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Utilizing Artificial Neural Network Models for Predicting High School Students' Final Grades and the Impact of Social Factors

*Ezeddin Ali Mohamed Eyad[1] and Muftah Ali Elmorabet Eniba[2] and Ahmad Abdurahman Abosleala [3]

[1] Department of Computer Technology – Higher Institute of Science and Technology, Misrata – Libya

[2] Department of Information Technology – College of Education – Misrata University – Libya

[3] Department of Computer Technology – Higher Institute of Science and Technology, Misrata – Libya

A B S T R A C T

In response to ongoing technical changes, it has become imperative to evolve educational methodologies to provide information when needed for making appropriate decisions. This necessitates a shift in the skills possessed by learners to keep pace with such advancements and carry out associated tasks. The primary challenge lies in the scarcity of using Artificial Neural Networks (ANN), one of the most important artificial intelligence tools due to their immense capability for prediction, classification, and simulation of human intelligence. They aid institutions in achieving their objectives and addressing the challenges they face. Hence, this research aims to utilize neural networks in predicting the outcomes of high school students and examine how neural networks integrate in forecasting final academic performance, focusing on social factors such as gender, family size, and parental occupations, among others. The research seeks to enhance the accuracy of academic performance predictions by incorporating these social aspects into the neural model, enabling a deeper understanding of the relationships between these factors and academic success.

The findings of this research offer valuable insights for educational institutions, which can be used to enhance academic support and develop educational plans. The attention to social factors is attributed to their impact and significance in shaping an active context that reflects the challenges students may encounter during their academic journey.

The research recommends using neural networks and their applications, employing artificial intelligence in machine learning and deep learning applications, such as other predictions, classification, and clustering. These aids in enhancing the educational process by identifying factors influencing the quality of education and obtaining indicators useful for decision-making and future planning before they occur.

Keywords: Artificial Neural Networks, deep learning applications, enhanced academic support, machine learning, Social Factors, Student Grade Prediction.

* Corresponding author:
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استخدام نماذج الشبكات العصبية في التنبؤ بمعدل الدرجات النهائية لطلبة الشهادة الثانوية وأثر العوامل الاجتماعية عليها

*عزالدين علي محمد عياد[1]، مفتاح علي المرابط عنيبة[2]، أحمد عبدالرحمن ابوسليلة [3]
[1] قسم تكنولوجيا الحاسب الآلي– المعهد العالي للعلوم والتكنولوجيا مصراتة – ليبيا
[2] قسم تكنولوجيا المعلومات – كلية التربية – جامعة مصراتة – ليبيا
[3] قسم تكنولوجيا الحاسب الآلي– المعهد العالي للعلوم والتكنولوجيا مصراتة – ليبيا

الملخص:

تماشيا مع التغييرات التقنية المستمرة اصبح لزاما مواكبة ذلك بتطوير أساليب العملية التعليمية لتوفير المعلومات عند احتياجها لاتخاذ القرارات المناسبة، الأمر الذي استوجب تغييرا في المهارات التي يمتلكها المتعلم ليتمكن من مواكبة ذلك التطور والقيام بالأعمال المناطة به، وتكمن المشكلة الأساسية هنا في ندرة استخدام الشبكات العصبية الاصطناعية Artificial Neural Networks (ANN)التي تعتبر من أهم أدوات الذكاء الاصطناعي لما لها من القدرة الهائلة على التبوء والتصنيف ومحاكاة العقل الإنساني فهي تساعد المؤسسات في تحقيق أهدافها، ومواجهة التحديات التي تعترضها، لذلك هدف هذا البحث الى استخدام الشبكات العصبية في التنبؤ بنتائج طلبة الشهادة الثانوية، وفحص كيفية تكامل الشبكات العصبية في توقع الأداء الأكاديمي النهائي لطلاب المدارس الثانوية، مع التركيز على العوامل الاجتماعية مثل: الجنس وعدد افراد الاسرة وحجم العائلة ووظيفة الأب ووظيفة الأم. ويتطلع البحث إلى تحسين دقة توقعات الأداء الأكاديمي من خلال تضمين هذه الجوانب الاجتماعية في النموذج العصبي. مما يتيح فهمًا أعمق للعلاقات بين هذه العوامل والنجاح الأكاديمي.

