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PREDICTING EFL LEARNERS' WRITING PROFICIENCY THROUGH READING AND WRITING PRACTICES: AN ARTIFICIAL NEURAL NETWORKS APPROACH

(Research article)

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Abstract

The current quantitative study explores the extent to which reading and writing practices predict the writing proficiency of 7th-grade EFL learners through Artificial Neural Networks in order to investigate nonlinear interactions among reading comprehension, writing volume, and writing proficiency. The participants of the study consisted of 173 students, and predictive efficacy was assessed using Multiple Linear Regression (MLR), Artificial Neural Network (ANN) and Radial-Basis Neural Networks (RBNNs) models. The obtained data were analysed using skewness and kurtosis values, as well as Kolmogorov-Smirnov and Shapiro-Wilk tests. The results indicate that reading comprehension and writing volume are strong predictors of writing proficiency, and ANN models perform better than traditional regression in capturing complex interdependencies. These findings have important pedagogical implications for EFL curriculum design and recommend systematic reading and writing interventions along with machine learning assessments and personalized instruction.

Keywords: Writing proficiency, artificial neural networks, machine learning, EFL learners

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1. Introduction

1.1. The problem and the purpose of the study

As one of the most demanding productive skills, writing can be challenging for many individuals, particularly in an English as a Foreign Language (EFL) context. Difficulties with grammar, vocabulary and punctuation, organization of thoughts, and the ability to express oneself effectively can be some of the factors that affect the development of this skill. EFL learners, in particular, are prone to these kinds of issues because they do not have sufficient vocabulary, which reduces their potential to express their ideas and thoughts in written form (Rabab'ah, 2003). A deficit in vocabulary also reduces the potential for originality and creativity in writing (Adas & Bakir, 2013). Although these problems have been increasingly realized, writing is still underrated among the skills taught in most EFL classes, as pointed out by the National Commission on Writing (2003). In most cases, writing is often viewed as an undervalued skill that is only practiced within the four walls of the classroom and not fostered into an ongoing independent activity. Without active involvement in writing independently, it is doubtful whether learners will develop any proficiency in this particular skill. All this goes on to underline the need for and importance of suitable pedagogical strategies that can help EFL learners improve their writing.

Several well-conducted studies have pointed out two intertwined activities whose significance for the process of writing cannot be overstated. Reading, as one such activity, has proven to play an instrumental role in language acquisition, serving as a catalyst for the emergence of other abilities, among which is writing (Fitzgerald & Shanahan, 2000; Krashen, 2004). Through extensive and intensive reading, students enrich their vocabularies and improve their grammatical intuition as well as familiarize themselves with the stylistic patterns typical of successful writing (Jouhar & Rupley, 2021). The other variable that matters much when it comes to writing development is the amount and regularity of writing practice. Students whose practice involves dedicating much time to writing through exercises in the classroom, online tools, or independently are bound to achieve higher gains in terms of writing fluency and competence (Graham & Perin, 2007; Carter & Townsend, 2022). Yet, no previous research has attempted to integrate the variables mentioned above in one systematic investigation aimed at determining the extent to which each of them predicts writing proficiency. What is more, most studies on the topic tend to focus on subjective indicators rather than collect empirical data, failing to reveal the exact impact of each variable.

How to change writing practices to be more efficient (Graham, 2019) must be one of the main concerns to be considered. Devoting considerable time and effort (Cutler & Graham, 2008; Graham, 2019; Parr & Jesson, 2016), using digital tools (Applebee & Langer, 2011; Graham, 2019; Simmerman et al., 2012) teaching with a variety of instructional strategies and giving constructive feedback for motivation are prevalent and crucial issues to teach writing. Since writing is a demanding skill to improve, teachers may not allocate an adequate amount

of time and effort to it. Furthermore, the lack of using digital tools in typical language classrooms (Applebee & Langer, 2011; Simmerman et al., 2012) may hinder the motivation of students in this digital era, which noticeably causes insufficient individual writing practices (Graham, 2019).

Modern research has also explored these issues within the realm of AI-supported teaching. According to Barrot (2023), students learning English as a foreign language (EFL) who were provided with automated written corrective feedback using AI technologies improved their grammatical proficiency at a significantly faster pace than students receiving no such feedback beyond the teachers'. Moreover, Zhang and Hyland (2022) have examined how EFL learners' interaction with AI-based writing support tools depends on their proficiency levels, which confirms the importance of differentiated writing pedagogy within the scope of digital learning environments. Overall, this evidence provides additional background for the analysis of the current study, which seeks to employ machine learning technology to investigate writing proficiency levels of EFL learners.

