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DEMATEL Method: The Causal Relationships Among Factors Influencing ESL Students' Collaborative Writing Effectiveness

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ABSTRACT

This study investigates the causal relationships among factors influencing ESL students' collaborative writing effectiveness by using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method. Collaborative writing has been widely acknowledged as a successful pedagogical approach in language classrooms but its effectiveness is depending on various interrelated factors such as proficiency level, group size, guidance, digital literacy, and fear of making mistakes. This study employed a quantitative research method involving expert evaluation in constructing a direct-relation matrix, which was subsequently normalized and analyzed to determine cause–effect relationships among the identified factors. The findings reveal that guidance is the most significant causal factor, making it the strongest influence on other factors. Whereas, fear of making mistakes is found to be the most prominent yet highly influenced factor. Digital literacy and proficiency level are classified as effect factors while group size demonstrates a relatively lower influence within the system. Moreover, this study highlights the crucial role instructional support in effectiveness of collaborative writing and consequently provides insights for educators in planning ESL writing environments. Through DEMATEL analysis, these findings contribute to expanding corpus of research on collaborative writing by offering a systematic understanding of factors interdependencies.

1. Introduction

Educathe tors all around the world have been using collaborative writing method in English as a Second Language (ESL) classrooms for its potential in enhancing learners' linguistic competence, critical thinking and social interaction skills. Ingrained in sociocultural theory, collaborative writing emphasises the significance of interacting and sharing knowledge in learning process. This is because it allows students to actively engage in meaning negotiation and problem solving. Learners are also able to provide feedback, develop writing skills and exchange ideas with their peers through

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collaborative writing, which cannot be done through individual writing tasks. Thus, collaborative writing is widely adopted in ESL classrooms to encourage student-centered learning method and improve students' writing performance.

Although collaborative writing has various advantages, its effectiveness is not guaranteed since it is influenced by various interconnected factors. Past studies discovered that a variety of variables work as critical determinants of collaborative writing outcomes. Such variables include learners' proficiency level, group dynamics, instructional guidance, digital literacy, and psychological factors [1]–[5]. For example, confidence is one main factor of academic achievement as learners who believe in their own capabilities are more likely to succeed through difficult tasks [6], hence, students who are confident have a higher chance of succeeding in collaborative writing. Also, digital literacy has become increasingly important in technology-related writing environments, where students are required to use online tools for collaboration [7].

Among these factors, instructional guidance plays a particularly crucial role in shaping students' collaborative experiences. Effective guidance, including clear instructions, scaffolding, and clear feedback, helps students understand the requirements of task and engage meaningfully in the writing process [8]. Contrastingly, Tseng [9] mentioned that insufficient guidance may lead to confusion, unequal participation from students, and poor learning outcomes. Moreover, structural factors such as group size can influence interaction patterns, although their impact may vary depending on the context.

Given the complexity of these interrelated variables, it is essential to examine not only their individual effects but also their causal relationships within a system. However, existing research on collaborative writing in ESL contexts has primarily focused on examining individual factors in isolation, with limited attention given to the interdependencies among them. This gap highlights the need for a more comprehensive analytical approach that can capture the complex cause–effect relationships between factors.

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) method offers a systematic way to analyze such relationships by identifying key driving and dependent factors within a network [10]. By using DEMATEL method, researchers can better understand how different variables interact and influence one another, even when working with small, information-rich expert panels [11]–[13]. Therefore, this research aims to examine the causal relationships among different factors affecting ESL students' collaborative writing effectiveness using the DEMATEL method. Specifically, it seeks to identify the most influential (cause) and most affected (effect) factors among proficiency level, group size, guidance, digital literacy, and fear of making mistakes. The findings of this study are expected to provide valuable insights for educators and researchers by highlighting key areas for intervention and improving the design of collaborative writing activities in ESL classrooms.

