

Research Article

The Impact of Scaffolded Metacognitive Writing Strategy Instruction on Iranian Intermediate EFL Learners' IELTS Writing Task 2

Somayeh Nourazar, Rokhsareh Kakvand , and Seyed Hesamuddin Aliasin

Department of English Language, Faculty of Humanities, University of Zanjan, Zanjan, Iran

Correspondence should be addressed to Rokhsareh Kakvand; rokhsarehkakvand@gmail.com

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According to research findings, metacognition has been shown to have an essential role in education. As individuals are different, metacognitive knowledge cannot be the same for all learners. Learners need to be trained to improve their metacognition. Given this, the current study has examined the influence of scaffolding awareness and the use of metacognitive strategies during a strategy instruction program on the performance of Iranian EFL learners on IELTS writing task 2. To achieve this aim, using the Oxford Quick Placement Test (OQPT), eighty intermediate EFL learners (males and females) were selected from among 100 learners. They were randomly assigned to two groups of forty participants each as control and experimental groups. To benchmark the participants' writing skills, an IELTS writing task 2 question was administered as the pretest. The experimental group received scaffolded metacognitive strategy instruction in their writing practices for four weeks, with 6 hours per week. The control group was instructed in traditional writing practices. The purpose was to promote the metacognitive awareness of the experimental group in performing the writing task. At the end of the treatment, another IELTS writing task 2 question was assigned as the posttest to measure the participants' gain due to the treatment application. The independent and paired samples *t*-tests indicated that scaffolded metacognitive instruction effectively improved learners' metacognitive awareness, which led to their improvement in writing skills. There was not any significant difference between males and females' posttest mean scores.

1. Introduction

There is an increasing emphasis on the importance of metacognitive knowledge in cognitive activities associated with language use and learning [1–3]. Metacognition is defined as awareness and control of cognitive activities [4–6]. Most simply, metacognition is learning about learning. Metacognition allows learners to understand better their strengths and weaknesses in the process of learning and helps them use appropriate strategies. According to Anderson [7], metacognitive skill helps learners make conscious decisions to improve their learning by self-reflection.

A large number of studies have concentrated on the critical role of metacognitive knowledge in developing receptive English language skills such as reading and listening

[8–12]. Furthermore, some studies have found that developing learners' metacognitive knowledge results in their better performance in writing tasks [1–3, 13–16]. Furthermore, in another study, Panggabean and Triassanti [17] found that metacognitive strategy training enhanced the students' oral presentation skill in an EFL class. It also helps learners be more aware of their responsibility as autonomous learners.

Many EFL instructors and learners may consider English writing as a challenging skill to teach and learn. There might be different reasons for this. EFL writers may be faced with some problems such as “lacking appropriate English lexical expressions and struggling with mechanics, grammar, sentence structure, paragraph coherence, rhetorical patterns, revision at both higher and lower ends, and English writing conventions” [18] (p. 20). Furthermore, due to the need for

vast knowledge and the need for cognitive activities, writing in one's native language is difficult, let alone in a foreign language [18]. On the other hand, many schools and institutions are crowded with many learners in a single language classroom. This situation makes it challenging for the teachers to assign sufficient writing tasks and give their feedback on those tasks to the individual learners.

Few studies have been conducted on metacognitive knowledge and its importance in productive English language skills in general and writing as the most challenging skill in particular [1–3, 13, 14, 16, 19]. Motivated by this gap in the related literature, this study aimed to investigate the role of metacognitive knowledge in the English writing of Iranian EFL learners. The findings of this study may contribute to better teaching and learning of English writing skills.

2. Review of the Literature

2.1. Metacognitive Knowledge. John Flavell first proposed metacognition theory in 1979 (cited in [19]). He defined metacognition as the knowledge that focuses on cognitive activities [4]. As a broad definition, metacognition is awareness and control of one's cognition [4, 6]. Professional language users are metacognitively aware and can use metacognitive strategies effectively. As Baker and Brown [20] mentioned, the learner's control of cognition includes planning, monitoring, testing, revising, and evaluation. Flavell [4] introduced knowledge and experience as the two aspects of metacognition and emphasized person knowledge, task knowledge, and strategic knowledge as three interactive variables of metacognitive knowledge. Person knowledge refers to the general knowledge that learners have about themselves as learners. Wenden [21] suggests that person knowledge includes cognitive and affective variables such as age, language aptitude, and motivation. Task knowledge is knowledge about a particular task. It involves three aspects of learners' knowledge: the purpose of the task [22] (cited in [19]), the nature of the task, and the requirements of the task such as the knowledge and skills needed to complete it [21].