The current study focuses on this challenging skill and aims to investigate the relationship between reading and writing practices which previous research in this field has largely neglected to fully understand. This study also seeks an answer to what extent the writing proficiency of 7th-grade EFL learners can be predicted by their reading and writing practices. In addition, it also reveals the extent to which the estimated power of learning time, reading comprehension skills, and writing practices correspond with the predictions made by the ANN.

1.2. The reading – writing connection

Modern research It is well understood that reading plays an important role in language development and is commonly regarded as a “springboard” for the acquisition of other skills (Ala & Derequito, 2022). Another crucial aspect is that learners attain good comprehension skills through reading. Studies have found that strategies like repeated reading enhance the reading fluency and word recognition abilities of students (Kuhn & Stahl, 2003). Furthermore, enhancing the capability of dealing with literary difficulties is considered one of the ways of becoming a good reader to become a good writer (Gunning, 2010).

It is also essential to understand the importance of writing as well as the connection between the writing and reading processes (Abdalrahman, 2021; Fitzgerald & Shanahan, 2000). Writing about something read can enhance comprehension since it affords students a chance to connect, evaluate, personalize, and modify the important ideas in the text (Graham & Hebert, 2011). Since both reading and writing have much in common in terms of their cognitive processes and prerequisites, it is quite logical that both skills have a mutually reinforcing relationship (Shanahan, 2006). Besides, analyzing literary context (Abdalrahman, 2021; Chicho, 2022) and focusing on coherent passages (Abdalrahman, 2021; Bartan, 2017) have a great role in improving writing skills.

From the foregoing studies, it is understood that the extent of reading can enhance the writing skills of the learner (Cunningham & Stanovich,1991; Grabe, 2003). It is about this idea that Krashen (2004) wrote when synthesizing the research on the connection between complete reading skills and writing abilities in L1. Krashen's hypothesis is focused on the impact of free voluntary reading on L2 writing improvement. Likewise, the existing literature suggests that independent reading not only develops students' creative and story-telling skills but also presents tangible growth in the technical aspects of writing such as mechanics, spelling, content, grammar, and organization (Jouhar & Rupley, 2021).

It has also been revealed that intensive reading is one of the most helpful strategies for raising the level of writing skills. Even though there are few studies on the causative relationship between intensive reading and writing skills, further evidence lies in the previous research revealing that utilizing heterogeneous texts increases reading comprehension, enhanced vocabulary, correct grammar, and critical thinking. This is because intensive reading entails a strict focus on the text and constant interaction with the content of the text. Intensive reading enables the students to concentrate on language aspects and establish a relationship between the text and their writing. Secondly, it can enhance students' critical thinking skills since intensive reading is cherished in students because such skills are also fostered in them hence aiding their writing skills. With this brief review, it can be pointed out that fluency in reading is positively related to fluency in writing.

1.3. Writing volume and proficiency

Writing is a skill not easily obtained just by attending some writing courses and doing writing or grammar exercises (Pawliczak, 2015). Students should be supported and given space to write not only in schools but everywhere they are. Nonetheless, when learners are tasked with homework that does not involve writing at some length, it can be obvious that their writing competencies are not perfect (Gilbert & Graham, 2010). Otherwise, learning how to write is a process that demands time, and this process has an enormous effect on writing performance (Bennett et al., 2020; Révész et al., 2022; Vandermeulen et al., 2024). Reading is highly praised and takes precedence over writing in schools (Hsiang et al., 2018; Hsiang et al., 2020). In fact, reading is only one part of the puzzle when it comes to identifying ways to make writing better. In addition to reading practices, those who put in a substantial slice of their time on writing practice (Bizzaro, 2013; Graham, 2019), and engage in extensive writing (Sun, 2010) exhibit the greatest improvements in this skill in comparison to those not doing the same.

The amount of writing is an extremely vital element in written communication. Studies claim that regular and repetitive writing exercises enable fluency and accuracy improvements (Carter & Townsend, 2022; Graham & Perin, 2007). It can be best summed up by the well-known phrase "Practice makes perfect" among writers. According to the concept of "deliberate practice", practicing a skill or performing an activity repeatedly leads to continued

improvement, provided that this practice is purposeful, targeted, and offers feedback to the learner. Thus, instruction also contributes to the development of writing. The student learns through instruction, collaboration, feedback, and mentorship knowledge and beliefs about how to write. This could be a teacher, peer, or even a machine (Graham, 2019). Moreover, frequent writing offers more than just technical proficiency. The ability to write coherently and persuasively fosters critical thinking, creativity, and self-reflection, which are all fundamental components of academic success.

In summary, the development of writing proficiency lies in regular and diverse practice. It has been empirically shown that the regularity of writing practice brings about dramatic improvement in fluency and overall quality of written works. This finding implies that the incorporation of regular and varied writing practice into curriculum design and daily routine is highly recommended if educators and students want to maximize their writing abilities and achieve academic success.