2. Methodology

This research employed the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method. This method represents a structural modelling technique that was originally developed by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva between the year 1972 and 1976 to probe complex world problems [14]. According to Si *et al*. [15], the DEMATEL method is a powerful multi-criteria decision-making tool that allows researchers to envision the causal relationships among factors in intricate systems through the impact-relation maps and construction of structural models. This method has the ability to convert qualitative assessments into quantitative indices, thus revealing the interdependencies and feedback mechanisms among system elements [16]. In contrast to traditional analytical methods, in which they assume independence among the criteria, DEMATEL acknowledges the complex interrelationships and correlative influences that characterise real-world decision-making scenarios, making it exceptionally valuable in identifying key factors and comprehending how other elements within a system are affected directly or indirectly [17]. Govindan *et al.* [18] and Zhou *et al.,* [19] emphasised that this method has been widely used across various domains such as environmental assessment, organisational performance analysis, supply chain management and technology evaluation, proving its robustness and versatility in dealing with complicated decision making.

2.1 DEMATEL Procedural Framework

DEMATEL works by transforming experts' judgment into structural matrices that reveal causal relationships through a systematic five-step procedure. The initial step requires establishing a direct-relation matrix by expert evaluation in which the experts assess the degree of direct influence between every pair of factors using a preset scale ranging from 0 (no influence) to 4 (very high influence) Seyed-Hosseini *et al.,* [20]. The second step normalises the direct-relation matrix through separating each element by the maximum row sum, making sure all values fall within a standardised range [8]. Next, the third step calculates the total-relation matrix by integrating both direct and indirect effects through matrix manipulation, using the formula T = X(I - X)^-1, where X represents the normalised direct-relation matrix and I is the identity matrix [9]. The fourth step calculates the prominence and relation indices by calculating the sum of rows (D) and columns (R) of the total-relation matrix, where D + R indicates the prominence of each factor in the system, while D - R distinguishes between cause factors (positive values) and effect factors (negative values) Liou *et al.,* [21]. Lastly, the fifth step requires assembling a causal diagram by plotting these indices on a two-dimensional graph, with the vertical axis representing relation and the horizontal axis representing prominence, hence providing a visual representation of the structural model that facilitates decision-making and strategic planning [10].

2.2 Steps in DEMATEL

STEP 1: GENERATE THE DIRECT RELATION MATRIX
To identify the model of the relations among the n criteria, an n × n matrix is first generated. The effect of the element in each row is exerted on the element of each column of this matrix. If multiple experts' opinions are used, all experts must complete the matrix. arithmetic mean of all of the experts ' opinions is used and then a direct relation matrix X is generated. $X = \left[0 \cdots x_{n1} \;\vdots\; \ddots \;\vdots\; x_{1n} \cdots 0 \right]$
STEP 2: COMPUTE THE NORMALIZED DIRECT-RELATION MATRIX
To normalize, the sum of all rows and columns of the matrix is calculated directly. The largest number of the row and column sums can be represented by k. To normalize, it is necessary that each element of the direct-relation matrix is divided by k. $k = max\left\{ max\sum_{j=1}^{n} x_{ij},\ \sum_{i=1}^{n} x_{ij} \right\}$ $N = \frac{1}{k} * X$
STEP 3: COMPUTE THE TOTAL RELATION MATRIX

After calculating the normalized matrix, the fuzzy total-relation matrix can be computed as follows: $$T = (N^1 + N^2 + \ldots + N^k)$$ In other words, an n × n identity matrix is first generated, then this identity matrix is subtracted from the normalized matrix and the resulting matrix is reversed. The normalized matrix is multiplied by the resulting matrix to obtain the total relation matrix. $$T = N \times (I - N)^{-1}$$
STEP 4: SET THE THRESHOLD VALUE
The threshold value must be obtained in order to calculate the internal relations matrix. Accordingly, partial relations are neglected and the network relationship map (NRM) is plotted. Only relations whose values in matrix T are greater than the threshold value are depicted in the NRM. To compute the threshold value for relations, it is sufficient to calculate the average values of the matrix T. After the threshold intensity is determined, all values in matrix T which are smaller than the threshold value are set to zero, that is, the causal relation mentioned above is not considered. In this study, the threshold value is equal to 0.4795
STEP 5: FINAL OUTPUT AND CREATE A CAUSAL DIAGRAM
The next step is to find out the sum of each row and each column of T (in step 3). The sum of rows (D) and columns (R) can be calculated as follows: $$D = \sum_{j=1}^{n} T_{ij}$$ $$R = \sum_{i=1}^{n} T_{ij}$$ Then, the values of D+R and D-R can be calculated by D and R, where D+R represent the degree of importance of factor i in the entire system and D-R represent net effects that factor *i* contributes to the system.

