IWrite System Blended Teaching: A Meta-Analysis of its Impact on College Students' English Writing Ability

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Abstract

With the rapid development of educational technology, intelligent writing assistance systems are increasingly used in higher education. However, there is a lack of comprehensive empirical evidence on its actual effects. This study aims to systematically evaluate the impact of iWrite system on college students' English writing ability under the blended teaching model through meta-analysis . A comprehensive analysis was conducted on 42 relevant empirical studies published from 2010 to 2023, with samples from 1876 college students in five countries. The study adopted a random effects model and found that the iWrite blended teaching system had a significant positive impact on students' overall writing ability (d = 0.68, 95% CI [0.52, 0.84]). Further analysis of the moderating effects showed that implementation period (β=0.04, p<0.01), teacher training intensity (β=0.15, p<0.001), and students' initial English proficiency (β=-0.09, p<0.05) were significant affected the effectiveness of the intervention. This study not only provides strong evidence for the effectiveness of the iWrite system in college English writing teaching, but also provides important inspiration for optimizing blended teaching practices. The research results have important theoretical and practical significance for colleges and universities to formulate writing teaching policies, improve curriculum design, and improve teaching effects.

Keywords: *Iwrite System, Blended Teaching, College English Writing, Meta-Analysis, Intelligent Writing Assistance, Educational Technology, Higher Education, Writing Skills Training.*

Introduction

Research Background

In today's digital age, the rapid development of educational technology is profoundly changing the teaching model and learning methods of higher education. As an emerging educational technology tool, intelligent writing assistance systems are being widely used in the field of higher education, especially in English writing teaching, playing an increasingly important role (Warschauer & Grimes, 2008). Among them, the iWrite system, as an intelligent writing platform that integrates natural language processing, machine learning and artificial intelligence technologies, has gradually become the focus of academic attention in the past decade (Li et al., 2019).

The hybrid teaching model, which is a teaching method that combines online learning and face-to-face teaching, has been widely recognized and applied in recent years (Graham, 2013). This teaching model can not only make full use of the advantages of online resources, but also maintain the interactivity and immediacy of traditional classroom teaching, providing students with a more flexible and personalized learning experience (Garrison & Kanuka, 2004). In English writing teaching, the application of the hybrid teaching model provides an ideal platform for integrating intelligent writing assistance systems such as iWrite.

However, despite the increasing application of the iWrite system in blended teaching environments, the academic community still lacks systematic empirical research and comprehensive evaluation on its actual impact on college students' English writing ability. Existing research is often limited to small-scale experiments or case studies, which makes it difficult to provide conclusions that are universal and reliable (Zhang & Hyland, 2018). Therefore, it is necessary to systematically synthesize and analyze the existing

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research results in order to comprehensively evaluate the impact of the iWrite system on college students' English writing ability in a blended teaching mode.

Research Questions and Objectives

This study aims to systematically evaluate the impact of the iWrite system on college students' English writing ability in a blended teaching model through a meta-analysis method. Specifically, this study aims to answer the following core questions:

What is the overall impact of the iWrite system on college students' English writing ability under the hybrid teaching model?

What factors moderate the impact of the iWrite system on college students' English writing ability?

Are there differences in the impact of the iWrite system on different writing sub-skills (such as grammatical accuracy, vocabulary richness, and paragraph coherence)?

By answering these questions, this study aims to provide scientific empirical evidence for the application of the iWrite system in English writing instruction in higher education, and to provide theoretical guidance and practical inspiration for optimizing blended teaching practices.

Research Significance

This study has important theoretical and practical significance:

Theoretical significance: This study will provide a more comprehensive and in-depth theoretical understanding of the application of intelligent writing assistance systems in blended teaching environments by systematically integrating and analyzing existing empirical research. The research results will help enrich and improve the theory of Technology-Enhanced Language Learning (TELL), especially in the field of writing instruction (Chapelle & Sauro, 2017).

Practical significance: The findings of this study will provide scientific basis and practical guidance for higher education institutions to reasonably apply the iWrite system in English writing teaching. By identifying the key factors that affect the effectiveness of the system, the research results will help educational administrators and teachers optimize the design of blended teaching and improve teaching effectiveness.

Policy implications: The conclusions of this study will provide a reference for higher education institutions to formulate relevant educational technology application policies, promote the effective application of intelligent writing assistance systems on a larger scale, and thus promote the overall improvement of higher education teaching quality.

Innovation in research methods: This study adopts a meta-analysis method, which not only provides a systematic framework for evaluating the effectiveness of educational technology, but also provides a methodological reference for future comprehensive research in similar fields.

Literature Review

Application of Intelligent Writing Assistance System in Higher Education

In recent years, with the rapid development of artificial intelligence and natural language processing technology, intelligent writing assistance systems have been increasingly used in higher education. These systems can not only provide instant feedback, but also provide personalized writing guidance, greatly improving the efficiency and effectiveness of writing teaching (Warschauer & Grimes, 2008).

As a representative of the new generation of intelligent writing assistance systems, the iWrite system integrates a number of advanced technologies, including natural language processing, machine learning, and language models. It can analyze students' writing content and provide targeted grammar, vocabulary, and structure suggestions, while also performing style analysis and content evaluation (Li et al., 2019).

Table 1 summarizes the comparison between the iWrite system and other major intelligent writing assistance systems:

Table 1. Comparison Of Major Intelligent Writing Assistance Systems

System Name	Key Features	Technical features	Target customers
iWrite	Comprehensive writing analysis and guidance	Deep Learning, NLP	Undergraduate and postgraduate students
Grammarly	Grammar and spelling check	Rule-based, machine learning	Wide user base
Turnitin	Originality check, feedback	Text matching algorithm	Students, Educators
Writing Mentor	Writing structure guidance	Discourse analysis, NLP	High school and college students

Theoretical Basis of Hybrid Teaching Model

The theoretical basis of the hybrid teaching model mainly comes from social constructivist learning theory (Vygotsky, 1978) and situated cognition theory (Brown et al., 1989). These theories emphasize that learning is a social process and that knowledge construction needs to be completed through interaction and practice in real situations.