1.4. Implications of artificial neural networks in ELT

Artificial Neural Networks (ANNs) have a potentially huge impact on English Language Teaching (ELT) in terms of easily enhancing the language teaching process and improving learning achievements. ANNs can be trained to tailor the process of language instructions according to the needs and abilities of every individual learner by analyzing their performance data and adapting curriculum sequencing accordingly.

Some recent studies have explored that there seems to be great potential to use ANNs in foreign language teaching (Frank, Monaghan & Tsoukala, 2019; Warstadt & Bowman, 2022). To begin with, ANNs can be trained on large corpora of text to learn the patterns and structure of a language and can be used to generate new text or predict the next word in a sentence, which can be useful for language generation tasks such as text completion, machine translation, and text-to-speech synthesis (Widyana et al., 2022). ANNs can also assist language learners with interactive opportunities for language practice and input acquisition with the help of chatbots (Gupta, Hathwar & Vijayakumar, 2020). In addition, ANNs can be utilized to classify text as positive, negative, or neutral, which can also be used to analyze student feedback (Katragadda et al., 2020; Oza, Kamat & Naik, 2018). This would allow instructors an insight into student perceptions and how to design more effective instruction. What is more, ANNs can be trained for the classification of texts into different categories; it not only enables the identification of the text's topic but also helps with the sorting and filtering of large amounts. Last but not least, ANNs can recognize speech (Dede & Sazlı, 2010; Kamble, 2016), and can help in transcribing spoken languages into written text. This would help develop listening and speaking skills among students. Besides, it will give learners chances for authentic language input and practice.

However, the specific application of ANNs in ELT will depend on the needs and resources of the teacher or institution. For instance, it can be used for automated essay scoring. It has

been shown to be effective in evaluating the grammatical and lexical complexity of student writing (Shermis et al., 2010). Another example is using ANNs for computer-assisted language learning (CALL) which can be used to generate personalized language learning activities for students and provide real-time feedback (Sykes & Thorne, 2008).

One of the lines of ongoing research in natural language processing and computational linguistics is the use of ANNs for the prediction of the writing proficiency of EFL learners by looking at their reading and writing practices. ANNs can recognize patterns in huge language data and make predictions based on them, which presents ANNs as a very useful tool in estimating the writing proficiency of EFL learners. While this is a certain approach to using reading and writing practices as input data for ANNs, it is relatively unexplored. This would require a very large dataset of reading and writing practices by EFL learners to train the ANNs and use them for predicting their writing proficiency. Further, there are ethical implications associated with the use of ANNs in assessing language proficiency. While the ANNs for ELT have huge potential to be of great benefit, trials are still underway to establish their efficacy and optimize their performance. These gaps are being addressed by recent investigations. In research done by Crossley et al. (2023), it was found that a combination of lexico-syntactic properties was able to improve prediction of L2 writing quality using machine learning models compared to predictions made by human raters. Similar findings were noted by Huang et al. (2024), who used transformer models to predict English as Foreign Language writing skills based on learner corpora. According to their findings, deep learning models performed better than linear regression models in predicting EFL skills, just like in the current study.

1.5. Theoretical framework

In this study, the theoretical framework is underpinned by cognitive load theory (Sweller, 1988) and self-regulated strategy development (Graham, Harris & Troia, 1998), which are two of the most significant educational theories when it comes to the writing process. These theories give a clear-cut idea of the whole metacognitive universe of the writing process and the micro-level strategies that can be used to improve writing performance. The discussion that follows in the upcoming pages will delve into the above theories as well as demonstrate their contributions to the fostering of writing skills among EFL learners.

Learners mostly focus on higher-order components like organization and coherence when writing in their first language since they already know the linguistic patterns and structures through practice. However, the target language requires learners to consciously remember and apply grammatical rules, vocabulary, and syntactic structures (Nawal, 2018). This is a process that leads to the working memory carrying a substantial cognitive load in the background because the room for information storage is very limited (Van Merrienboer & Sweller, 2005). Based on *the cognitive load theory*, which was first presented by Sweller (1988), up to a point where cognitive requirements outstrip the capacity of the system, learning can be blocked. Additionally, a high cognitive load with L2 writing can distract learners from the main content

or global clarity that constitutes the essence of the text due to form accuracy. Techniques such as the breaking down of tasks into parts, the provision of scaffolding, and giving learners the opportunity for more practice reduce the cognitive load and as a result help in developing writing and second language proficiency.

