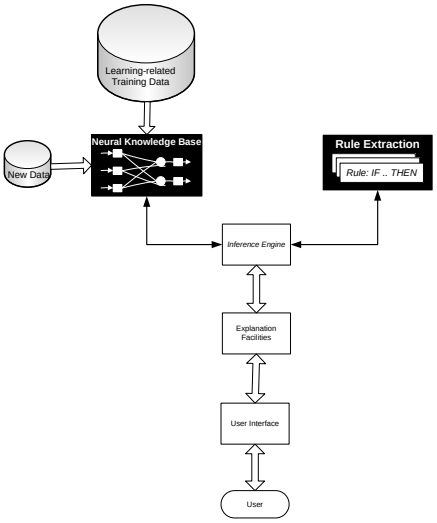

Figure 6: Artificial Neural Network-based Learning Analytics (ANN-based LA) System

In the event the network output differs from the data output, an error occurs and the ANN-based LA system will adjust network parameters until an acceptable error size is attained. At this point, the ANN-based LA system is said to have learnt sufficiently the instance of the data. It then moves to other instances and learn the pattern in each sufficiently. Once this pattern recognition process is completed for all instances of data, the system has sufficiently learnt and is stable for prediction services. It can then predict output from any new data (or future inputs) as indicated in Fig. 6 above.

The proposed ANN-based LA system possesses both usage and knowledge generation components as indicated in Figure 6. The generation of rules (or knowledge) based on patterns learnt in the learning-related data using appropriate learning algorithm is done by the Neural Knowledge Base. The Inference Engine has the mandate to extract and interpret the rules for informed decision making. The Explanation Facilities are used to enhance learners' understanding of the system's actions and decisions by providing user-friendly intuitive details. The medium for interacting with the system is the User Interface; learners can leverage on it to submit inputs and receive outputs.

C. **Proof of Concept**

To validate the proposed model, the study used MATLAB as tool for proof of the ANN-based LA concept. The Adaptive Neuro-Fuzzy Inference System (ANFIS) in MATLAB was used as the network model. The subjects were final year university students. The input data were their examination scores The output is the Remark with two classes – Pass and Fail. The pattern recognition (classification) process ensured that each tuple (student record) in the supplied data set was classified as Pass or Fail. Thereafter, the system was considered to be sufficiently trained for predicting student result from future input data.

The network (ANFIS) training process is indicated in Figure 7 while screenshots (interfaces) indicating data input and output from the MATLAB experiments are shown below in Figures 8 to 12.