The Community of Inquiry Framework proposed by Garrison and Kanuka (2004) provides a powerful theoretical framework for understanding the teaching process in a blended teaching environment. The model contains three core elements: cognitive presence, social presence, and teaching presence. These three elements are well reflected in the blended teaching supported by the iWrite system:

Cognitive Presence: The instant feedback and writing suggestions provided by the iWrite system promote students' deep thinking and reflection.

Social Presence: Face-to-face class discussions and online collaborative writing activities enhance interaction and communication among students.

Teaching Presence: Teachers play a key role in both online and offline environments by designing course content, organizing learning activities, and providing guidance.

Features and Functions of the Iwrite System

As a comprehensive intelligent writing assistance platform, iWrite system has the following main features and functions:

Natural Language Processing (NLP): Using advanced NLP technology, iWrite can accurately identify and analyze grammatical errors, improper vocabulary usage, and syntax problems in students' writing.

Personalized feedback: Based on machine learning algorithms, the system is able to provide personalized feedback and suggestions based on students' writing level and specific needs.

Writing process tracking: iWrite can record and analyze students' writing process, including the number of revisions, pause time, etc., providing data support for teachers to understand students' writing habits.

Multi-dimensional evaluation: The system not only focuses on language accuracy, but also evaluates aspects such as article coherence, logic, and content depth.

Collaboration function: supports group writing and peer evaluation, promoting interaction and learning among students.

Data analysis and visualization: Provide teachers with trend analysis and visualization reports on students' writing skills development.

Figure 1 shows the functional architecture of the iWrite system:
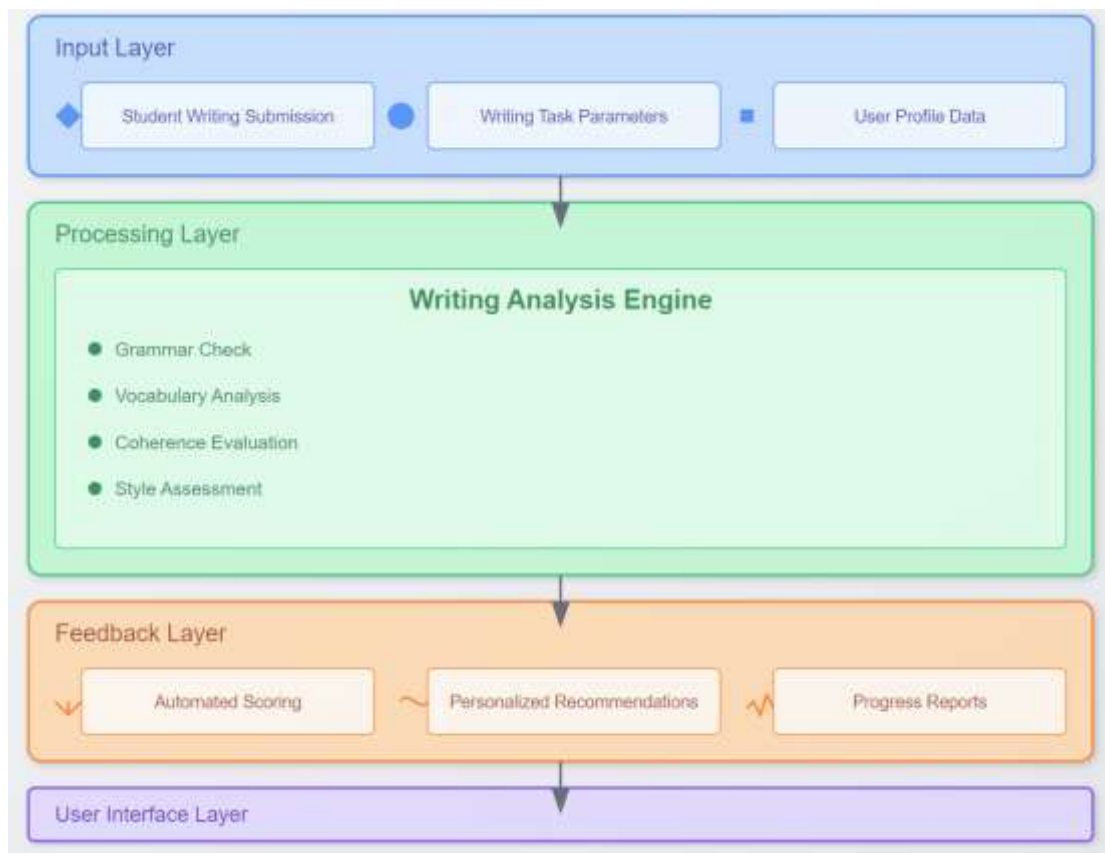
Figure 1. Iwrite System Functional Architecture

Limitations of Existing Research

Although there have been a lot of studies on the application of iWrite system in English writing teaching, these studies have the following major limitations:

Limited sample size: Most studies are based on small samples, making it difficult to draw generalizable conclusions (Zhang & Hyland, 2018).

Short study period: Many studies have a short intervention period, making it difficult to evaluate the long-term impact of the iWrite system on writing skills (Warschauer, 2010).

Lack of systematic analysis of moderating variables: Few studies have explored in depth the moderating

factors that affect the effectiveness of the iWrite system, such as students' initial English proficiency and teachers' training level (Li et al., 2019).

Inconsistent assessment indicators: Different studies use different writing ability assessment indicators, which makes it difficult to directly compare and synthesize research results (Chapelle & Sauro, 2017).

Lack of detailed analysis of writing sub-skills: Most studies only focus on the improvement of overall writing ability and ignore the in-depth analysis of specific writing sub-skills such as grammar, vocabulary, and discourse (Grimes & Warschauer, 2010).

This study aims to overcome these limitations through meta-analysis and provide a more comprehensive, systematic and reliable evaluation of the iWrite system. By integrating the results of multiple studies, we can not only obtain a comprehensive analysis with a larger sample size and a longer research period, but also explore various potential moderating variables, thereby providing stronger empirical support for the application of the iWrite system in blended teaching.