The writing strategy *self-regulated strategy development* (SRSD) is a structured approach to writing that helps students in every step of the writing process giving them specific strategies from planning to revising and editing, which causes constant improvement (Harris et al., 2018; Zimmerman, 2002). The approach highlights the principle of step-by-step learning (Mason et al., 2011), starting with writing under the supervision of the teacher, and gradually moving to independent writing through regular practices. Success in writing tasks reinforces students' beliefs in their abilities, which ultimately motivates them to practice more. Besides, SRSD helps the students engage in regular and different kinds of writing practice which is very important for developing writing proficiency (Sun et al., 2022).

The main purpose of this research is to contribute to understanding the relationship between reading and writing in EFL learners, and to the field of language proficiency assessment using ANN. In this respect, the current study tries to address the following research questions:

(1) To what extent do learning time, number of reading comprehension questions completed, reading comprehension points, and total words written predict writing proficiency in EFL learners?

(2) How do artificial neural networks (ANNs) compare to multiple linear regression in predicting writing proficiency?

2. Method

2.1. Research design

This quantitative research utilized the following methodologies.

2.1.1. *Artificial neural networks (ANNs):* Artificial neural networks (ANNs) are machine learning algorithms created to imitate human brain structure and function. One of the major benefits of ANNs is that they learn from data and, in the process, increase performance over time. This is realized through the backpropagation of errors from the output back to the network to effect changes in the connection weights. Applications of ANNs vary from image and even speech recognition (Dede & Sazlı, 2010), natural language processing (Otter et al., 2021), and even control systems (Schmidhuber, 2015).

2.1.2. *Multilayer perceptron (MLP):* A Multilayer perceptron (MLP) is a type of ANN including multiple layers of artificial neurons, connected in a feedforward manner. Each neuron receives input from the previous layer, performs some mathematical operation on

that input, produces an output to be passed on to the next layer, and is followed by some activation function that allows a network to model complex relationships in the data because they add some non-linearity into the network. The links between neurons are weighted, and these weights are changed during the training process to achieve optimum performance. Backpropagation is by far the most common training algorithm for MLPs, which adjusts the weights concerning the difference between what the network comes up with and the desired output; this cycle is repeated until the error becomes minimized. However, their performance is limited when dealing with highly non-linear and complex problems (LeCun et al., 2015).

2.1.3. *Radial-basis neural networks (RBNNs)*: Radial basis neural networks (RBNNs) are an artificial neural network based on the kernel, the RBF kernel, a function that measures input similarity in a high-dimensional space (Haykin, 1998). They are composed of an input layer and an RBF layer. While the input layer projects the data into the high-dimensional feature space in the input layer, the RBF layer, also called the hidden layer, applies the RBF kernel to generate a set of nonlinear features that can approximate the target function. The output layer, also known as the linear layer, receives such nonlinear features and produces the final output of the network.

Applications of RBNNs include function approximation (Tanrikulu, 2009), pattern identification, and time series prediction (Afan et al., 2020). More specifically, RBNNs are very appropriate in problems where there is a nonlinearity relationship between the input and output variables. They are frequently applied in situations when the number of inputs is high, but the number of outputs is low.

2.2. Model development

It is a common problem in artificial neural networks that trying to find the relationships between input and output variables can end up being overfitting. This is one vision of what will happen when the model has been trained too well on the training data; thus, it results in poor performance on new data. Overfitting can be prevented by regularization methods, stopping early, and collecting enough data for the training. This dataset is then divided into two sub-sets that are the training data set and the testing data set (Ghorbani et al., 2020).

The test dataset, which included 17% (n=29) of all data, was separated for validation purposes, while the other 83% (n=144) of the total amount of data was utilized for training purposes. This ratio was chosen in an attempt to maximize the training set size due to the small amount of available data. The entire set of ANN and MLR models were built and tested using MATLAB (R2022b). According to Gandomi et al. (2013), in the present research, the recommended ratio of data to input variables must be more than 5. In the present study, it is 34.6 indicating that the number of data is sufficient to obtain a reliable ANN model.

In the study, several multiple linear regressions, multi-layer perceptron, and radial basis neural network models were developed to predict the final writing scores of the students considering four variables; namely learning time (minutes), number of reading comprehension questions completed, reading comprehension points, and total words written. Different models were designed to get the best performance. For MLP models, different hidden neurons and spread coefficients with hyperbolic tangent sigmoid, log sigmoid, and linear functions were configured. That resulted in 60 models for the MLP method using Levenberg-Marquardt for the training function. Similarly, for RBNN models, a radial basis transfer function (radbas) in the hidden layer and a purelin transfer function in the output layer was employed. The study also uses a range of number of hidden neurons from 1 to 20 and spread coefficients from 1 to 15 to develop the best RBNN models to predict the writing scores. Accordingly, 300 models for the RBNN method were achieved. The best-performing model within each architecture was selected based on the lowest RMSE on the test set combined with the highest R^2 value, ensuring that model selection prioritized generalizability rather than training fit alone.