تتيح نتائج هذا البحث إمكانية تقديم توجيهات قيمة للمؤسسات التعليمية، حيث يمكن استخدامها لتعزيز الدعم الأكاديمي، وتطوير خطط التربية والتعليم. ويُعزى الاهتمام بالعوامل الاجتماعية إلى تأثيرها وأهميتها في تكوين سياق فاعل يعكس التحديات التي قد يواجها الطلاب خلال رحلتهم الأكاديمية.

ويوصي البحث إلى استخدام الشبكات العصبية وتطبيقاتها الأخرى، استخدام الذكاء الاصطناعي في تطبيقات التعلم الآلي والتعلم العميق، مثل التنبؤات الاخرى، والتصنيف، والتجميع. وغيرها، الامر الذي يساعد في تطوير العملية التعليمية من خلال التعرف على العوامل التي تؤثر في جودة التعليم والحصول على مؤشرات تفيد في اتخاذ القرار والتخطيط المستقبلي له قبل حدوثه.

الكلمات المفتاحية: التنبؤ بمعدل درجات الطلبة، الشبكات العصبية الاصطناعية، العوامل الاجتماعية، تطبيقات التعلم الآلي، تطبيقات التعلم العميق، تعزيز الدعم الأكاديمي

1. Introduction

Artificial Intelligence (AI) is a branch of computer science that enables the creation and design of computer programs mimicking human intelligence, allowing computers to

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perform tasks traditionally requiring human intervention, such as learning, adaptation, reasoning, and interaction with the surrounding environment.

The success and sustainability of institutions significantly depend on their ability to respond to the changes occurring in their environment, especially rapid changes in information technology, which serves as a crucial tool enabling institutions to swiftly respond and adapt. Therefore, the shift towards reliance on machinery has become inevitable for institutions to remain capable of improving, growing, and competing. [3]

These changes, whether internal or external, have necessitated substantial changes in educational systems to respond to and evolve with these variables. Hence, there is a clear interest in the development of educational institutions. Failure to develop adequately may render educational institutions incompatible with and incapable of keeping pace with rapid scientific progress. [9]

To facilitate understanding of the impacts of social factors on student achievement, this research aligns within the evolutionary context, seeking a deep understanding of the interaction between Artificial Neural Networks (ANN) and social changes in predicting students' final grades. Neural networks represent a branch of artificial intelligence through which computers perform tasks requiring human-like thinking, understanding, hearing, and movement.

Neural networks are information-processing systems that mimic the human brain's neural networks. [1]

2. Research Problem:

Considering that students' overall cumulative GPA is influenced by external environmental changes, which necessitated a change and development in its calculation method to provide accurate information for making timely decisions, a shift in the responsible skills for implementing new and advanced methods has occurred. Thus, the fundamental problem of the research lies in the scarcity of mathematical methods based on Artificial Neural Network (ANN) models as a form of artificial intelligence techniques in developing grading systems and enhancing their effectiveness in predicting students' semester and cumulative grades.

3. Research Objectives:

The primary objective of the research is to explore the impact of using Artificial Neural Networks (ANN) in predicting the final grades of high school students based on social factors. This involves studying the concept, types, and characteristics of Artificial Neural Networks (ANN) to assess the influence of social variables on the prediction process of students' final grades, and to utilize this information in constructing the network.

4. Significance of the Research:

The scientific and practical significance of the research lies in:

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- The vital need of educational institutions, companies, establishments, and factories, across various sectors, for accurate information to make informed decisions crucial for achieving their objectives. Prediction processes serve as effective tools to assist them in obtaining the necessary information to realize their goals and ensure continuous growth.
- Highlight the importance of using Artificial Neural Networks (ANN) as a model of artificial intelligence in enhancing prediction processes across various fields and levels, leading to outputs with high accuracy.

5. Research Limitations:
- Spatial limitations: The study could not be conducted in a local educational institution due to social reasons beyond our control. Therefore, the sample consisted of students from Portugal recruited online, totaling 650 students.
- Technical limitations: Utilization of the latest forms of artificial intelligence: Predictive Artificial Neural Networks.
- Temporal limitations: Academic year 2022/2023.