2.3 Sampling Technique for DEMATEL Application

It is very crucial to choose suitable sampling techniques in implementing DEMATEL method. This is because the representativeness and quality of experts' judgements directly influence the validity and reliability of the results. According to Patton [12], purposive sampling is the most common technique employed in DEMATEL studies as participants are selected based on their forte, comprehensive experience and in-depth knowledge of the problems. For years, scholars have argued about the optimal sample size when it comes to the DEMATEL method. Most recommendations range from 5 to 15 experts since this scale balances the need for diverse perspectives against the practical constraints of data collection and consensus building [10]. Dalalah et al. [11] and Shieh *et al.* [13] added that there are several criteria used by researchers in selecting the experts: academic qualifications at the master's level or higher, more than five years of professional experience in the relevant field, current involvement in related decision-making processes, and exhibited expertise through publications or practical achievements. For this study, 5 experts were employed as the main participants.

2.4 DEMATEL Questionnaire Scale Explanation

This study utilises the DEMATEL method in analysing the causal relationships among the identified factors. The respondents are required to assess the direct influence of each factor on the other factors using a five-point scale. The scale is defined as follows: 0 = No influence, indicating that one factor has absolutely no impact on another; 1 = Low influence, suggesting minimal impact; 2 = Moderate influence, representing a reasonable degree of impact; 3 = High influence, indicating substantial impact; and 4 = Very high influence, indicating an extremely strong causal relationship between factors. The purpose of this five-point scale is to ensure that there is a systematic quantification of expert judgments regarding the interdependencies among variables. The experts' responses are collected and subsequently clustered to form an initial direct-relation matrix, which undergoes mathematical normalisation and matrix operations to derive the total-relation matrix. From this matrix, key indicators including prominence values (R+C) and relation values (R-C) are calculated, enabling the classification of factors into cause-and-effect groups. The prominence value indicates the overall importance of a factor within the system, while the relation value determines whether a factor primarily influences others (cause) or is predominantly influenced by others (effect). This analytical approach provides valuable insights into the structural relationships among variables and facilitates evidence-based decision-making by identifying critical factors that warrant prioritised attention in intervention strategies.

3. Findings

3.1 Finding 1: Generate the direct-relation matrix

Table 2 reveals the results of the direct-relation matrix. The direct-relation matrix indicates that Guidance (F3) is the most influential causal factor in the system, exerting very strong effects on Proficiency Level (4.0000) and Fear of Making Mistakes (4.0000), as well as a high influence on Digital Literacy (3.4000).

Table 1
Direct-Relation Matrix Result

	PROFICIENCY LEVEL	GROUP SIZE	GUIDANCE	DIGITAL LITERACY	FEAR OF MAKING MISTAKES
PROFICIENCY LEVEL	0.0000	1.0000	2.4000	2.2000	3.4000
GROUP SIZE	1.0000	0.0000	2.2000	1.6000	2.4000
GUIDANCE	4.0000	2.0000	0.0000	3.4000	4.0000
DIGITAL LITERACY	2.0000	1.0000	1.2000	0.0000	3.0000
FEAR OF MAKING MISTAKES	3.2000	1.6000	2.4000	2.2000	0.0000

This result suggests that instructional support plays a crucial role in enhancing students' effectiveness in collaborative writing. Correspondingly, Proficiency Level (F1) shows strong influence on Fear of Making Mistakes (3.4000) and moderate influence on Guidance (2.4000) and Digital Literacy (2.2000), signifying its importance as a secondary causal factor. Whereas, Fear of Making Mistakes (F5) shows moderate reciprocal influence on other factors (e.g., 3.2000 on Proficiency), indicating it functions both as a cause and an effect variable. Digital Literacy (F4) presents moderate influence mainly on Fear (3.0000), while Group Size (F2) appears to be the least influential factor, with relatively lower influence scores among the variables. Generally, the matrix suggests that pedagogical guidance is the primary driving force, while psychological and structural factors are more reactive within the collaborative ESL writing ecosystem.