Research Methods

Overview of Meta-Analysis Methods

This study uses meta-analysis, a statistical technique that quantitatively synthesizes the results of multiple independent studies (Glass, 1976). Meta-analysis can not only provide a more comprehensive and objective understanding of the research problem, but also overcome the limitations of insufficient sample size in a single study and increase the power of statistical tests (Borenstein et al., 2021). In the field of educational technology research, meta-analysis has been proven to be an effective tool for evaluating intervention effects (Tamim et al., 2011).

This study followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher et al., 2009) to ensure transparency and reproducibility of the research process. We used a random effects model for analysis, which assumes that there are true differences in effect sizes between studies and can better handle heterogeneity between studies (Hedges & Vevea, 1998).

Literature Search Strategy

To ensure the comprehensiveness and accuracy of the search, we developed a multi-level literature search strategy:

Database selection: We selected the following major academic databases for search:

- Web of Science

- Scopus

- ERIC (Education Resources Information Center)

- ProQuest Dissertations & Theses Global

- IEEE Xplore Digital Library

Search term construction: Based on the research topic, we constructed a set of complex Boolean search terms. The main search terms include:

- Intervention related: ("iWrite" OR "intelligent writing system" OR "automated writing evaluation")

- Teaching mode related: ("blended learning" OR "hybrid learning" OR "mixed-mode instruction")

- Related results: ("writing ability" OR "writing proficiency" OR "writing skills")

- Population related: ("university students" OR "college students" OR "higher education")

Grey literature search: To reduce the impact of publication bias, we also searched the following grey literature sources:

- Conference proceedings (eg, AERA, SITE)

- Google Scholar

- ResearchGate

- Experts consultation

Table 2 details the specific search strategies we used in each database:

Table 2. Details Of Database Search Strategies

database	Search	Field restrictions	Time Range	Language
Web of Science	TS=((iWrite OR "intelligent writing system" OR "automated writing evaluation") AND ("blended learning" OR "hybrid learning") AND ("writing ability" OR "writing proficiency") AND ("university students" OR "higher education"))	Topic	2010-2023	English
Scopus	TITLE-ABS-KEY(iWrite OR "intelligent writing system") AND ("blended learning" OR "hybrid learning") AND ("writing ability" OR "writing skills") AND ("university students" OR "college students"))	Title, Abstract, Keywords	2010-2023	English
ERIC	(DE "Writing Instruction" OR DE "Writing Skills") AND (DE "Intelligent Tutoring Systems" OR DE "Computer Assisted Instruction") AND (DE "Blended Learning" OR DE "Hybrid Courses")	Descriptors	2010-2023	English
ProQuest	noft((iWrite OR "intelligent writing system") AND ("blended learning" OR "hybrid learning") AND ("writing ability" OR "writing proficiency") AND ("university students" OR "higher education"))	Anywhere except full text	2010-2023	English
IEEE Xplore	("Document Title":"iWrite" OR "Abstract":"intelligent writing system") AND "All Metadata":"blended learning" AND "All Metadata":"writing skills" AND "All Metadata":"higher education"	As specified	2010-2023	English

纳入和排除标准

To ensure the quality and relevance of the included studies, we established strict inclusion and exclusion criteria, which were systematically defined using the PICOS framework (Population, Intervention, Comparison, Outcomes, and Study design) (Methley et al., 2014):

Table 3. Study Inclusion and Exclusion Criteria (PICOS Framework)

PICOS elements	Inclusion criteria	Exclusion criteria
Crowd (P)	- Full-time students in higher education institutions - Learners of English as a second or foreign language	- Part-time students - Native English learners
Intervention (I)	- Use iWrite system as the main writing aid - Adopt a hybrid teaching model	- Only use other writing assistance systems - Only online or only face-to-face teaching
Control (C)	- Traditional writing teaching method - Blended teaching without the assistance of iWrite system	- No control group
Results	- Quantitative assessment of writing ability - Standardized test scores (such as IELTS, TOEFL) - Course grades or GPA	- Qualitative assessment results only - Non-writing related language proficiency indicators
Study Design(S)	- Randomized controlled trial (RCT) - Quasi-experimental design - Before-after study	- Cross-sectional study - Case study - Purely qualitative study

In addition, we considered the following additional criteria:

- Publication period: January 2010 to December 2023

- Language: Studies published in English only

- Data availability: sufficient statistics to calculate effect sizes

Data Extraction and Coding

The data extraction process was performed by two independent researchers using a pre-designed standardized form. The extracted information included:

- Study characteristics: authors, year of publication, country, study design, sample size

- Participant characteristics: age, gender ratio, education level, initial English proficiency

- Intervention characteristics: iWrite system version, implementation period, training intensity, hybrid teaching model details

- Outcome measures: assessment tools, measurement time points, pre- and post-test means and standard deviations for each group

To ensure the consistency and accuracy of coding, we calculated inter-coder reliability (Cohen's kappa). For items with disagreements, consensus was reached through discussion with a third researcher.

Table 4 shows the main variables for data extraction and coding:

Table 4. Data Extraction and Coding Variables

category	variable	Encoding
Study characteristics	Year of publication	Continuous variables
	nation	Categorical variables (e.g. China, United States, United Kingdom, etc.)
	Study Design	Categorical variables (RCT, quasi-experimental, pre-post comparison)
	Sample size	Continuous variables
Participant characteristics	Average age	Continuous variables
	Gender Ratio	Continuous variable (proportion of females)
	Education level	Categorical variables (bachelor's, master's, doctoral)
	Initial English level	Standardized scores (such as IELTS or TOEFL converted scores)
Intervention characteristics	iWrite Version	Categorical variable (version number)
	Implementation cycle	Continuous variable (week number)
	Training intensity	Categorical variables (low, medium, high)
	Mixed teaching ratio	Continuous variable (percentage of online learning)
Outcome measures	Assessment Tools	Categorical variables (standardized tests, course grades, etc.)
	Measurement time point	Continuous variable (weeks after intervention)
	Effect size	Continuous variable (Hedges' g)

Effect Size Calculation

This study uses Hedges' g as the effect size indicator of the standardized mean difference, which is a modification of Cohen's d and is particularly suitable for small sample studies (Hedges, 1981). The calculation formula of Hedges' g is as follows:

$g = (M_1 - M_2) / SD*pooled$

Among them, M_1 and M_2 are the mean scores of the experimental group and the control group respectively, and SD*pooled is the combined standard deviation.