6. Research Plan:

To achieve the main research goal and its derived subsidiary objectives, the following approaches were adopted:

- Theoretical understanding of Artificial Neural Networks (ANN) in terms of components, types, and processing methods within them, by incorporating social variables and students' grades in the first and second periods to reach reliable predictions.
- Review relevant previous studies.
- Examine students' grades in the first and second periods of secondary school certificates to predict the overall GPA.
- On the practical aspect, reliance on an applied study aimed at testing the research hypothesis to achieve the objectives, using Artificial Neural Networks due to their proven effectiveness in prediction and estimation tasks.

7. Research Hypothesis:

To achieve the main research goal, the researchers assumed the following hypothesis:
- The use of Artificial Neural Networks (ANN) leads to elucidating the impact of social variables on the accuracy of predicting students' final grades.

8. Concepts and Terminologies Regarding Artificial Neural Networks (ANN) and Biological Neural Networks:

8.1 Biological Neural Network:

It is derived from the human brain, where the brain contains billions of neurons, each neuron connected to other neurons through thousands of synapses, forming a network processing system. [6]

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8.2 Artificial Neural Networks (ANN):

These networks are based on simulating biological neural networks. They attempt to mimic human cognitive abilities in acquiring and organizing information as concepts. ANN consists of interconnected cells, functioning in parallel.

It is defined as a subset of machine learning algorithms designed to mimic the structure and function of the human brain. It consists of interconnected layers of nodes or artificial neurons that receive input data, process it, and produce outputs. These networks can learn and improve from experience, making them powerful tools for tasks such as pattern recognition, classification, and prediction.

8.3 Structure of Artificial Neural Networks (SANN):

Artificial Neural Networks (ANN) are a set of computational learning models that mimic the function of neurons in the human brain. Each network consists of a group of interconnected nodes organized in layers. Neurons in each layer send messages to neurons in the next layer, and each artificial neural network contains at least one input and output layer. The input layer sends data, and its outputs serve as inputs to the next layer and so on until the final output layer of the model. Training algorithms determine how these layers operate. Training enables the artificial neural network to learn by providing it with a vast amount of data during a training period. It begins classifying future data into different categories based on the data during the training period. [8]

8.3.1 Components of Artificial Neural Networks:

The Artificial Neural Network consists of:

8.3.1.1 Layers: There are three layers:

Input Layer: It represents the independent variables of the problem. It receives the data, which are the influencing factors of the problem to be solved, and distributes them.

Output Layer: It represents the dependent variables and consists of artificial neurons. It is responsible for receiving the outputs and is the feeder for the neural network.

Hidden Layer: Also known as the Middle Layer, it is located between the previous two layers and performs the aggregation process. These units are interconnected to transfer information between nodes, which are used for weight distribution.

8.3.1.2 Weights:

The weight is the main element in the network and represents the relative importance of the variables for processing units.

8.3.1.3 Neuron Function:

Summation Function: This function calculates the weighted average of each input to the processing element by multiplying each result by its weight to obtain the sum.

Activation or Transfer Function: This function transfers data from one layer to another, determining the output values by aggregating input weights in the cell.

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8.4 Training and Learning of Neural Networks:

The study conducted by Hebb in 1949 identified the connectivity structure of neural networks and how to represent knowledge. Others applied this study to neural networks, confirming that training and learning determine the relative weights. Relative weight expresses the relative strength of the input data. Neural networks are not programmed but trained on a set of data and adjust the relative weights to achieve the best results. They learn from their mistakes and previous experiences, initially determining initial values for relative weights or randomly selecting them, which aid in determining effectiveness and learning duration. [5], [2]

9. Study Population and Sample:

Due to the unavailability of local scientific and social student data, information was collected by relying on data from 650 high school students in Portugal published on the NASA website (Kaggle). The data were distributed by gender, with 383 males and 267 females, and included information about students' lives such as gender, age, address, family size, parent's marital status, mother's education level, father's education level, parents' occupation, study hours, number of failures, extracurricular courses, internet availability at home, first semester GPA, and second semester GPA.