The best model was determined through the root mean square error (RMSE) and the coefficient of determination (R2). RMSE measures the difference between predicted and true values, while R2 indicates how close the dependent variables are predicted from the independent variables wherein values at 1 show good fit and 0 show poor fit in a regression model. It's important to note that having a high R2 value does not necessarily mean that the model is a good fit. It only measures the goodness of fit of the model to the data.

2.3. Setting and participants

The participants of this study were 7th-grade students (n = 173) from a private school in Ankara, Turkey. The sample represented varying levels of academic performance and English language proficiency within the same institution. Given that all participants attended a single private school, claims of broad socioeconomic or educational diversity should be interpreted with caution. The students in the sample were allocated an English language instruction of eight hours per week; however, there might be reasons to believe that the levels of interest and motivation towards the English Language lessons would be at varying levels.

It is also important to highlight that none of the participants reported any issues when accessing the online reading and writing platform used throughout the school year. Moreover, the time allocated to the tasks was enough for all participants, and they could use their time for the tasks as they wished during the given time slot.

2.4. Data collection procedure

Throughout the academic year, students were provided with an online reading platform that facilitated the distribution of weekly articles, along with accompanying comprehension questions. The students were expected to read the articles and respond to the questions during

the weekend, including an open-ended opinion question, by the following Monday. To facilitate the development of their writing skills, students received individualized, constructive feedback on their responses, which was based on four key criteria: task response, lexical resource, coherence and cohesion, and grammatical accuracy. The accessibility of the online platform 24/7 in addition to classroom interaction and feedback provided students with more practice (O'Donnell, 2006), which can be deemed a great solution to the challenges of writing (Adas & Bakir, 2013).

The online platform also provided a detailed report on each student's usage of the platform, including the amount of time spent, the number of comprehension questions completed, the success rate for each student, and the number of written words produced during the academic year. At the end of the second semester, students wrote an opinion paragraph as part of their progress evaluation sessions. The paragraphs were rated on a 36-point scale where 9 points for each of the above criteria were assigned according to the IELTS Writing Band Descriptors. These descriptors function as a useful tool in an academic sense by giving transparent and objective criteria for assessing the quality of written responses. There were two aims of this assessment: to assess the progress of students with respect to writing skills and to express an opinion in a clear, coherent, and grammatically correct form. To ensure scoring reliability, all writing samples were independently rated by two trained raters. Inter-rater reliability was calculated using the intraclass correlation coefficient, yielding a value of .87, which indicates strong agreement. Discrepancies of more than two points on any criterion were resolved through discussion until consensus was reached.

2.5. Data analysis

During the data analysis, acquiring skewness and kurtosis values, normality may be evaluated to some extent (Pallant, 2020). For a closer examination, Kolmogorov-Smirnov and Shapiro-Wilk tests were employed. There is a dataset with 173 cases and five variables: "learning time" (measured in minutes), "questions completed," "reading comprehension points," "total words written," and "final writing evaluation." Since the tests of normality showed that the assumptions for the parametric tests were not met, the scores were checked for the 'evidence of outliers' (Abulela & Harwell, 2020, p. 67). The multivariate normal distribution was ensured through data transformation so that the strong skewness and kurtosis could be overcome, and the outliers could be detected (n = 6). Descriptive statistics with z-scores obtained after data transformation showed that the data were distributed normally.

Table 1. Descriptive statistics

	N	Skewness		Kurtosis	
		Statistic	Std. Error	Statistic	Std. Error
Learning time	173	1.39	.19	1.75	.37
Questions completed	173	.03	.19	-.53	.37
Reading comprehension points	173	.02	.19	-.33	.37
Total words written	173	1.31	.19	1.24	.37
Final writing evaluation	173	-.17	.19	-.53	.37

The skewness values suggest that the data is moderately skewed for all variables except the final writing evaluation (-.17), which is moderately skewed in the opposite direction. This indicates that the data is not perfectly symmetrical, but it is not extremely skewed either. Likewise, the kurtosis values suggest that the data is moderately peaked for all variables, indicating that the data is not extremely flat or extremely peaked (Field, 2024; Tabachnick & Fidell, 2013).

3. Results

3.1. Multiple linear regression

A standard multiple regression was employed between the learning time, the number of reading comprehension questions completed, the success in reading comprehension, and the number of words written in writing practice as independent variables and final writing proficiency scores as the dependent variable. The variables were transformed to reduce skewness and kurtosis, decrease the number of outliers, and confirm normality considering the evaluation of the assumptions. Six outliers among the cases were found and excluded (n = 167).

