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Automated Writing Evaluation in EFL Instruction: A Systematic Review of Pigai's Applications, Learner Heterogeneity, and Methodological Implications

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Abstract: This study employs a systematic review approach to review research on the application of Pigai in English writing instruction from 2020 to 2024, aiming to optimize the use of the Pigai system and deepen the integration of educational technology with language teaching. The review finds that existing studies mainly focus on technology validation and basic effectiveness evaluation, integration of feedback modes and innovation in instructional applications, and mechanisms of student differences and individualized effects. Significant differences in needs and evaluations are observed among learners with varying language proficiency, academic majors, and educational levels. Although various methods have been employed in existing studies, improvements are needed in sample representativeness, and research on long-term effects. Future research should focus on enhancing the comprehensibility of feedback, developing personalized feedback strategies, and addressing challenges related to educational equity.

1. Introduction

Recently, with the deep integration of AI technology in education, the Automated Writing Evaluation (AWE) system has become an important tool for teaching English as a Foreign Language (EFL) writing. Based on Intelligent Tutoring System (ITS) and Natural Language Processing (NLP) algorithms, the system integrates formative assessment functions [1]. By analyzing syntactic complexity, lexical complexity, and other linguistic indicators[2], AWE provides learners with instant feedback on multiple dimensions, such as grammar and syntax[3]. Empirical studies have shown that the application of the system can significantly

enhance students' writing ability by promoting grammatical accuracy and syntactic complexity development at the linguistic level[4], and enhancing students' writing self-efficacy indirectly increases their class participation [5]. At the same time, the system can help teachers free themselves from the heavy workload of essay correction [2] [6] [7].

Various types of AWE tools are available, such as iWrite, Pigai, Criterion, Grammarly, MI Write, and QuillBot. Among them, Pigai (or JUKU) has become one of the most widely used platforms in China. As a typical representative of localized AWE tools in China, Pigai was developed by Beijing Word Network Technology Co., Ltd. in 2011 and fully considered the interlanguage features of Chinese English learners [3]. The system is driven by both error detection algorithms and statistical language models, forming a technical closed loop at the two levels of text surface error recognition and deep language optimization. It adopts a percentage-based comprehensive scoring scale, covering four dimensions: vocabulary (43%), sentence structure (28%), chapter organization (22%), and content (7%)[8][9], which is more suitable for the second language development needs of Chinese students compared to international tools such as Grammarly and Criterion.

The technical features and assessment system of Pigai enable it to demonstrate the values of multidimensional application in instructional design and effectively support various aspects of English writing instruction; thus, it is widely used as a teaching aid, has an important place in English language teaching and learning [1]. Specifically, Pigai enhances students' writing abilities through real-time correction and iterative revision mechanisms, allowing them to simultaneously improve their language accuracy (vocabulary/grammar) and pragmatic appropriateness (register/style), which is consistent with the conclusion of feedback loops promoting interlanguage reconstruction[10]. Meanwhile, Pigai boosts teachers' instructional efficiency by providing automated scoring and diagnostic reports. Teachers can not only alleviate the assessment burden in large classes[6-7], but also conduct precise interventions [11]. Such targeted interventions enhance teaching efficiency and enrich students' learning experiences. The average frequency of writing exercises in courses using Pigai has increased, significantly improving instructional efficiency and student engagement [12]. As a regular component of blended teaching, Pigai is deeply integrated into writing teaching processes, reconstructing the traditional writing teaching mode.

Recent research on Pigai in EFL writing has increased, but most studies rely on a single empirical paradigm, focusing narrowly on specific groups (e.g., college students or English majors) without broader comparisons across diverse learners. This limits the comprehensive analysis of AWE tools in varied teaching scenarios[13]. Additionally, despite the diversity of research methods employed in existing studies on Pigai, significant gaps remain in the comprehensiveness and depth of methodological approaches.