10. Previous Studies:

10.1 In a study titled "Predicting University Students' Performance Using Artificial Neural Networks," multilayer artificial neural network models were developed with a backpropagation algorithm to classify average grade levels, academic retention, and degree completion outcomes in a sample comprising 655 students from a private university. The results demonstrated a high level of accuracy across all classifications. Among predictors, learning strategies contributed significantly to predicting average grades. Coping strategies emerged as the best predictors of academic degree completion, while basic information had the greatest predictive weight in identifying students who might drop out of university programs.[7]

10.2 In the study titled "Predicting Academic Performance of Students Using Artificial Neural Networks," the research examined and reviewed current literature related to ANN methods used in predicting students' academic performance. This study also aimed to capture patterns of the most commonly used ANN techniques and algorithms. The reviewed articles primarily focused on higher education. The results indicated that artificial neural networks are consistently used with data analysis and data extraction methodologies, allowing studies to assess the effectiveness of their academic achievement evaluations. No pattern was revealed regarding the selection of input variables as it primarily depends on the study context and data availability. Moreover, the highly limited tangible results pointed to the use of techniques in actual contexts and the target objective of improving students' outcomes and achievements. An important recommendation from this work is to overcome the specific gap related to the sole theoretical and limited application of artificial neural

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networks in a realistic setting to help achieve educational objectives. [10]

10.3 In a study titled "Modeling Student Success Prediction Based on Artificial Neural Networks and Feature Selection Methods," this paper presented a predictive model based on artificial neural networks by implementing feature selection. A survey was created to collect student responses using Lime Survey and Google models. The survey consisted of 61 questions covering various domains such as sports, health, residence, academic activities, social information, and administrative data. A total of 161 students from two departments (Computer Science and Computer Information Systems) participated in the survey, College of Computer Science and Information Technology, University of Basra. The dataset was merged from two source applications and preprocessed by removing incomplete responses to produce 151 responses used in the model. Aside from the model, a feature selection approach was applied to identify the most important interrelated questions affecting the final semester (grade). The goal of feature selection is to eliminate irrelevant questions and identify important ones, along with improving the model's accuracy. A set of four feature selection methods (Information Gain, Correlation, SVM, and PCA) were tested, and the average rank of these algorithms was obtained to find the best 30 questions out of 61 in the survey. The artificial neural network was applied to predict the grade (Pass (P) or Fail (F)). The model's performance was compared with three previous models to demonstrate its superiority. [4]

11. Practical Aspects:

11.1 Programming Language Used:

The programming language used is Python. Python is widely used in web applications, software development, data science, and machine learning (ML) applications. Developers use Python because of its efficiency, ease of learning, and its ability to run on various platforms. Data scientists use Python libraries for machine learning to train ML models and create classifiers that accurately classify data. People in various fields use Python-based classifiers to perform classification tasks, such as image classification, text classification, network data traffic analysis, speech recognition, and facial recognition. Some of the libraries used in the research include:

TensorFlow Library: TensorFlow is an open-source library used for numerical computation and machine learning in Python. It makes machine learning faster and easier by providing complex machine learning systems. Applying machine learning models has become less challenging than before, thanks to machine learning frameworks like TensorFlow from Google, which simplify the process of obtaining data, training models, making predictions, and improving future results. The Google Brain team created Tensor Flow, and it's an open-source library for numerical computation and machine learning on a large scale. TensorFlow brings together a collection of machine learning models, deep learning (also known as neural networks), and algorithms, making them useful through common use.

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11.2 Mean Square Error (MSE):

Mean Square Error (MSE) is a statistical measure of error or the difference between expected values and actual values in prediction models. It represents the average of the squares of the differences between expected and actual values. MSE is a commonly used measure for model performance in time series prediction analysis and machine learning domains. It is also known as Mean Squared Prediction Error (MSPE) in some contexts.

$$\text{MSE} = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2$$

MSE: Mean Square Error
n: The number of samples.
Y: The actual data.
Y: The predicted data.

12. Discussion of Results:

Multiple scenarios were utilized for neural networks regarding activation function and the number of hidden layers to achieve the best outcome. Initially, the data was divided into 80% for training and 20% for testing. A small number of nodes were assumed in the hidden layer, and then the number of nodes was increased to reach the optimal number. It was observed that the error rate became constant regardless of the increasing number of nodes. Then, it was assumed that the number of hidden layers was one, which was gradually increased after fixing the number of hidden nodes. Additionally, the activation function used was the linear function, and then more than one activation function was changed until the best estimate was obtained. The activation function used at the output was constant, which was linear. Figure (2) demonstrates the convergence of the expected results with the actual results, where the maximum error rate between the predicted and actual results is 10.37%.