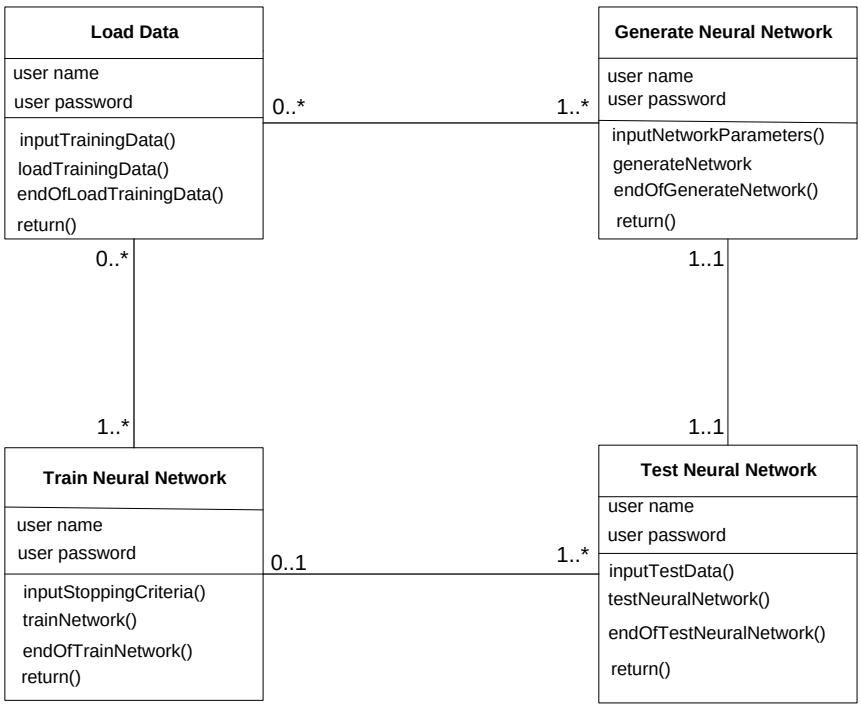

Figure 7: Class Diagram for the ANFIS training process

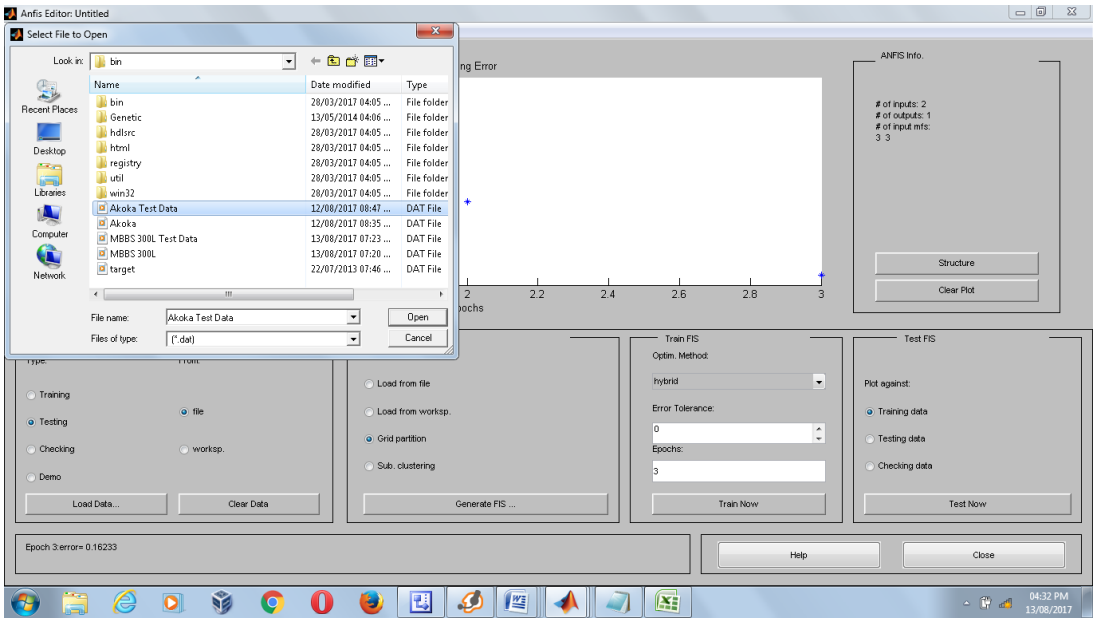

Figure 8: Loading of student data in MATLAB

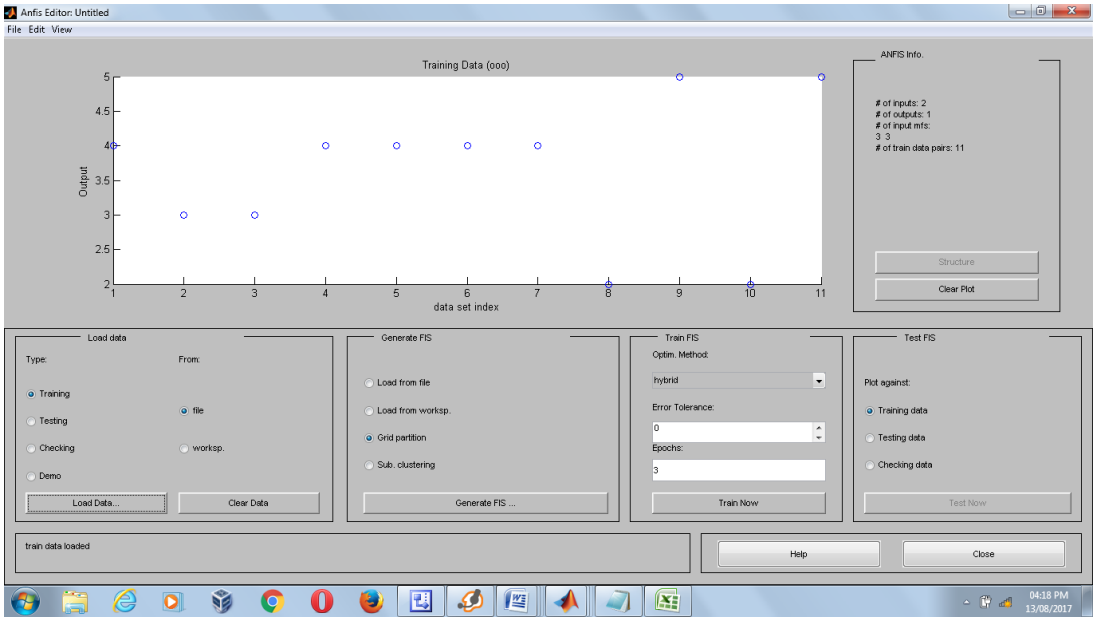

Figure 9: Student data loaded and analyzed in MATLAB

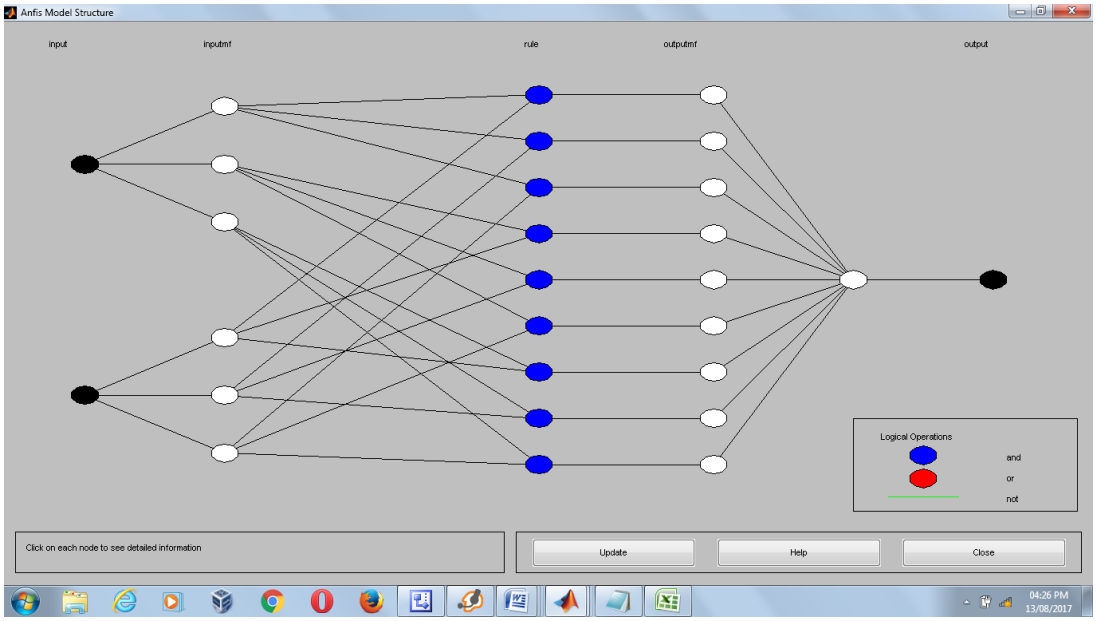