Based on the research background, this study explores in depth the application of Pigai in English writing teaching, aiming to achieve the following objectives: firstly, to identify the thematic distribution characteristics of research on Pigai, revealing its research focus and trends; Secondly, to explore the differences in application effectiveness and evaluation feedback of the tool among learners with different language proficiency levels, professional backgrounds, and educational levels; finally, to analyze the type distribution of existing research methods, explore their possible limitations, and provide reference for subsequent research. The research questions are as follows:

I. What are the existing themes of Pigai network-related research, and what are their research focuses and future research trends?

II. What are the differences in the effectiveness and evaluation of Pigai's application among learners with different language levels, professional backgrounds, and educational

levels?

III. What are the characteristics, advantages, and limitations of the research methodology of Pigai in the research of English writing instruction, and how should the research design be optimized in the future to enhance the scientific and practical value of the study?

2. Research Method

This study utilizes a systematic literature review (SLR) approach to examine the research achievements of Pigai in English writing instruction from 2020 to 2024. By utilizing cross-database searches and multidimensional keyword combination strategies, the research conducted collaborative searches across six authoritative databases. Eight sets of search terms were constructed using Boolean logic operators to ensure a comprehensive and diverse range of literature sources. Additionally, strict selection criteria—such as including only English empirical studies—further enhance the quality of the literature and provide strong support for an in-depth analysis of Pigai's application in teaching English as a foreign language (EFL) writing.

2.1 Literature Retrieval Strategy

This study used six major databases (Web of Science, Scopus, ERIC, ScienceDirect, SpringerLink, and Taylor & Francis) to find literature on using the Pigai system in English writing instruction. Boolean logic was applied to create search equations like: ("Pigai" OR "JUKU") AND ("English writing" OR "English"), and others covering technical aspects (e.g., "automatic writing assessment") and applications (e.g., "teaching practice"). To ensure comprehensive and accurate results, each database had a tailored search scope: Web of Science (subject, title, abstract), Scopus (title, abstract, keywords), Taylor & Francis (full text), SpringerLink (articles, journals, books, etc.), and ScienceDirect (full-text search).

2.2 Literature Selection Strategy

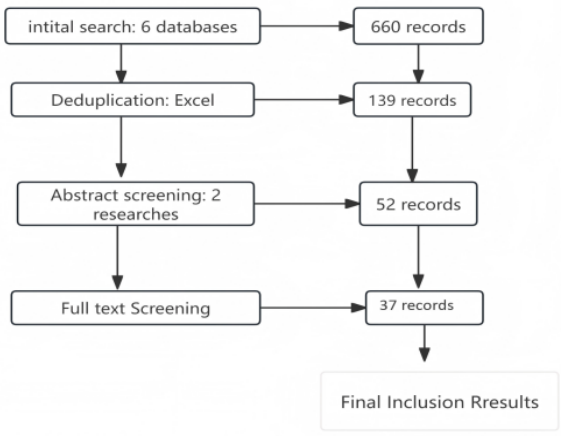

Figure 1. Flowchart of the Literature Screening Process

Strict criteria and a three-stage screening process were utilized to select relevant literature on Pigai's application in English writing teaching. Inclusion criteria were empirical studies (journal and conference papers) published in English between 2020 and 2024, focusing on

teaching practice, effect evaluation, or student feedback. Excluded were non-empirical studies, those unrelated to Pigai, and inaccessible full texts. After removing duplicates and screening titles, abstracts, and full texts, 37 studies (including experiments, case studies, and surveys) were included.

2.3. Data Analysis Methods

The included literature was analyzed and coded in terms of research themes, object characteristics, and research methods. Qualitative and quantitative methods were combined to reveal the current status and research trends. By organizing the core findings in the literature, the application mode, influencing factors, and existing deficiencies of Pigai in English writing teaching were sorted out to provide a theoretical basis for subsequent research.