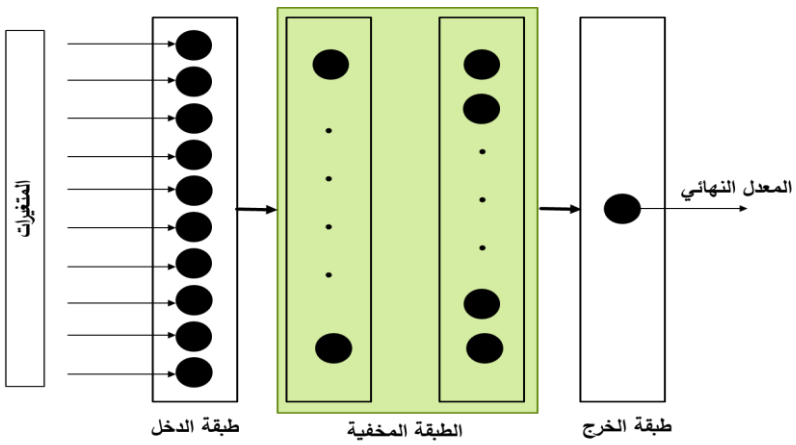

Figure (1): The Neural Network Used

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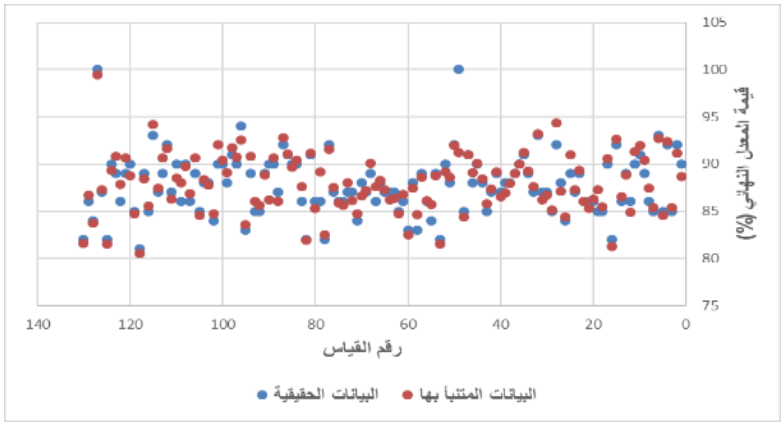

Figure (2): The predicted final grade value (number of hidden layers = 1, number of nodes = 5, activation function = Linear).

In the case of increasing the number of nodes from 5 nodes to 255 nodes gradually by about 50 nodes, it was observed that the best result was obtained with 255 nodes in the hidden layer, which equalled 8.44%. It was also noted that the error value started to stabilize, and increasing the number of nodes did not affect the average error rate. Figure (3) illustrates the relationship between the error and the number of nodes in the hidden layer.

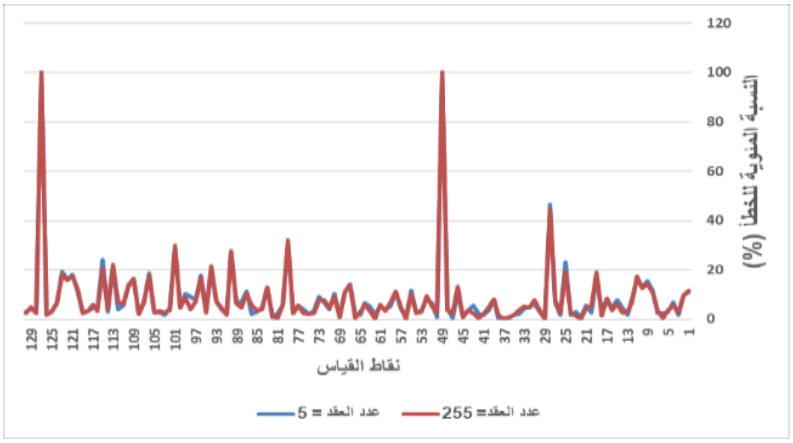

Figure (3): The Impact of the E

rror Rate on the Number of Nodes in the Hidden Layer.