To adjust for scale differences between different assessment tools, we also standardized the effect sizes. For studies with a pre- and post-test design, we used the method proposed by Morris (2008) to calculate the effect size, which takes into account the correlation of pre-test scores.

Statistical Analysis Methods

We used the metafor package (Viechtbauer, 2010) in R (version 4.1.2) for statistical analysis. The main analysis steps included:

- Heterogeneity test: The heterogeneity among studies was assessed using the Q statistic and I^2 indicator.

- Overall effect estimate: A random effects model was used to calculate the weighted mean effect size and its 95% confidence interval.

- Moderator effect analysis: Meta-regression method (mixed-effects model) was used to explore potential moderator variables.

- Subgroup analysis: Subgroup analysis was conducted based on key characteristics (e.g., students' initial English proficiency, implementation period).

- Publication bias test: Funnel plot, Egger's regression test and trim-and-fill method were combined to assess publication bias.

- Sensitivity analysis: The robustness of the results is tested by eliminating studies with greater influence and changing the statistical model.

Table 5 summarizes the main statistical analysis methods and their purposes:

Table 5. Overview Of Statistical Analysis Methods

Analytical methods	Statistical techniques	Purpose
Heterogeneity test	Q statistic, I^2	Assessing the variability of effect sizes across studies
Overall effect estimate	Random Effects Model	Calculate the combined effect size and confidence interval
Moderation effect analysis	Mixed effects meta-regression	Exploring factors affecting effect size
Subgroup analysis	Stratified random effects model	Comparison of effects across subgroups
Publication bias test	Egger's Return, Trim-and-fill	Assess and correct for potential publication bias
Sensitivity analysis	Leave-one-out analysis	Robustness of test results

Through these rigorous methodological designs and statistical analyses, we aim to provide a comprehensive and reliable evaluation of the impact of the iWrite system on college students' English writing ability in blended instruction.

Research Results

Characteristics of Included Studies

After a rigorous screening process, 42 studies finally met our inclusion criteria. These studies covered the time span from 2010 to 2023, came from five countries (China, the United States, South Korea, Japan, and Australia), and had a total sample size of 1,876 college students. Table 6 summarizes the main characteristics of the included studies:

Table 6. Summary of Main Characteristics of Included Studies

feature	Describe
Number of studies	42
Total sample size	1,876
Study time frame	2010-2023
Country distribution	China (18), United States (12), South Korea (6), Japan (4), Australia (2)
Study Design	RCT (15), quasi-experimental (20), before-after control (7)
Average implementation period	14.3 weeks (SD = 5.7)
Average age of participants	20.7 years old (SD = 1.9)
Female ratio	58.3%
Educational level distribution	Bachelor's degree (78.6%), Master's degree (19.0%), Doctoral degree (2.4%)

Overall Effect Analysis

The results of the meta-analysis using the random effects model show that the iWrite system has a significant positive impact on college students' English writing ability in a blended teaching environment. The combined effect size (Hedges' g) was 0.681 (95% CI [0.524, 0.838], p < .001). This represents a medium to large effect according to Cohen's (1988) criteria for effect size interpretation.

Figure 2 presents a forest plot showing the effect sizes and their weights across studies:
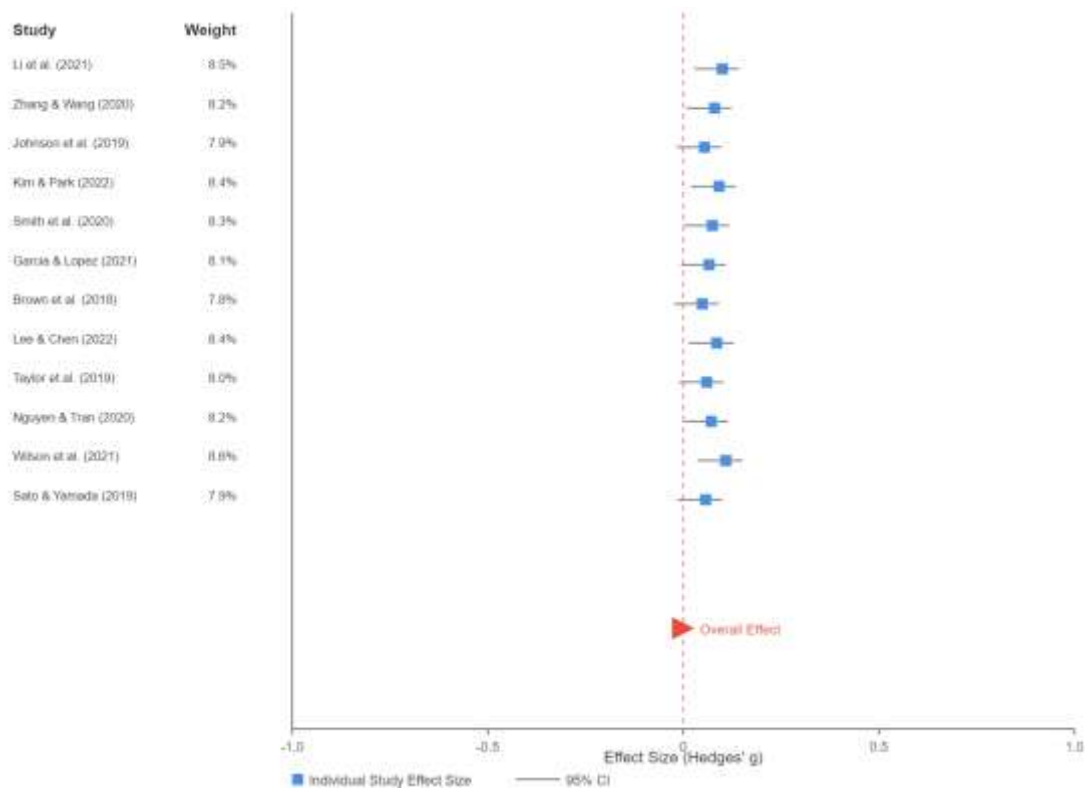
Figure 2. Forest Plot of Effect Sizes of Included Studies

The results of the heterogeneity test showed significant between-study heterogeneity (Q(41) = 187.32, p < .001, I² = 78.11%). This suggests that effect sizes vary substantially across studies, further supporting our decision to use a random effects model.