3. Result and Discussion

3.1 Analysis of Existing Research Themes, Focus and Future Trends

3.1.1 Existing Research Themes: Three Core Areas Affecting Writing Quality

There are three core areas in Pigai's writing teaching. As shown in Figure 2, a total of 17 studies (45.9%) were conducted on the integration of feedback modes and instructional application innovation, followed by 16 studies (43.2%) in the area of technology validation and basic efficacy assessment. Student differences and personalized influence mechanisms were relatively low, with 14 studies accounting for 37.8%.

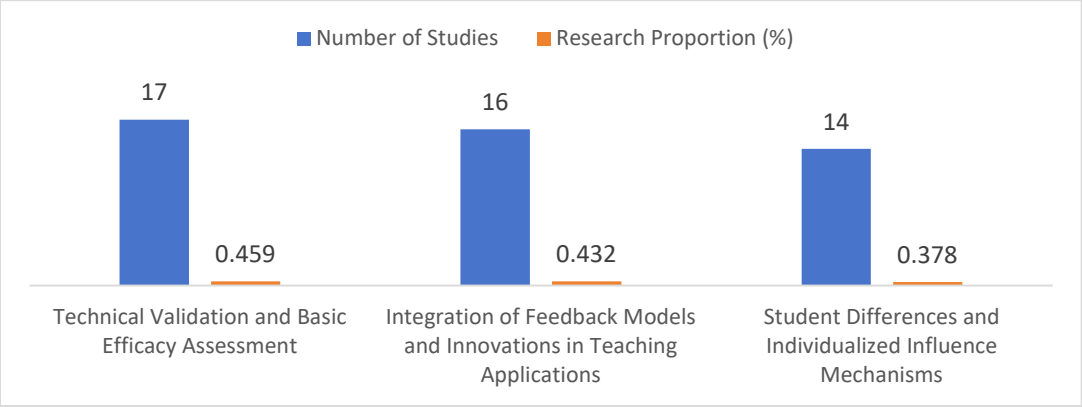

Figure 2. Comparison of Research Quantity and Proportion by Theme: Technical Validation, Feedback Models, and Student Differences

（1）Technology Validation and Basic Effectiveness Evaluation

Current studies have highlighted the practical benefits of Pigai's language error recognition and immediate feedback. Zhang & Huang (2020) reported that Pigai's overall accuracy in recognizing grammatical and lexical errors is 58%, with 89.3% for spelling errors and 70.6% for article errors, showing significant effectiveness in correcting basic language mistakes[14]. Guo (2020) confirmed that with continuous feedback from Pigai, students' writing scores increased by 11.95% from pre-test to post-test [7]. Chen (2024) found that repeated use of Pigai reduced students' vocabulary error rate by 29% [15]. This real-time intervention enhances

writing efficiency and helps learners develop an automated mechanism for processing language forms through repeated reinforcement of correct expressions.

（2）Integration of Feedback Modes and Innovation in Instructional Applications

Existing literature has explored two core models combining Pigai with other feedback modes or instruction methods: the "Pigai + Teacher Feedback" mode and the "PBWA + Pigai" mode.

The "Pigai + Teacher Feedback" mode is more effective than using Pigai alone, significantly improving students' writing quality, particularly in argument logic (22% improvement) and vocabulary richness (18% increase) [16]. It prompts teachers to focus on higher-level skills while Pigai handles low-level errors, resulting an efficient "machine screening–teacher refining" division of labor [17].

The "PBWA + Pigai" mode integrates process-based writing approaches with Pigai's feedback, significantly enhancing the writing performance and error correction ability of Chinese EFL undergraduate students [18]. It is ideal for improving overall writing structure and process management, as it combines Pigai's feedback with process writing techniques to optimize students' planning and writing processes.

Both models leverage Pigai's automatic feedback and the strengths of teachers or specific writing methods to provide comprehensive feedback. The "Pigai + Teacher Feedback" mode is best for improving logic and vocabulary, while the "PBWA + Pigai" mode is better for enhancing overall structure and process management. Future research could explore integrating these modes into a "PBWA + Pigai + Teacher Feedback" mode to further improve writing instruction.