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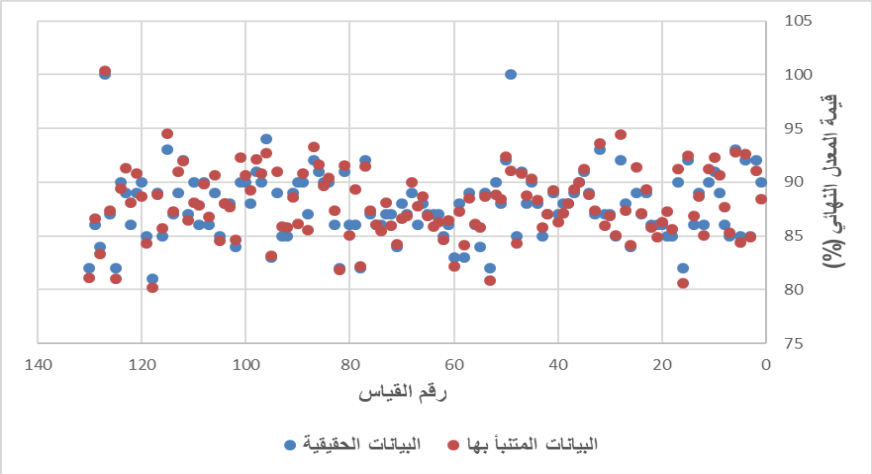

Figure (4): Predicted Final Grade Values (Number of Hidden Layers = 1, Number of Nodes = 255, Activation Function = Linear).

When the number of nodes is fixed, experimentation continues with activation functions and the number of hidden layers to achieve the best predictive outcome, as shown in Table (1).

Table (1): Results of the Neural Network

Error Rate(%)	Number of Hidden Layer	Activation Function in the Hidden Layer
8.44%	1	Linear
%11.37	3	Linear
11.46%	1	Relu
12.62%	3	Relu

Figures (5) to (7) illustrate the difference between predicted values and actual values, where the number of hidden layers is 1, and the activation function used in the hidden layer and the output is the linear function (Linear)

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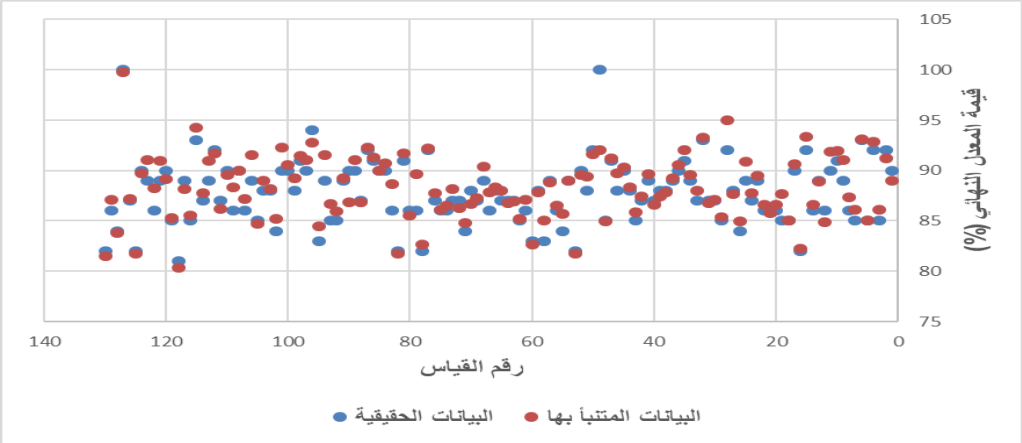

Figure (5): The predicted final grade values (number of hidden layers = 3, number of nodes = 255, activation function = Linear**).**