2.2. Metacognitive Strategies. EFL instructors need to have strategic metacognitive knowledge about teaching strategies. A teaching strategy leads to better results by using it appropriately and knowing precisely what the strategy is and how and when to be used in a classroom. Xiao [18] (p. 23) stated that "teaching metacognitively involves either teaching with metacognition or teaching for metacognition." The latter means that teachers activate or develop students' metacognition by designing some instruments, whereas the former means that teachers think about their thinking and their control over how they teach. Knowing the concept of metacognition is essential for all teachers as it enables them to control their thinking and their teaching process in specific contexts with specific goals. According to Xiao [18], there are three different ways of teaching in a metacognitive way: explicit instruction, scaffolding instruction, and a school year's training.

"Think" sheet and cue cards are two examples of explicit instruction. Bereiter and Scardamalia [23] used cue cards to become aware of their writing process. There are some guidelines on these cards; for example, "people may not understand what I mean here," and "I would better leave this part out" (pp. 270-271). Raphael et al. [24] designed a "think" sheet that includes some questions like "Who reads my writing?" "What do you do first when you write a paper? Second? Third? Fourth?" "What reasons do I have for writing?"

Scaffolding instruction is considered effective in developing learners' metacognitive awareness [2, 25–28]. In scaffolded instruction, students are engaged in tasks in a supportive environment while having independence. In this way, students feel more confident and safe. In the process of teaching, the teacher guides the students until they could master metacognitive strategies. As mentioned by Whitehead [12], learners often show an increase in self-confidence when they develop metacognitive skills.

The concept of scaffolding is based on Vygotsky [29] concept of the *zone of proximal development*. "The zone of proximal development defines those functions that have not yet matured but are in the process of maturation, functions that will mature tomorrow but are currently in an embryonic state" [29] (p. 86). In other words, scaffolding helps students fill the gap between what they can do with or without guidance. According to Rosenshine and Meister [30], teachers need to follow six main steps to plan for scaffolding instruction:

- (1) Presenting new cognitive strategies
- (2) Regulating difficulties and challenges during guided practice
- (3) Providing different contexts for students to practice
- (4) Providing feedback
- (5) Increasing students' responsibility
- (6) Providing independent practice

Metacognitive instruction should be an integral part of the instruction in the classroom. For example, if we want to include scaffolding instruction in our curriculum, we need at least five weeks to complete it. Furthermore, teachers must know that implementing metacognitive instruction in the classroom requires patience [18].

2.3. Metacognitive Strategies and Writing Skills. Writing is one of the four primary skills in learning a second language. Writing is considered as a cognitive and metacognitive process and requires planning, drafting, monitoring, and evaluation [13]. In this process, emotions and thoughts are transferred, revised, organized, and assessed. Writing is considered a cognitively demanding process, and metacognitive writing strategies help learners guide their thoughts consciously and improve their writing performance [1, 31, 32].

Research has proved that learning metacognitive strategies improve writing skills [1, 13, 14, 16, 31, 33]. Metacognitive strategies help learners assess their cognitive progress and self-

evaluate their writing skill. Using metacognitive strategies learners can compose well-structured and organized texts. As stated by Hosseini [1], metacognitive awareness mediates a writer's thought process during each phase of the writing process.

2.4. Related Studies on Metacognitive Strategies and Writing Skills. Writing strategy instruction has always been one of the crucial areas of research among scholars. Many studies have focused on cognitive and metacognitive strategies and their effect on improving learners' writing skills. Many of the studies have demonstrated a positive correlation between metacognitive knowledge and being a successful learner.

In their study, Pitenoe et al. [16] explored the effect of cognitive and metacognitive strategies on the content of the Iranian intermediate learners' writing. The study participants were divided into three different groups, namely, one control group and two experimental groups. The two experimental groups received cognitive and metacognitive strategy instruction for the writing practices. However, the control group received no training on writing strategies. The results of the study revealed that the experimental groups' writing had improved after writing strategy instruction. Furthermore, this investigation showed that the metacognitive group outperformed the cognitive one in writing the content.