Table 2. Pearson correlation

	learning time	questions completed	reading comp. pts	total words written	final writing evaluation	Sig.
Learning time	1.00	.55	.67	.69	.54	.00
Questions completed	.55	1.00	.59	.44	.50	
Reading comprehension points	.67	.59	1.00	.65	.56	
Total words written	.69	.44	.65	1.00	.60	
Final writing evaluation	.54	.50	.56	.60	1.00	

As provided in Table 2, the correlations between the variables reveal that all the scales correlate substantially with final writing evaluation scores. In addition, there is a noticeable

but not too high –'a bivariate correlation of .7 or more' (Pallant, 2020, p. 158) correlation between the independent variables. As for the extent of the variance in writing evaluation scores explained by the model, the R square value is .448, which is statistically significant (Sig. = .00; $p < .01$).

Considering the results of multiple regression, the contribution of learning time, the number of reading comprehension questions completed, the success in reading comprehension, and the number of words written to writing proficiency scores were compared. In Table 3, it is shown to what extent each of the independent variables was involved in the dependent variable's prediction.

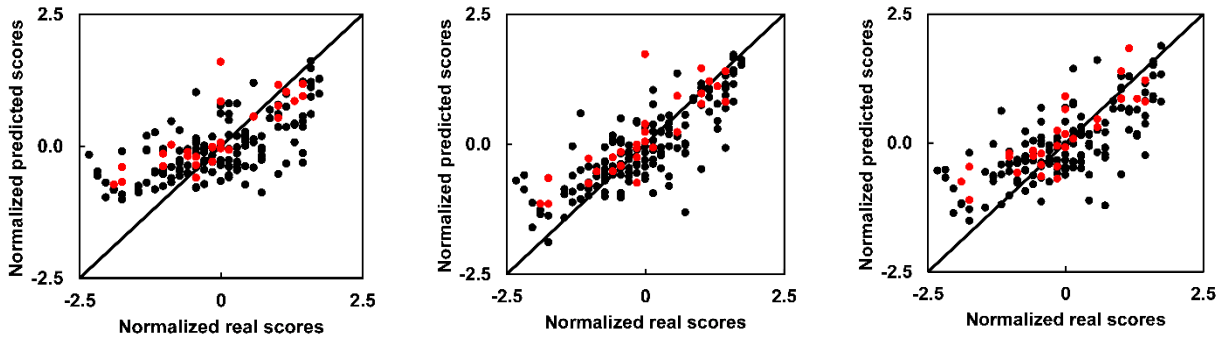
Table 3. The contribution of independent variables

Variables	Beta	Sig.
Learning time	.07	.45
Questions completed	.22	.00
Reading comprehension points	.15	.09
Total words written	.36	.00

Based on the data specified in Table 3, the total number of words written makes the strongest contribution with a value of .36, and it is statistically significant ($p < .01$). Similarly, the contribution of the number of reading comprehension questions completed is significant ($p < .01$) with the Beta value of .22; however, this contribution is less than the contribution of the words written. The other two independent variables do not have a significant contribution ($p > .05$). A higher β value indicates a strong relationship between the independent and dependent variables.

3.2. Estimation of ANN

The normalized actual and predicted scores are plotted in Figure 1. Therefore, it is the adaptiveness of ANNs, combined with their non-parametric structure, that makes them particularly well suited to modeling complex and nonlinear relationships between input and output variables. By contrast, the normality and linearity assumptions underlying MLR modeling can limit its effectiveness in such settings (Pallant, 2020; Tabachnick & Fidell, 2013). Accordingly, the results that were obtained in this study have shown that MLP and RBNN models had better predictive performances compared to MLR, as indicated by the superior goodness-of-fit metrics given by their application.



(a) (b) (c)

Figure 1. Comparison of normalized real and predicted writing scores with (a) MLR, (b) MLP, and (c) RBNN (black and red circles show the data used for training and validating, respectively)

Table 4 presents the performance of three different regression models (MLR, MLP, and RBNN) on a given dataset, measured by the RMSE and R2 metrics. Notably, the results reveal that the MLP model yields the lowest RMSE and the highest R2 values, implying that it outperforms the alternative models in terms of predictive accuracy. These findings underscore the potential utility of ANNs for modeling complex data relationships and inform the selection of optimal modeling approaches for predictive analytics in relevant contexts.

Table 4. Performance of the methods

Method	Dataset	RMSE	R^2
MLR	Train	0.742	0.415
	Test	0.619	0.547
MLP	Train	0.586	0.635
	Test	0.515	0.687
RBNN	Train	0.680	0.508
	Test	0.537	0.660

Table 5 displays the outcomes of the MLP method, wherein the best predictions were attained when implementing the tansig function with 13 hidden layers. Conversely, the optimal number of hidden layers and spread coefficient for the RBNN method were identified as 10 and 2, respectively.