3.2 Finding 2: Compute the Normalize Direct-Relation Matrix

Furthermore, Table 3 shows the results tabulated for normalised direct-relation matrix. Guidance (F3) stays the strongest causal driver in the system, exerting the highest influence on Proficiency Level (0.2985), Fear of Making Mistakes (0.2985), and a strong effect on Digital Literacy (0.2537).

Table 2
Normalised Direct-Relation Matrix Result

	PROFICIENCY LEVEL	GROUP SIZE	GUIDANCE	DIGITAL LITERACY	FEAR OF MAKING MISTAKES
PROFICIENCY LEVEL	0.0000	0.0746	0.1791	0.1642	0.2537
GROUP SIZE	0.0746	0.0000	0.1642	0.1194	0.1791
GUIDANCE	0.2985	0.1493	0.0000	0.2537	0.2985
DIGITAL LITERACY	0.1493	0.0746	0.0896	0.0000	0.2239
FEAR OF MAKING MISTAKES	0.2388	0.1194	0.1791	0.1642	0.0000

This corroborates that instructional support has a crucial role in shaping both cognitive and psychological features of collaborative writing. Besides, Proficiency Level (F1) and Fear of Making Mistakes (F5) also shows fairly strong influence values, particularly F1 → F5 (0.2537) and F5 → F1 (0.2388), indicating a reciprocal relationship between language competence and writing anxiety. Whereas, a moderate influence shown by Digital Literacy (F4), mainly affecting Fear (0.2239), which suggests that technological competence may aid in reducing students' anxiety. Meanwhile, Group Size (F2) records the lowest influence values overall, indicating that structural classroom arrangement plays a comparatively smaller role in determining collaborative writing effectiveness. In general, the results reinforce Guidance as the primary causal factor within the system.

3.3. Finding 3: Compute the Total Relation Matrix

Next, Table 4 exhibits the results of total-relation matrix. It reveals that Guidance (F3) is the most powerful and influential factor in the system, exerting the strongest overall effects on the other variables, especially Fear of Making Mistakes (0.8375), Proficiency Level (0.7529), and Digital Literacy (0.6695).

Table 3
Total Relation Matrix Result

	PROFICIENCY LEVEL	GROUP SIZE	GUIDANCE	DIGITAL LITERACY	FEAR OF MAKING MISTAKES
PROFICIENCY LEVEL	0.3820	0.2835	0.4526	0.4814	0.6443
GROUP SIZE	0.3825	0.1759	0.3873	0.3851	0.5095
GUIDANCE	0.7529	0.4171	0.4133	0.6695	0.8375
DIGITAL LITERACY	0.4324	0.2395	0.3262	0.2701	0.5344
FEAR OF MAKING MISTAKES	0.5815	0.3222	0.4610	0.4894	0.4524

This proves that guidance from educators substantially reduces psychological barriers and enhances technological engagement in collaborative writing, and influences the language ability of students. Similarly, Fear of Making Mistakes (F5) also shows relatively high total influence values (e.g., 0.5815 on Proficiency and 0.4894 on Digital Literacy), suggesting that it plays both reactive and interactive roles within the system. On the other hand, Proficiency Level (F1) shows a moderate-to-strong influence, particularly on Fear (0.6443), reinforcing the close relationship between competence and writing anxiety. Digital Literacy (F4) exerts moderate influence across factors, while Group Size (F2) consistently records the lowest total influence values, indicating it is comparatively less critical in shaping overall collaborative writing effectiveness. Overall, the findings indicate that Guidance is the central driving force within the causal network.

3.4 Finding 4: Cause and Effect Relationship

Finally, as for the cause and effect relationship, the results is shown in Table 5. It can be seen that Fear of Making Mistakes (F5) has the highest prominence value (R+C = 5.2846), suggesting it is the most critical factor within the system, followed closely by Guidance (F3) (5.1308), indicating that both play central roles in ESL collaborative writing effectiveness.