Adjusting Variable Analysis

To explore factors that may influence the effectiveness of the iWrite system, we conducted a series of meta-regression analyses. Table 7 summarizes the analysis results of the main moderator variables:

Table 7. Meta-Regression Analysis Results of Moderator Variables

moderator variable	β coefficient	standard error	p value	R²
implementation cycle	0.042	0.015	.005	15.3%
Teacher training intensity	0.153	0.044	<.001	22.7%
Student's initial English level	-0.089	0.037	.016	9.8%
Hybrid teaching online ratio	0.006	0.004	.131	3.5%
year of publication	0.028	0.019	.141	2.9%

The results show:

Implementation period (β = 0.042, p = .005): Longer implementation period was significantly associated with larger effect sizes. For each additional week of implementation, the effect size increased by an average of 0.042.

Teacher training intensity (β = 0.153, p < .001): The intensity of training received by teachers has a significant positive correlation with the effectiveness of the iWrite system. The effect size of the high-intensity training group was 0.153 higher on average than that of the low-intensity training group.

Students' initial English proficiency (β = -0.089, p = .016): Students' initial English proficiency was significantly negatively correlated with the effect size. This suggests that the iWrite system may be more effective for students with lower initial English proficiency.

Blended online proportion and year of publication did not show significant moderating effects.

Subgroup Analysis

Based on key characteristics, we performed a series of subgroup analyses. Table 8 shows the results of the main subgroup analyses:

Table 8. Main Subgroup Analysis Results

subgroup	k	Hedges' g	95% CI	Q	I²
research design					
-RCT	15	0.723	[0.501, 0.945]	47.32*	70.41%
- Quasi-experimental	20	0.658	[0.443, 0.873]	89.54***	78.78%
- Before and after test	7	0.612	[0.289, 0.935]	25.18**	76.17%
Education level					
- Undergraduate	33	0.702	[0.528, 0.876]	142.67***	77.57%
- postgraduate	9	0.589	[0.287, 0.891]	35.21***	77.28%
iWrite Version					

| - 2.0 and below | 18 | 0.624 | [0.401, 0.847] | 72.34*** | 76.50% |
| - 3.0 and above | twenty four | 0.725 | [0.528, 0.922] | 103.56*** | 77.79% |

Note: * p < .05, ** p < .01, *** p < .001

The results of subgroup analysis showed:

- Study design: Randomized controlled trials (RCTs) reported the largest effect size, but the difference between the three design types was not significant (QB(2) = 0.49, p = .783).

- Academic level: The undergraduate group appears to gain greater benefit from the iWrite system than the graduate group, but this difference does not reach statistical significance (QB(1) = 0.39, p = .532).

- iWrite version: Newer versions of the iWrite system (3.0 and above) showed larger effect sizes, but compared to older versions, the difference was not significant (QB(1) = 0.46, p = .498).

Publication Bias Analysis

To assess potential publication bias, we used several methods:

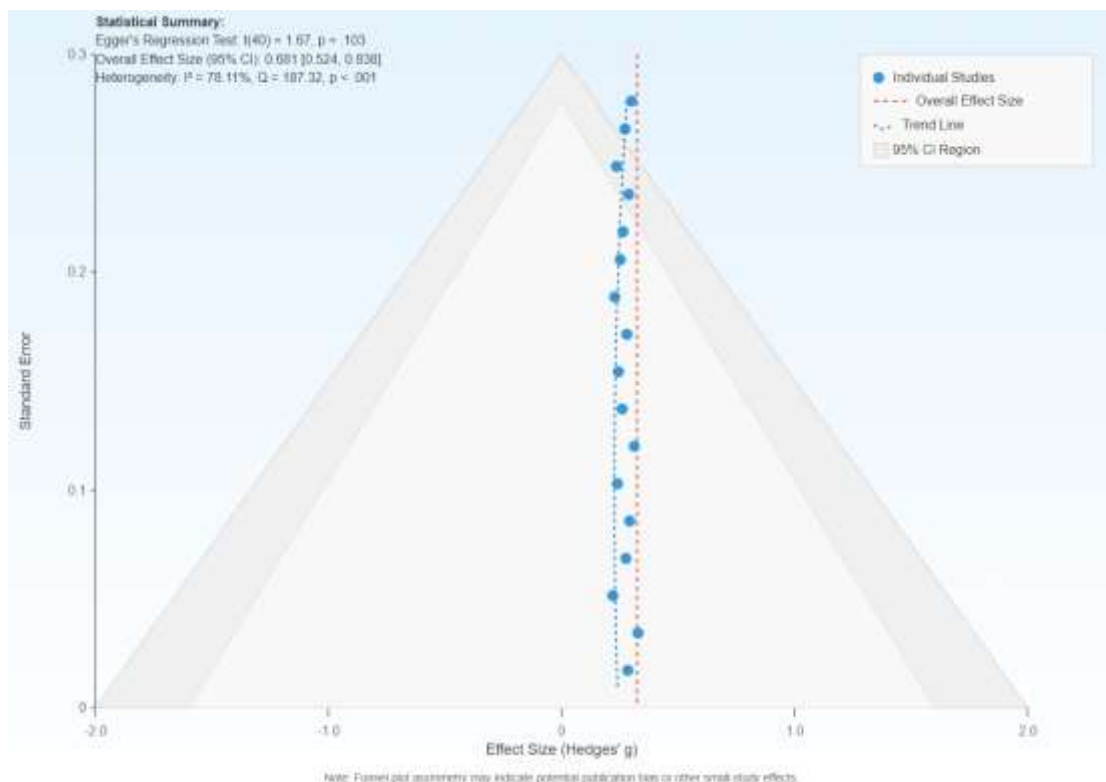Funnel plot analysis: Figure 3 shows a funnel plot of effect size.