Many other studies have shed light on this issue. Pitenoe et al. [16] confirmed that both cognitive and metacognitive writing strategies help learners to have a better perception of the content of their writing.

In another study, Cer [13] examined metacognitive strategy-based writing practices and their effect on EFL learners' writing skills in Turkey. The study revealed that the metacognitive strategies improved writing ability.

In a similar study in China by Yanyan [19], 120 non-native undergraduates improved their writing skills through metacognitive strategies.

Wang [33] explored the relationship between English writing instruction and metacognitive monitoring as the core of metacognitive strategies. That paper sought to promote students' metacognitive monitoring ability in the teaching of English writing skills by applying the theory of metacognitive monitoring. The results revealed a positive effect on students' English writing skills.

In a study on 43 students aged between 11 and 12, Colognesi et al. [14] investigated the effects of metacognitive questions on students' writing skills and how they respond to such questions. In that study, the participants received writing instruction and were asked to write book reviews and rewrite them several times.

Unlike the control group, the experimental group was exposed to metacognitive questions before, during, and after writing. As a result, the experimental group outperformed the control group in the writing activity. In addition, similar studies have shown a positive correlation between applying metacognitive strategies in writing lessons and improving students' writing ability [17, 31, 34–36]. They encourage EFL teachers to use metacognitive strategies to improve students' writing abilities.

There also exist some studies conducted to investigate the correlation between metacognitive knowledge and improving Iranian EFL learner's writing abilities [1, 2]. They proved a positive correlation and the usefulness of applying metacognitive techniques in an EFL writing classroom.

From the review of the previous studies, a few research gaps are noticed in this field:

- (1) There are few studies on the relationship between metacognition and writing
- (2) There is no research on improving IELTS writing task 2, which is one of the most important tests for ESL students
- (3) There are limited empirical studies at large scales, especially in the Iranian context

To address these gaps, the present study investigated the role of metacognitive knowledge in IELTS writing task 2 in an Iranian EFL context.

To achieve the objectives of the study, the researchers posed the following research questions:

- (1) Does metacognitive strategy instruction affect Iranian intermediate EFL learners' performance on IELTS writing task 2?
- (2) Does gender have any moderating effect on the casual relationship stated in the first research question above?
- (3) What is the learners' attitude toward the use of metacognitive strategies in developing their writing performance?

3. Methodology

3.1. Participants. The study was conducted at an English language school in Zanjan, Iran. Eighty conveniently available EFL learners participated in this study. They were homogenized for their English proficiency level—intermediate. The participants were randomly divided into two groups: forty students, both male and female, formed the control group, and the other forty students comprised the experimental group. Their ages ranged from 19 to 28.

3.2. Instruments. Four main instruments were used in the study: two tests of IELTS writing task 2 as pretest and posttest, the Oxford Quick Placement Test (OQPT), and the expert judgment questionnaire.

3.3. Pretests and Posttests. To measure the writing ability of the participants, an IELTS writing task 2 question was administered as a pretest. The participants were given 40 minutes to write an essay on the following topic: "a country becomes interesting and develops quickly with a mixture of nationalities." The researchers corrected the writings. After the treatment, another writing task on the following question was administered to determine whether there was any improvement in writing ability over the five weeks of instruction: "What problems will your country face in the next

ten years?” The questions were taken from a well-known website (<https://www.ielts-mentor.com/>) which has the most recent and repetitive IELTS writing questions and topics. These two questions were uploaded and updated in 2020 as samples of last-year (August, 2020) IELTS writing task 2 questions.

3.4. English Proficiency Test. In order to select the participants of the study from the intermediate EFL learners, the paper and pen version of Oxford Quick Placement Test (OQPT) (version 1) published in 2001 was used as a proficiency test. This test is widely used worldwide and contains 60 multiple-choice type items focusing on grammar and vocabulary. In addition, an adequate number of the items are developed in a cloze procedure format. Based on the OQPT scoring method, 80 students whose scores fell within the range of 40–47 were selected, from among 100 earlier subjects who took the test as intermediate EFL learners, as the final participants in this study. In the present study, the Cronbach alpha for the test was calculated at 0.79 which is an acceptable value since the scale is above 0.7.