Table 4
Cause and Effect Relationship

CRITERIA	RI	CI	RI + CI	RI - CI	CAUSE / EFFECT
PROFICIENCY LEVEL	2.24	2.53	4.78	-0.29	Effect
GROUP SIZE	1.84	1.44	3.28	0.40	Cause
GUIDANCE	3.09	2.04	5.13	1.05	Cause

DIGITAL LITERACY	1.80	2.30	4.10	-0.49	Effect
FEAR OF MAKING MISTAKES	2.31	2.98	5.28	-0.67	Effect

Nonetheless, the relation values (R−C) distinguish cause and effect groups: Guidance (1.0499) and Group Size (0.4022) fall into the cause group (positive R−C), which means that they exert more influence on other factors than they receive, with Guidance being the strongest driving factor overall. Contrastingly, Proficiency Level (−0.2877), Digital Literacy (−0.4928), and especially Fear of Making Mistakes (−0.6716) belong to the effect group, indicating that they are more influenced by other variables in the system. Even though Fear of Making Mistakes is highly prominent, its negative R−C value shows it is largely a resultant outcome caused by instructional and structural conditions, particularly Guidance. Generally, the findings justify that pedagogical guidance acts as the primary causal driver, while psychological and competency-related factors function mainly as outcomes within the collaborative writing framework.

4. Discussion

The findings of this study highlight Guidance as the most significant causal factor that influences ESL students' collaborative writing effectiveness. Its high influence (R) and strong positive relation (R−C) indicate that it acts as the primary driving force within the system, shaping both cognitive and affective dimensions of learning. This suggests that when teachers provide clear instructions, structured scaffolding, and continuous feedback, students are able to navigate collaborative writing tasks better [5]. The strong influence of Guidance on other factors such as Proficiency Level, Digital Literacy, and Fear of Making Mistakes reinforces the idea that effective pedagogical support is fundamental in facilitating successful collaboration, aligning with existing literature that emphasizes the role of teacher intervention in ESL writing environments [16].

In contrast, it is revealed that Fear of Making Mistakes is the most notable and highly influenced factor, as shown by its highest prominence (R+C) and most negative relation (R−C). This suggests that while fear plays a central role in the system, it is largely an outcome shaped by other variables rather than a primary driver. The strong influence received from Guidance and Proficiency Level implies that students' anxiety in collaborative writing can be reduced significantly through supportive teaching practices and improved language competence. This finding is consistent with research in second language acquisition, which highlights that a low-anxiety environment enhances learners' participation and their writing performance [1-3].

Next, Digital Literacy and Proficiency Level are also categorised in the effect group, meaning that they are influenced by other factors, especially Guidance. Even though Proficiency Level displays high prominence, its negative relation value suggests that students' language ability develops in response to instructional support and collaborative experiences rather than acting as an independent driver. Comparably, although Digital Literacy is crucial in facilitating interaction in technology-mediated writing environments, it still depends on the level of guidance and task structure provided to the learners. Thus, it is important to integrate digital tools with proper instructional design to maximise their effectiveness, as according to Warschauer [22], students' familiarity with technology and how much instructional support is provided to them affect the effectiveness of these digital tools.

Meanwhile, Group Size is identified as a secondary causal factor with a positive relation value but lower prominence compared to Guidance. This explains that while group size does influence collaborative dynamics [23], its impact is less substantial. Suitable group structuring may enhance participation and coordination, but without strong instructional guidance, its effect remains limited. This finding suggests that optimising group size alone is insufficient to ensure effective collaborative writing outcomes.

Generally, the study demonstrates that instructional and pedagogical factors outweigh structural and individual factors in determining the effectiveness of collaborative writing in ESL contexts. Guidance serves as the central mechanism through which other variables are shaped, while psychological and competency-related factors function largely as outcomes. These results emphasise the need for educators to prioritise structured support, give clear guidance, and provide a supportive learning environment to enhance students' collaborative writing experiences.

5. Conclusions

In conclusion, this study establishes that the effectiveness of collaborative writing among ESL students is largely driven by instructional factors, with Guidance as the most critical determinant within the system. The DEMATEL analysis reveals that while factors such as Proficiency Level, Digital Literacy, and Fear of Making Mistakes are highly prominent, they function primarily as outcomes influenced by stronger causal variables rather than independent drivers. Notably, students' fear of making mistakes, despite being the most significant factor in terms of overall involvement, is shaped by the quality of guidance and learning support provided. Meanwhile, Group Size plays a comparatively minor yet still contributory role. Overall, the findings highlight the importance of effective pedagogical strategies as well-structured guidance, supportive learning environments, and thoughtful instructional design are essential in enhancing ESL students' collaborative writing performance.

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