Table 5. The best predictions in MLP

Function	# of hidden layer	RMSE train	RMSE test
logsig	14	0.6519	0.7018
tansig	13	0.5147	0.5860
purelin	17	0.5603	0.5836

These results thus mirror the importance of selecting and optimizing the hyperparameters in ANNs, which impact predictive accuracy and overall performance of the model. As such, the findings presented here bring forth the essence of having an overall hyperparameter tuning process in the development and implementation of ANNs.

4. Discussion

The study aimed to investigate the effects of EFL learners' reading and writing practices on their performance at writing tasks and to find out to what extent ANNs predict writing proficiency. The results of this study demonstrate that all variables considered in this research, such as the amount of learning time, the number of reading comprehension questions completed, the rate of success in reading comprehension, and the word writing frequency in the writing practice, appear to exhibit a relationship with the level of writing proficiency. The findings indicate that the identified factors play an important role in shaping the writing abilities of EFL learners. Besides, the non-linear relations captured with ANNs reveal that difficult patterns within data cannot be easily handled by linear models. The study also points out that ANNs can spot implicit as well as complicated correlations between variables, thus leading to more precise predictions and a better understanding of factors affecting writing proficiency.

4.1. Identifying the principal factors influencing writing proficiency

The correlation analysis indicated that the independent variables ranged from moderately to highly intercorrelated. The linear correlation analyses show that ‘the number of reading comprehension questions completed’ and ‘total words written’ are strong predictors of writing ability. Most significantly, these findings suggest that intensive reading instruction and writing practice are pedagogical approaches language educators can apply to best develop writing skills. The literature based on the practice of writing is voluminous, and many point to a positive correlation between the frequency of writing and overall writing proficiency (Graham & Perin, 2007; Sun, 2010). Research shows that practice is related to improvement in fluency, accuracy, and overall quality of writing (Graham & Perin, 2007) if it is a regular and varied process (Bennett et al., 2020; Révész et al., 2022; Vandermeulen et al., 2024).

The results of the study, which are based on cognitive load theory and self-regulated strategy development, propose a holistic strategy for teaching writing. An important aspect of fostering writing skills is engaging in extensive reading (Abdalrahman, 2021) and consistent writing exercises, which aid in automating language knowledge and reducing mental strain. Nawal (2018) also claims that switching between languages can result in a high cognitive

load. Therefore, regular engagement in the act of writing in the target language serves to reinforce the cognitive processes and linguistic structures by reducing this load. Similarly, SRSD plays a vital role by providing organized and strategic assistance throughout the writing process, promoting students' self-control and continual progress (Harris et al., 2018). It ensures the development of writing competence with the regular and diverse application of writing to the real-world environment (Sun et al., 2022). Another benefit of SRSD is that students can get familiar with different kinds of writing and a huge range of vocabulary through extensive and intensive reading so they can learn writing effortlessly and speedily. Overall, the combination of the practice of writing on a regular basis and the provision of intensive and extensive reading creates a holistic view of writing instruction, hence lifelong literacy and learning skills are developed.

4.2. Comparison of non-linear and linear relationships

In the area of language assessment research, it is crucial to evaluate the effectiveness and feasibility of nonlinear models in comparison to traditional linear models to revisit existing data-driven theories by advanced analysis methods (Aryadoust & Baghaei, 2016). Nonlinearity stands as a major development in statistical data analysis in the education field. The current study proves the advantages of ANNs over MLR models in dealing with complex and nonlinear data relations. The specific function of ANNs is to detect and represent these complicated interconnections, whereas MLR can only describe linear relationships (Elangasinghe et al., 2014; Otchere et al., 2021). In the present study, the first independent variable, which is learning time, has been found to be statistically significant at the threshold necessary for multiple linear regression analysis. Consequently, such alternative modeling methods as MLP and RBNN have been utilized to find the relationships between the variables and to estimate the final scores. It is worth mentioning that MLP was the clear winner in terms of predictive accuracy among all models that were tested. The results highlight that ANNs are potential tools for practitioners to analyze such nonlinear relationships.

Some of the key reasons behind ANN's better performance than MLR include its architecture characteristics. The first reason lies in the linear relationship assumed by MLR, meaning that there cannot be any non-linear relationships between independent and dependent variables in its models. ANN, however, utilizes the non-linear activations between different layers, allowing the model to account for multiplicative relationships and thresholds between the predictor variables, such as the interaction between reading and writing volumes. In addition, the flexibility of ANN makes it possible to model more complex functions than those modeled by linear regression. It can be expected that these are the main factors accounting for the higher coefficient of determination (.687) produced by the MLP model on the test data compared to .547 from MLR. However, ANN model performance depends on certain aspects of its architecture, meaning that these should be considered in future research.