Figure 10: MATLAB generates neural network structure for the student data

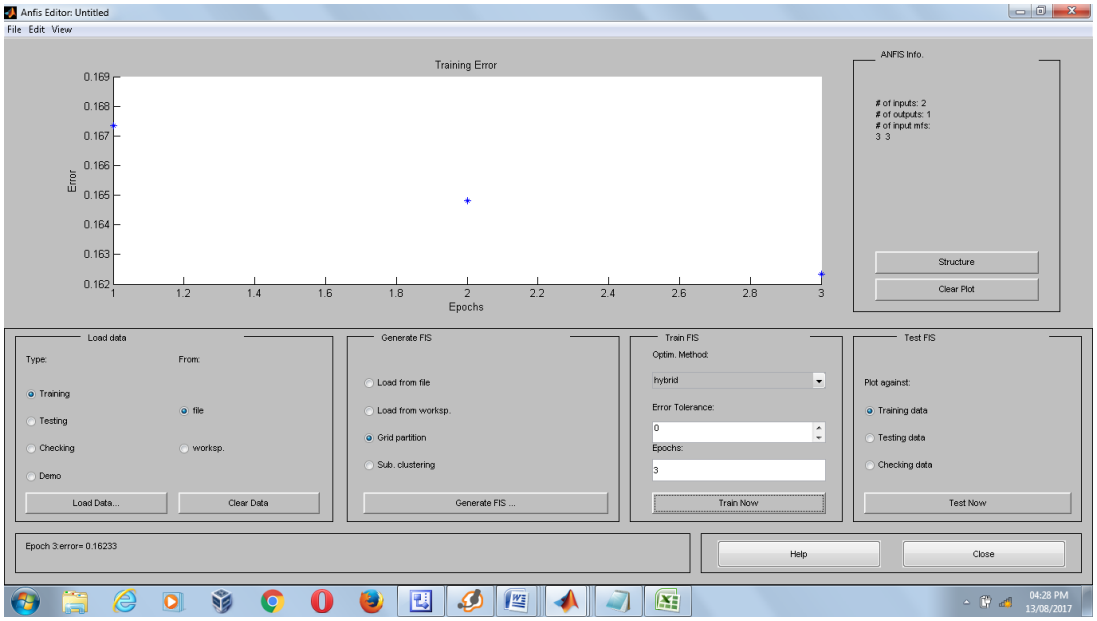

Figure 11: Training of generated neural network using student data in MATLAB

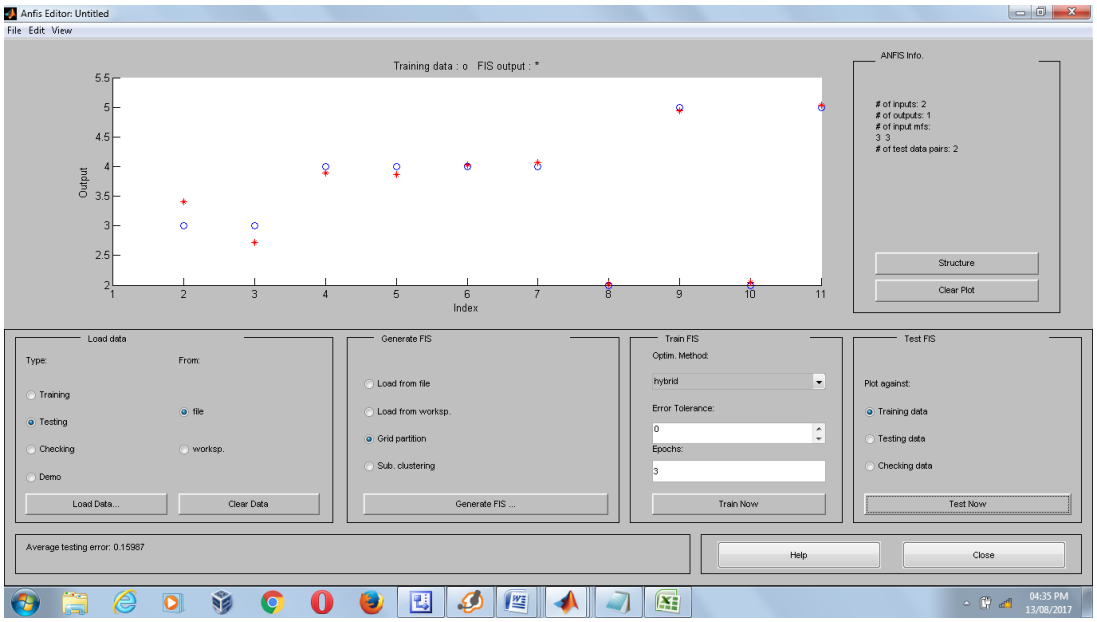

Figure 12: Testing of the trained neural network in MATLAB

The MATLAB transcript of the neural network (ANFIS) training is as follows:

ANFIS info:

Number of nodes: 35
Number of linear parameters: 9
Number of nonlinear parameters: 12
Total number of parameters: 21
Number of training data pairs: 11
Number of checking data pairs: 0
Number of fuzzy rules: 9

Warning: number of data is smaller than number of modifiable parameters

Start training ANFIS ...