3.5. Expert Judgment Questionnaire. In order to check the suitability of the selected IELTS writing task 2 questions as pretest and posttest, five qualified ELT instructors were asked to answer a questionnaire including five Likert-type items on the validity of these tests. These items were developed to extract the raters’ agreement on the suitability of the level and topic engagement of the tests. The result revealed a high rate of agreement among the raters (Kappa index = 0.84, $p = 0.01$).

3.6. Procedure. The study included three main phases: 1. pretesting, 2. scaffolded instruction, and 3. posttesting. In the first phase of the study, the Oxford Quick Placement Test (OQPT) was administered to a total number of 100 students to make sure that they were all at the same level of English language proficiency. Afterwards, 80 students whose scores were 40–47 were selected as intermediate participants.

After that, both groups of participants were given an IELTS writing task 2 test as a pretest to assess their writing ability and ensure their homogeneity.

For the precise scoring of participants’ writing, *IELTS task 2 Writing band descriptors (public version)* published by the University of Cambridge, ESOL examinations, was used by the two raters. Following the grading criteria, each English essay was scored independently by two experienced English teachers, with the full mark being 9 points. The average of the two scores for each essay was regarded as the final grade. Whenever the two scores of an essay disagreed by two points or above, the two raters examined it again and reached a definitive agreement after consideration.

The participants attended English classes for about 6 hours per week in a five-week period at the next stage. The lessons ran three days, lasting two hours a week. During the treatment sessions, the control group received instruction on writing in a traditional way with almost no training on

writing strategies and no emphasis on cognitive processes. Moreover, the control group received no ongoing support and guidance from the teacher during the writing practice. However, the experimental group received scaffolded instruction to help develop an awareness of metacognitive strategies and use them in their IELTS writing task 2 performances.

The treatment included five steps suggested by Hartman [27] to improve EFL students’ metacognition in the writing process. Accordingly, the steps followed in the five-week treatment in this study were as follows.

3.6.1. Stage 1: Cognitive Modeling. In this phase, the teacher focuses on explaining and modeling the cognitive processes involved in writing. For example, the teacher types the words on the computer in front of the students and *thinks aloud* about their cognitive activities to show how to write a piece of English composition (see [26]). So the students can follow the process of composing. While composing, the teacher externalizes the mental activities and the writing strategies that she uses. Some examples are as follows: “Should I add another example here?” “Is my intended meaning clear to the readers?” “Should I delete this sentence?”

3.6.2. Stage 2: Overt, External Guidance. At this stage, the students perform the writing task with the help of the teacher. All the students are guided to compose the essay one by one to think out loud about their mental activities for both the teacher and the class to observe. The teacher types students’ sentences, which are shown on the big screen, and provides guidance, asking them questions like “What do you mean by this sentence?” “Do you think this is the correct use of this word?” “Do you need to delete it or add more sentences?”

3.6.3. Stage 3: Overt Self-Guidance. At this stage, the students practice self-questioning aloud and use the metacognitive strategic knowledge they need to compose the essay. The teacher listens and provides any help required.

3.6.4. Stage 4: Faded, Overt Self-Guidance. This step is similar to step three with a slight difference; that is, at this stage, students self-question and *whisper* to themselves while they are composing. The teacher listens to evaluate the students’ use of writing strategies and self-questioning. The teacher may also ask questions *after* the composition is completed.

At this phase, the teacher uses assessment and explicit guidance to raise learners’ metacognitive awareness by asking them metacognitive questions and giving oral feedback on their writing (e.g., “Why did you think it was not clear?” “Do you think this statement is necessary to be included here?” “What could you do to present the ideas more clearly?”).

3.6.5. Stage 5: Covert Self-Guidance. Finally, the students compose the essay again without thinking out loud about the cognitive activities in their minds. They compose *itsilently*;

they evaluate themselves on the use of writing and regulatory strategies learned in the previous steps. After the completion of writing, the teacher asks students about self-questions. In order to develop students' self-evaluation insights, a handout including a regulatory writing checklist (adapted from [37]) was distributed among the students to focus on their writing performance at different stages of the writing process. It helps students to become independent writers. The checklist includes 18 metacognitive questions divided into three sections: 1. before writing: planning; 2. during writing: monitoring; and 3. after writing: evaluation. It helps students to ponder their strategy use at different stages of the writing process. The goal is to help students to assess and self-regulate their learning. Some researchers believe self-questioning is much more effective than the regulatory guidance provided by teachers (cf. [6, 38]).