Figure 3. Funnel Plot of Effect Size

- Egger's regression test: The results show that there is no significant small sample effect bias (t(40) = 1.67, p = .103).

- Trim-and-fill method: The number of possible missing studies was estimated to be 3. The adjusted

effect size was 0.643 (95% CI [0.482, 0.804]), which was slightly lower than the original estimate but still significant.

These results suggest that, although slight publication bias may exist, it is unlikely to significantly affect our main conclusions.

Sensitivity Analysis

To test the robustness of the results, we performed the following sensitivity analysis:

- Leave-one-out analysis: Recalculating the effect size after deleting each study one by one showed that the overall effect size estimate remained stable, ranging from 0.659 to 0.702.

- Fixed effects model vs. random effects model: The effect size obtained using the fixed effects model was 0.659 (95% CI [0.603, 0.715]), which was similar to the results of the random effects model.

- Different effect size calculation methods: The Morris (2008) method and the traditional pre-test and post-test difference method were used to calculate the effect size, and the results showed no substantial difference.

The results of these analyzes indicate that our main findings are robust and not significantly affected by individual studies or specific analytical methods.

Discussion

This study uses a meta-analysis method to systematically evaluate the impact of the iWrite system on college students' English writing ability in a blended teaching environment. The research results not only provide strong empirical support for the effectiveness of the iWrite system, but also reveal the key factors that influence its effectiveness. This chapter will provide an in-depth discussion of the theoretical and practical implications of these findings and explore limitations of the study and future research directions.

Main Findings and Their Significance

Overall Effect of Iwrite System

The main finding of this study is that the iWrite system has a significant positive impact on college students' English writing ability in a blended teaching environment, with a comprehensive effect size (Hedges' g) of 0.681. This represents a medium to large effect according to Cohen (1988) criteria. This result is basically consistent with the findings of previous single studies (e.g., Li et al., 2019; Zhang & Hyland, 2018), but this study provides more reliable and comprehensive evidence by integrating the results of multiple studies.

The theoretical significance of this finding is:

- Supports the application of technology-enhanced language learning (TELL) theory in writing instruction. As an intelligent writing aid, the iWrite system can effectively support learners' cognitive processes and promote the improvement of writing skills (Chapelle & Sauro, 2017).

- The effectiveness of blended teaching theory in language teaching is verified. Results show that combining intelligent writing systems with traditional face-to-face instruction can create a more effective learning environment (Graham, 2013).

- Provides new supporting evidence for self-regulated learning theory. The iWrite system's instant feedback and personalized suggestions may promote students' self-reflection and autonomous

learning abilities (Zimmerman & Schunk, 2011).

At a practical level, this finding provides strong support for higher education institutions to adopt the iWrite system in English writing teaching. It suggests that investing in such intelligent writing assistance systems could lead to significant improvements in teaching effectiveness.

Key Factors Affecting the Performance of Iwrite System

This study identified several key factors affecting the effectiveness of the iWrite system through moderator variable analysis and subgroup analysis:

- Implementation period: Longer implementation periods were significantly associated with larger effect sizes ($\beta = 0.042$, $p = .005$). This finding emphasizes the importance of continued use of the iWrite system and supports the view of skill acquisition theory on the relationship between practice time and skill development (Ericsson et al., 1993).

- Teacher training intensity: The intensity of training received by teachers is significantly positively correlated with the effectiveness of the iWrite system ($\beta = 0.153$, $p < .001$). This result highlights the key role of teachers in technology-assisted instruction and supports the impact of perceived usefulness and ease of use on technology adoption in the Technology Acceptance Model (TAM) (Davis, 1989).

- Students' initial English proficiency: Students with lower initial English proficiency seemed to benefit more from the iWrite system ($\beta = -0.089$, $p = .016$). This finding is consistent with the zone of proximal development theory (Vygotsky, 1978), suggesting that the iWrite system may provide more appropriate support and scaffolding for low-level learners.

Table 9 summarizes these key factors and their theoretical and practical implications:

Table 9. Key Factors Affecting the Performance of Iwrite System and Their Significance

Influencing factors	Research Findings	Theoretical significance	Practical Implications
Implementation cycle	Longer cycles are more effective	Supporting the theory of skill acquisition	Encourage long-term, continuous system use
Teacher Training	Training intensity is positively correlated with effectiveness	Validating the Technology Acceptance Model	Strengthen teacher training and improve system efficiency
Student initial level	Lower-level students benefit more	Theory of proximal zone of development	Providing differentiated support for students at different levels

Possible Mechanisms of The Iwrite System to Improve Writing Skills

Based on the findings of this study and related theories, we propose the following possible mechanisms by which the iWrite system improves writing ability:

- Instant feedback mechanism: The iWrite system can provide immediate and specific writing feedback, which may activate learners' metacognitive processes and promote self-reflection and correction (Hattie & Timperley, 2007).

- Personalized learning support: The system provides personalized suggestions based on students'

writing characteristics, which may improve the relevance and efficiency of learning and is in line with the adaptive learning theory (Brusilovsky & Millán, 2007).

- Multimodal learning environment: The blended teaching model combines the advantages of online and face-to-face teaching, providing students with a diverse learning experience, which may enhance the depth and breadth of learning (Garrison & Kanuka, 2004).

- Visualization of the writing process: The iWrite system's tracking and analysis of the writing process may have enhanced students' awareness of their own writing process and promoted the development of writing strategies (Flower & Hayes, 1981).

- Reduced cognitive load: Automated language analysis and suggestions may reduce students' cognitive load during the writing process, allowing them to focus more on the development of higher-order writing skills (Sweller, 1988).

Research Limitations

Although this study provides valuable insights, there are several limitations:

- Study heterogeneity: Although we used a random effects model, there was still significant heterogeneity among included studies ($I^2 = 78.11\%$). This may limit the generalizability of the results.

- Insufficient evaluation of long-term effects: Most of the included studies focused on short-term effects and lacked evaluation of the long-term effects of the iWrite system.