1 0.167339
2 0.164825

Designated epoch number reached --> ANFIS training completed at epoch 2.

4.0 IMPLICATIONS OF ANN-BASED LEARNING ANALYTICS FOR SUSTAINABLE DEVELOPMENT GOALS

This The global policy instrument, SDGs, adopts a multi-sectoral approach to sustainable development and well-being of citizens [5]. Specifically, 17 goals covering health, education, climate action, among others have been articulated as thematic policy frameworks for achieving the future we desire. The place of robust human capital for achieving these goals cannot be over-emphasized. Knowledge and skills are the competences that make a robust human capital and education is the channel for acquiring these competences. SDG 4 which harps on education therefore becomes pivotal to the attainment of all other SDGs [6]. To uplift all people and unite them in global partnership for sustainable development, education must be affordable and accessible [33]. ANN-based LA delivers on this mandate by combining social, technical and pedagogical domains for enhancing rich learning experience of all. It leverages on inclusive innovation that aims at making low-cost digital devices such as phones and cheap Internet available to all so that accessibility to global knowledge base is guaranteed. As explained above, the software architecture proposed in this study contains mechanisms that ensure interoperability of various platforms or user interfaces with the ANN-based LA system. Also, the explanation facility of the system is people-friendly, ensuring that outputs from the system are well explained to learners. Moreover, to ensure that education via LA systems is affordable, the n-tier architecture uses open source components except in extreme cases where propriety components cannot be substituted. Open source components are relatively cheap [34] and their use will force the cost of education down as learners increasingly rely on online learning for skills and knowledge. Another positive implication of ANN-based LA for the attainment of SDGs is that the process of collecting, measuring, and analyzing learning-related data, coupled with reporting of learning activities for purposes of developing adaptive solutions does not only improve learning experience, it inculcates data analytics and team work skills in the learners. Hence, as students graduate, they have critical employability and entrepreneurial skills that make them industry-ready. In this sense, ANN-based LA boosts the global human resource base for attainment of the Sustainable Development Goals.

5.0 EVALUATION THREATS

Like all expert systems, there are likelihoods that the proposed ANN-based LA system may predict inaccurately sometimes. This is attributable to two main factors – quality and quantity of input data and adequacy of network training. Hence, to improve on its prediction capability, accuracy and adequacy of input data should be guaranteed during the data pre-processing stage. Also, the use of rigorous network training technique such as deep learning will ensure a well-trained ANN-based LA that predicts accurately.

6.0 FURTHER WORK

The multi-tier layered architecture proposed

in this study is aimed at addressing the system quality issues of ANN-based LA. However, as earlier identified in this study, there are challenges of prolonged training time of neural network as well as the huge memory space requirements. For ANN-based LA as a social, pedagogical and technical framework for learning and knowledge to deliver affordable, inclusive, and functional education in tandem with SDG 4, more advances in research are required to tackle these neural network tissues.

7.0 CONCLUSION

This work took into cognizance the invaluable role of education in achieving sustainable development and the Sustainable Development Goals. To deepen rich learning experience and enhance learning outcome, ANN-based-LA has been suggested. ANN-based LA is a pedagogical approach that relies on learner-related data to measure, analyze, and report on learning activities so that adaptive learning solutions can be developed for richer learning experience. As learners go through the process of measuring learning and adjusting learning styles in groups, they imbibe data analytics and team work, two critical skills required for employability and entrepreneurship in today's industry. Hence, ANN-based LA promotes learning experience as well as industry-readiness. In view of the challenges confronting ANN-based LA, the study proposed an n-tier layered software architecture to tackle the system indicator concerns while hoping that future researchers will channel efforts towards resolving the neural network problems of prolonged training time and huge memory space requirements.

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