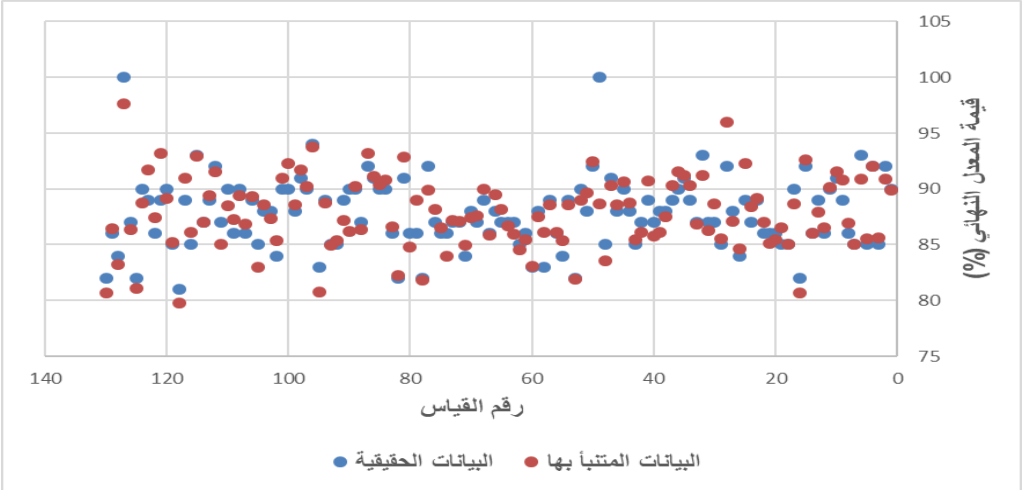

Figure (6): The predicted final grade values (number of hidden layers = 1, number of nodes = 255, activation function = ReLU).

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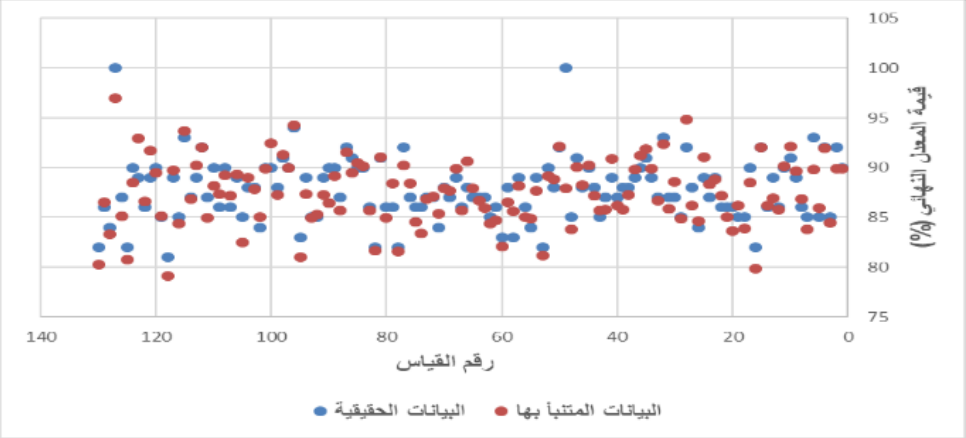

Figure (7): The predicted final grade values (number of hidden layers = 3, number of nodes = 255, activation function = ReLU).

From the previous results, we observe that the best outcome is achieved when using a neural network with a single layer consisting of 255 nodes, with the activation function being Linear. As for Table (2), it presents a sample of predicted values alongside the actual values.

Table (2): Sample of Predicted Values.

The percentage error.	The actual final grade.	The predicted final grade.	i
0.947846	92	91.13616943	1
0.397643	85	85.33934593	2
0.371347	92	92.34291267	3
0.512212	85	84.56683826	4
0.299013	93	92.72274685	5
0.465689	85	85.39768791	6
1.616469	86	87.41300392	7
1.524535	89	90.37784195	8
1.03203	91	91.94894028	9
1.421189	90	91.29751015	10

Through Table (2), the hypothesis has been demonstrated, indicating that the use of Artificial Neural Networks (ANN) leads to elucidating the impact of social variables on the accuracy of predicting students' final grades, which were estimated with high accuracy.

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13. Recommendations:

The research recommends the utilization of neural networks and their diverse applications, leveraging artificial intelligence in machine learning and deep learning applications, such as in other predictions, classification, clustering, and beyond. This aids in advancing the educational process by identifying factors influencing the quality of education and obtaining indicators useful for informed decision-making and proactive future planning.

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