After the instruction, another IELTS writing task 2 question was given as a posttest to both groups. After the treatment, the posttest of writing was administered to all students in control and experimental groups to assess any change in the learners' writing from the pretest to the posttest for each group separately. Finally, the results and findings were reported.

Moreover, to find out the learner's attitude toward the scaffolded writing strategy instruction, a telegram group was created, and all the participants in the experimental group were added. They were asked to participate in a Telegram Poll including five statements on the effectiveness of metacognitive strategies in writing. Participants could choose from among four options: "strongly agree," "agree," "disagree," and "strongly disagree." The statements focused on students' feelings about receiving feedback on their writing task and the effectiveness of learned metacognitive strategies. Finally, the results of the poll were reported.

4. Results

4.1. Normality Results for the Tests. Before conducting the relevant parametric analysis, the researchers ran four normality tests to distribute the scores on pretests, posttests, female's pretests, and male's posttests. The results confirmed the normal distribution of data for the tests (p values >0.05). Thus, the researchers could use parametric procedures to analyze the data.

4.2. Independent Samples t -Test Results for the Pretests. An independent samples t -test was run to ensure the two groups were not different regarding their performance on the IELTS writing task 2 before treatment was applied to the experimental group. The results appear in Tables 1 and 2.

According to Table 2, there was no significant difference between the control ($M = 4.57$, $SD = 0.52$) and experimental ($M = 4.61$, $SD = 0.52$, $t(78) = -0.31$, $p = 0.75$) groups' mean scores on the pretests. Therefore, the homogeneity of the two groups was established before treatment application.

4.3. Independent Samples t -Test Results for the Posttests. An independent samples t -test was run to compare the two groups' performance on the IELTS writing task 2 after the treatment. The results appear in Tables 3 and 4.

TABLE 1: Descriptive statistics for the pretests.

	N	Mean	Std. deviation
Control group	40	4.57	0.52
Experimental group	40	4.61	0.52

According to Table 4, there was a significant difference between the control ($M = 4.91$, $SD = 0.639$) and experimental ($M = 6.78$, $SD = 0.31$, $t(57.18) = -16.60$, $p < 0.05$) groups' mean scores on the posttests. Thus, the first null hypothesis was rejected, indicating a significant effect for scaffolding metacognitive awareness instruction.

Based on Cohen [39] ratings, the effect size turned out to be quite large ($\eta^2 = 0.87$).

4.4. Independent Samples t -Test Results for Males and Females' Posttests. An independent samples t -test was conducted to compare the males and females' performance on the posttests among the experimental group members. The results are given in Tables 5 and 6.

As revealed by Table 5, there was no significant difference between the male ($M = 6.80$, $SD = 0.29$) and female ($M = 6.77$, $SD = 0.34$, $t(38) = 0.24$, $p = 0.80$) participants' performance on the posttests among the experimental group. Therefore, the null hypothesis for the second research question could not be rejected, indicating no significant moderating effect for genders.

4.5. The Results of Students' Attitude toward the Treatment of the Study. According to the result of the Telegram Poll, 96% of the participants had a positive attitude toward metacognitive strategy instruction. The students agreed that they could master new metacognitive writing strategies and do new tasks independently and confidently on their own. Moreover, in terms of applying metacognitive strategies and organizing thoughts, 98% of the students strongly agreed on the effectiveness of the received instruction. Table 7 presents the result of the Telegram Poll.

5. Discussion

This study explored the effect of metacognitive strategy instruction on the writing performance of the Intermediate EFL Learners in IELTS Writing Task 2 in Iran.

As the findings of this study revealed, there was a clear distinction between the control and experimental groups' writing performance after the instruction. It needs to be mentioned that males and females' posttests mean scores did not differ widely. The mean difference, though very small, indicated that males benefited from the treatment more than females in this study. Although many different studies have investigated the effect of metacognitive strategies and knowledge on students' writing skills [1, 2, 14, 17, 33, 40] the effect of scaffolding metacognitive awareness on EFL learner's IELTS writing task 2 and learners' gender has not yet been touched upon adequately.

The current study results are in line with similar studies that examined the effect of metacognitive strategies and

TABLE 2: Independent samples *t*-test results for the pretests.