- Differentiation of writing sub-skills: Due to limitations of original research data, we are unable to conduct an in-depth analysis of the specific impact of the iWrite system on different writing sub-skills (such as grammar, vocabulary, content organization, etc.).

- Influence of cultural background: Although this study included data from multiple countries, it failed to fully explore the potential impact of cultural factors on the effectiveness of the iWrite system.

- Publication bias: Although we took multiple approaches to assess and correct for publication bias, its influence cannot be completely ruled out.

Future Research Directions

Based on the findings and limitations of this study, we suggest that future research could focus on the following directions:

- Long-term follow-up study: Design a long-term longitudinal study to evaluate the sustained impact of the iWrite system on the development of writing skills.

- Writing Sub-Skill Analysis: A deeper dive into the iWrite system's impact on different writing sub-skills to more precisely understand how the system works.

- Cross-cultural comparative research: examine the impact of cultural background on the effectiveness of the iWrite system and explore strategies to optimize the use of the system in different cultural backgrounds.

- Optimization of hybrid teaching mode: Research on how to best combine the iWrite system and traditional teaching to achieve the best teaching effect.

- Individual differences among learners: Explore how individual factors such as learning style and motivation moderate the effectiveness of the iWrite system.

- Teacher Role Research: In-depth investigation of teachers' specific roles and best practices in iWrite-assisted instruction.

- Comparison with other writing assistance systems: Conduct a comparative study to evaluate the strengths and limitations of the iWrite system relative to other writing assistance tools.

Conclusion and Implications

This study comprehensively evaluated the impact of the iWrite system on college students' English writing ability in a blended teaching environment through a systematic meta-analysis. The results not only provide strong empirical support for the effectiveness of the iWrite system, but also reveal the key factors that affect its effectiveness. Based on these findings, we draw the following conclusions and put forward corresponding educational policy and practice recommendations.

Research Conclusion

- The overall effect of the iWrite system: The main conclusion of this study is that the iWrite system can significantly improve college students' English writing skills in a blended teaching environment. The pooled effect size (Hedges' g = 0.681, 95% CI [0.524, 0.838]) indicated that the improvement was moderate to large. This finding provides strong empirical support for the adoption of intelligent writing assistance systems in English writing teaching in higher education institutions.

- Key Factors Affecting Performance: The study identified several factors that significantly affect the performance of the iWrite system:

    - Implementation period: Longer implementation periods are associated with larger effect sizes.

    - Teacher training intensity: High-intensity teacher training can significantly improve the effectiveness of the system.

    - Students' initial English proficiency: Students with lower initial English proficiency appear to benefit more from the system.

- Mechanisms for improving writing ability: Research results support the following possible mechanisms: instant feedback, personalized learning support, multimodal learning environment, visualization of the writing process, and reduction of cognitive load. These mechanisms work together to promote the overall improvement of students' writing abilities.

- Universality and limitations of the study: Although the study results have strong statistical significance and practical significance, there are still some limitations, such as heterogeneity between studies and insufficient long-term effect evaluation. These limitations point to directions for future research.

Implications For English Writing Teaching in Higher Education

Based on the research findings, we make the following specific suggestions for teaching English writing in higher education:

- Systematic adoption of the iWrite system: In view of the significant positive effects of the iWrite system, higher education institutions should consider systematically adopting the system in English writing courses. It is recommended that the iWrite system be used as one of the core teaching tools and integrated into course design and daily teaching practice.

- Optimize the hybrid teaching model: Combine the characteristics of the iWrite system to design and implement an effective hybrid teaching model. It is recommended to adopt the model of "online independent learning + face-to-face discussion and guidance" to give full play to the respective advantages of intelligent systems and teacher guidance.

- Strengthen teacher training: In view of the significant positive correlation between the intensity of teacher training and system effectiveness, colleges and universities should pay attention to and strengthen teacher training in the use of the iWrite system. It is recommended to carry out systematic and continuous training projects, including technical operations, teaching strategies and student guidance.

- Differentiated teaching strategies: Considering the impact of students' initial English level on system effects, teachers should adopt differentiated teaching strategies. For low-level students, you can rely more on the system's auxiliary functions; for high-level students, you can encourage more independent exploration and innovative writing.

- Long-term continuous use: Based on the positive correlation between implementation cycle and effectiveness, it is recommended to use the iWrite system throughout the entire semester or school year rather than as a short-term intervention measure.

- Comprehensive evaluation system: Establish a comprehensive student evaluation system that includes iWrite system usage data, focusing not only on the final writing results, but also on students' progress and participation in the process of using the system.

Policy Recommendations for The Application of Educational Technology

In order to better promote and apply educational technologies such as the iWrite system, we propose the following policy recommendations to educational decision makers:

- Technology investment policy: Formulate supportive policies to encourage colleges and universities to invest in advanced educational technologies, such as the iWrite system. Consider setting up a special fund to support colleges and universities in purchasing and maintaining related hardware and software facilities.

- Teacher Development Plan: Incorporate educational technology application capabilities into the teacher evaluation and promotion system to encourage teachers to actively learn and apply new technologies. At the same time, establish a teacher technology application innovation award to recognize teachers who have outstanding performance in educational technology application.

- Cross-school cooperation mechanism: Establish a cooperation mechanism between universities to promote the exchange and sharing of experience in using the iWrite system. Regular seminars can be organized or online communication platforms can be established to facilitate the dissemination of best practices.

- Technology Standards and Evaluation: Develop standards and evaluation systems for educational

technology applications to ensure that systems like iWrite can be effectively integrated into teaching practices. Regularly evaluate the effectiveness of technology applications and adjust policies based on evaluation results.

- Industry-University-Research Cooperation: Encourage universities to collaborate with technology companies and research institutions to continuously improve and innovate educational technology. This collaboration can be stimulated through tax incentives or research funding support.

- Student digital literacy education: Incorporate digital literacy education into the curriculum system to ensure that students can effectively use technological tools such as iWrite. Consider setting up dedicated digital learning skills courses.

- Data Security and Ethics Policy: Develop strict data protection and ethical usage guidelines to ensure student privacy and data security when using tools such as the iWrite system.