The result of the ANN analysis confirms the argument to some extent that the writing proficiency of the EFL essays can be affected by the amount of intensive reading and the frequency of writing activities. These findings imply that learners' writing skills in EFL would be developed through the balance of intensive writing and greater engagement in reading activities. Further, all analyzed variables, including the amount of time dedicated to learning,

the number of reading questions completed, the effectiveness in the process of understanding, and how regularly they communicated in writing, showed a significant correlation with the performance represented by the research participants. In conclusion, results from the ANN model suggest that the study variables may serve as meaningful indicators of writing proficiency among EFL learners, highlighting their potential importance for writing instruction and the design of curriculum in an EFL setting.

5. Conclusion

The findings of this study have both theoretical and practical implications for the teaching of English as a foreign language (EFL). The study, which focuses on the connected themes of cognitive load theory and self-regulatory strategy development, is supported by analytic findings collected from reading and writing activities. This paper leads to the discussion of new perspectives on writing strategies designed to boost EFL learners' productivity. The next sections examine the consequences of these discoveries and discuss future areas of research.

5.1. Theoretical and practical implications

For the teaching of English as a Foreign Language (EFL), the research findings are crucial. It is therefore suggested that EFL teachers should employ intensive and extensive reading techniques among other methodologies within their lesson plans to enhance reading comprehension and writing abilities among learners, based on the linkages that were found to hold between the identified variables and writing proficiency levels seen in the subjects. Furthermore, it is necessary for EFL educators to give a reason why pupils should love reading and writing outside class regularly to overcome obstacles towards learning how to write well enough. In order for this article’s objectives to be accomplished, instructors of EFL need to think thoroughly about student interests, make sure there are plenty of resources and materials available for learning, and allow them enough time to improve their writing proficiency so they can become better writers in the future.

5.2. Theoretical and practical implications

Writing proficiency is a multifaceted construct that is impacted by many aspects that extend outside the scope of our investigation. The current study has some limitations, despite the researcher’s belief that increased reading and writing practice can predict writing skill (Cunningham & Stanovich, 1991; Grabe, 2003). To begin with, the sample size in this study could not be typical of the whole population. All subjects in the study were recruited from a particular private high school located in Ankara, Turkey. This makes the research’s findings specific to this demographic, and it will be impossible to generalize the outcomes across schools from other geographical areas and social backgrounds. Second, even though the ANN models exhibited better prediction accuracy compared to regression models, the ANN algorithm is susceptible to architecture, random weights, and sampling factors. Therefore, it is likely that some of the patterns discovered in the study might not generalize to other data sets. Future research should incorporate methods of cross-validation or replicate findings using an

independent data set to validate the ANN model. Third, the validity of the 36-item rating scale used to measure writing ability depends on how consistently the score is being applied. The inter-rater reliability coefficient was estimated at 0.87, but future work should establish other forms of validity for the outcome variable (e.g., test-retest reliability). Another drawback is that there was no way to regulate other factors like the pupils' motivation for writing or having various teachers. As a result, even while the current findings provide insightful information about the link between particular characteristics and writing skills, a more thorough investigation must be carried out. Future studies might look at additional possible predictors of writing proficiency and investigate how these variables interact to affect the development of writing skills.

This research will, on the other hand, help researchers understand better how language acquisition and assessment operate by scrutinizing the intricacies in nonlinear relationships among variables. ANN has a sound effect in estimating the writing ability of EFL learners using an artificial neural network by studying their reading and writing practices. ANN is one form of machine-learning algorithm that can be made to analyze language data to predict language proficiency. Through the examination of reading and writing practices, ANN can recognize the language use patterns among EFL learners and give predictions about writing skills. However, further studies will be required to understand the potential and limitations of ANNs fully in the field of ELT. Anyway, it is being researched and there should be more studies to confirm its effectiveness.

All in all, it is suggested that more research be conducted to compare conventional linear models with non-linear models in terms of efficiency and practicability, as well as refine current data-driven theories using advanced quantitative techniques.

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Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. It is important to note that the students did not take part in any experiment as part of this research. There was no need to introduce any other test, task, or treatment for the purposes of this research. In this case, the analysis focused only on performance results which were recorded automatically through the use of the online platform for reading and writing. As for the research design, there was no need to interact directly with the participants or manipulate any variables, nor was there a need to collect any extra data other than that which was created during the learning process. This meant that there was no need for the researchers to obtain ethical committee approval for this research.

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