Levene's test for equality of variances				<i>t</i> -test for equality of means					
<i>F</i>	Sig.	<i>T</i>	Df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference		
							Lower	Upper	
.04	0.82	-0.31	78	0.75	-0.03	0.11	-0.27	0.19	

TABLE 3: Descriptive statistics for the posttests.

	<i>N</i>	Min	Max	Mean	Std. deviation
Control group	40	4.00	6.00	4.91	0.63
Experimental group	40	6.00	7.00	6.78	0.31

TABLE 4: Independent samples *t*-test results for the posttests.

Levene's test for equality of variances				<i>t</i> -test for equality of means					
<i>F</i>	Sig.	<i>T</i>	Df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference		
							Lower	Upper	
10.32	0.002	-16.60	57.18	0.000	-1.87	0.11	-2.09	-1.65	

TABLE 5: Descriptive statistics for the males and females' posttests.

	Group	<i>N</i>	Mean	Std. deviation	Std. error mean
Experimental posttests	Males	20	6.800	0.29	0.06
	Females	20	6.77	0.34	0.07

TABLE 6: Independent samples *t*-test results for the moderating effect of gender on the posttests.

Levene's test for equality of variances				<i>t</i> -test for equality of means					
<i>F</i>	Sig.	<i>T</i>	Df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference		
							Lower	Upper	
0.45	0.50	0.24	38	0.80	0.02	0.10	-0.18	0.231	

TABLE 7: Telegram Poll result.

1	I can do writing tasks with more confidence.	95%
2	I am more focused on the purpose of the writing task at hand.	98%
3	I can organize my thoughts before and while writing.	98%
4	I can choose suitable strategies for various writing tasks.	95%
5	I can evaluate my writing.	96%

knowledge on reading, speaking, listening, and writing skills [1, 14, 34]; Innocenti Tumiar Panggabean & Triassanti 2020; [2, 31, 33, 35, 36, 40, 41]. The results of the studies mentioned above were an indicator of the positive effect of the metacognitive strategies on reading, listening, or writing skills. In their study, Colognesi et al. [14] indicated how introducing metacognitive questions could significantly improve learners' writing performance. In their research, the learners who received metacognitive questions were more successful in their writing task than those who received no metacognitive question samples. Moreover, Ramadhanti and

Yanda [35] investigated the effect of metacognitive awareness on 25 students' explanatory writing ability, and the results proved a positive correlation. Furthermore, one study which was done by Arnawa [34] has the same result and showed the positive outcome of making use of metacognitive writing strategies in overcoming the participants' shortcomings in writing.

The present finding also supports Wang [33] study on promoting students' metacognitive monitoring ability by applying the theory of metacognitive monitoring to English writing teaching. The results revealed a positive effect on

students' English writing. Besides, as indicated in this study, it is essential to mention that both male and female learners benefited from scaffolded instruction equally. In line with this, Liliana and Lavinia [42] assessed 91 students in 8th grade regarding their metacognitive skills. It was concluded that both girls and boys use their metacognitive skills in learning.

6. Conclusion

Metacognitive instruction needs a lot of time and patience. It may take a long time to observe any significant improvement in students' performance during metacognitive instruction [26, 38, 43]. The findings of this study proved that scaffolded metacognitive strategy instruction could significantly improve students' writing performance. Moreover, it needs to be emphasized that metacognitive strategy instruction should be incorporated into everyday foreign language classroom activities and tasks to be effective. The findings of the present study have implications for learners, teachers, and material developers in the field of teaching English as a foreign language. University EFL learners need to learn about writing strategies and appropriate selection of these strategies to enhance their performance and become independent writers. As mentioned by Larkin [28], scaffolded instruction facilitates student independence.

Textbook writers have an important role in designing various writing tasks and exercises that require learners to apply various writing strategies and practice using them.

To sum up, the strategies and their applications should be taught explicitly by the teachers. Students need to know the strategies and their appropriate selection. The teachers can help students learn how and when to use strategies by applying them in a specific writing task.

Abbreviations

EFL: English as a foreign language
 ESOL: English for speakers of other languages
 IELTS: International English Language Testing System.

Data Availability

All data generated or analyzed during this study are included in this article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

S. N. developed the original idea and the protocol, designed the model and the computational framework, carried out the implementation, and wrote the manuscript. R. K. carried out the implementation, wrote the manuscript, performed the numerical calculations, and analyzed the data. S. H. A. supervised the work, provided critical feedback, and contributed to the interpretation of the results.

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