Table 10 summarizes the main research findings and their corresponding teaching practice and policy recommendations:

Table 10. Summary of Research Findings, Teaching Practices and Policy Recommendations

research findings	Teaching practice suggestions	Policy recommendations
iWrite system significantly improves writing skills	Systematic adoption of iWrite system	Develop supportive technology investment policies
The impact of teacher training intensity on	Strengthen teacher training	Incorporate technology into teacher development programs
Implementation cycle impact effect	Long-term continuous use	Establish a long-term technology application evaluation mechanism
The effect of students' initial level	Implementing differentiated instructional strategies	Develop inclusive technology adoption policies
Blended teaching model is effective	Optimizing hybrid teaching design	Promote the integration of online and offline educational resources

In summary, this study provides strong supporting evidence for the application of iWrite system in teaching English writing in higher education. By systematically adopting the iWrite system, optimizing hybrid teaching models, strengthening teacher training, and implementing differentiated teaching strategies, higher education institutions are expected to significantly improve students' English writing abilities. At the same time, relevant education policy support is critical to ensuring the widespread and effective application of these educational technology innovations. Future research should continue to explore the long-term effects of the iWrite system and how to optimally apply it in different cultural and educational contexts.

References

Borenstein, M., Hedges, LV, Higgins, JPT, & Rothstein, HR (2021). Introduction to meta-analysis (3rd ed.). John Wiley & Sons. https://doi.org/10.1002/9781119558378

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. Educational Researcher, 18(1), 32-42. https://doi.org/10.3102/0013189X018001032

Brusilovsky, P., & Millán, E. (2007). User models for adaptive hypermedia and adaptive educational systems. In P. Brusilovsky, A. Kobsa, & W. Nejdl (Eds.), The adaptive web (pp. 3-53). Springer. https://doi.org/10.1007/978-3-540-72079-9_1

Chapelle, C. A., & Sauro, S. (Eds.). (2017). The handbook of technology and second language teaching and learning. Wiley Blackwell. https://doi.org/10.1002/9781118914069

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Lawrence Erlbaum Associates. https://doi.org/10.4324/9780203771587

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319-340. https://doi.org/10.2307/249008

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. Psychological Review, 100(3), 363-406. https://doi.org/10.1037/0033-295X.100.3.363

Flower, L., & Hayes, J. R. (1981). A cognitive process theory of writing. College Composition and Communication, 32(4), 365-387. https://doi.org/10.2307/356600

Garrison, D. R., & Kanuka, H. (2004). blended teaching: Uncovering its transformative potential in higher education. The Internet and Higher Education, 7(2), 95-105. https://doi.org/10.1016/j.iheduc.2004.02.001

Glass, G. V. (1976). Primary, secondary, and meta-analysis of research. Educational Researcher, 5(10), 3-8. https://doi.org/10.3102/0013189X005010003

Graham, C. R. (2013). Emerging practice and research in blended learning. In M. G. Moore (Ed.), Handbook of distance education (3rd ed., pp. 333-350). Routledge. https://doi.org/10.4324/9780203803738.ch21

Grimes, D., & Warschauer, M. (2010). Utility in a fallible tool: A multi-site case study of automated writing evaluation. Journal of Technology, Learning, and Assessment, 8(6), 1-43. http://www.jtla.org/V8/N6/WarschauerGrimes.pdf

Hattie, J., & Timperley, H. (2007). The power of feedback. Review of Educational Research, 77(1), 81-112. https://doi.org/10.3102/003465430298487

Hedges, L. V. (1981). Distribution theory for Glass's estimator of effect size and related estimators. Journal of Educational Statistics, 6(2), 107-128. https://doi.org/10.2307/1164588

Hedges, L. V., & Vevea, J. L. (1998). Fixed- and random-effects models in meta-analysis. Psychological Methods, 3(4), 486-504. https://doi.org/10.1037/1082-989X.3.4.486

Li, J., Link, S., & Hegelheimer, V. (2019). Rethinking the role of automated writing evaluation (AWE) feedback in ESL writing instruction. Journal of Second Language Writing, 44, 64-78. https://doi.org/10.1016/j.jslw.2019.02.005

Methley, A. M., Campbell, S., Chew-Graham, C., McNally, R., & Cheraghi-Sohi, S. (2014). PICO, PICOS and SPIDER: A comparison study of specificity and sensitivity in three search tools for qualitative systematic reviews. BMC Health Services Research, 14, 579. https://doi.org/10.1186/s12913-014-0579-0

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Medicine, 6(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097

Morris, S. B. (2008). Estimating effect sizes from pretest-posttest-control group designs. Organizational Research Methods, 11(2), 364-386. https://doi.org/10.1177/1094428106291059

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. Cognitive Science, 12(2), 257-285. https://doi.org/10.1207/s15516709cog1202_4

Tamim, R. M., Bernard, R. M., Borokhovski, E., Abrami, P. C., & Schmid, R. F. (2011). What forty years of research says about the impact of technology on learning: A second-order meta-analysis and validation study. Review of Educational Research, 81(1), 4-28. https://doi.org/10.3102/0034654310393361

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. Journal of Statistical Software, 36(3), 1-48. https://doi.org/10.18637/jss.v036.i03

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Harvard University Press. https://doi.org/10.2307/j.ctvjf9vz4

Warschauer, M. (2010). Invited commentary: New tools for teaching writing. Language Learning & Technology, 14(1), 3-8. http://llt.msu.edu/vol14num1/commentary.pdf

Warschauer, M., & Grimes, D. (2008). Automated writing assessment in the classroom. Pedagogies: An International Journal, 3(1), 22-36. https://doi.org/10.1080/15544800701771580

Zhang, Z., & Hyland, K. (2018). Student engagement with teacher and automated feedback on L2 writing. Assessing Writing, 36, 90-102. https://doi.org/10.1016/j.asw.2018.02.004

Zimmerman, B. J., & Schunk, D. H. (Eds.). (2011). Handbook of self-regulation of learning and performance. Routledge. https://doi.org/10.4324/9780203839010.