(3)Mechanisms of Student Differences and Individualized Effects

Existing literature focuses on how individual learner characteristics, particularly language proficiency and digital literacy, affect the effectiveness of Pigai. Pigai significantly improves basic language abilities for low-level students, increasing writing accuracy by 30.77%[19]. However, high-level students find Pigai efficient for vocabulary correction but insufficient in supporting syntactic complexity [20].

Meanwhile, students' familiarity with digital technology significantly impacts their effectiveness in using Pigai. Those with high digital literacy tend to use Pigai's functions more effectively and achieve better learning outcomes. In contrast, those with low digital literacy may encounter barriers at behavioral, cognitive, and affective levels, negatively affecting their learning outcomes[21]. This highlights the need to enhance Pigai's educational value by improving learners' digital literacy and reducing the technology use threshold.

The three research themes indicated that current research has focused more on feedback models and teaching applications, while there is relatively less research on personalized impact mechanisms. Future research could further explore the impact of student differences on the application of the Pigai system to meet the needs of different student populations.

3.1.2 Existing Research Focus: Core Contradictions and Bottlenecks in Current Research

Two core foci can be identified from the three major research themes, addressing unresolved key issues in writing instruction within the Pigai field and highlighting the deep contradictions between the technological features of the tool and the actual needs of education.

Focus 1: Structural contradiction between technological advantages and shortcomings in content instruction

Although Pigai provides an efficient error identification, but its ability to recognize deep-level errors is limited[18]. Furthermore the effect of using Pigai alone to increase syntactic complexity is not significant[20]. This contradiction is essentially attributed to the mismatch between Pigai's technological limitations and the needs of writing instruction. The technical strengths of Pigai are primarily based on algorithms for rule and pattern matching, which are highly effective in dealing with lower-order errors in linguistic forms, but are ineffective in dealing with higher-order writing skills (e.g., content logic, syntactic complexity). Therefore, relying solely on Pigai is insufficient to meet the higher-order needs of writing instruction. The "human-machine integrated" mode (i.e. "Pigai+teacher feedback") effectively compensate for the shortcomings of technology. It can increase the frequency of clause usage by 20.42% [22].

Focus 2: Challenges to Educational Equity

The existing 37 studies focus on higher education or urban teaching settings, with a complete research gap in rural schools and township areas. This reflects that there are still two core issues with Pigai's adaptability in the field with weak educational resources: first, rural teachers lack necessary technical training and find it difficult to efficiently utilize system functions; second, rural students may be constrained in their acceptance of feedback due to their relatively low digital literacy as a result of the limitations of family and school resources.

These two issues highlight the inequity in the distribution of educational resources, which results in rural learners lagging significantly behind urban learners in terms of learning opportunities and academic achievements, thereby exacerbating educational inequality. Therefore, promoting the transition of Pigai from an “elite-oriented tool” to a “universal application” is not only a necessity for technological dissemination but also a crucial step in achieving educational equity.

3.1.3 Future Research Trends: Four Major Directions Based on Contradiction Breakthrough

Future studies should integrate technological advancements with educational needs to address core contradictions, focusing on four key areas: in-depth content guidance, personalized feedback strategies, educational equity practices, and innovative technological integration.

Trend 1: Construction of Content Depth Guidance System

Although Pigai has demonstrated remarkable performance in correcting linguistic form errors, it still has limitations in enhancing content logic and syntactic complexity. Future research should focus on developing teaching models that integrate visual auxiliary tools such as charts and images and explore the application of multimodal feedback. The teaching models can help students understand and improve their writing from multiple dimensions, thereby promoting the transformation of Pigai from a mere "language error correction" tool to a "writing creation" auxiliary tool, enabling it to better serve teaching objectives.

Trend 2: Design of Dynamic Hierarchical Personalized Feedback Strategies

Current research shows that Pigai's feedback effectiveness varies significantly among students of different language proficiency levels, with strategies for intermediate-level students still underexplored. Future research should develop dynamic hierarchical personalized feedback strategies by combining Pigai's data with external resources. Differentiated feedback modes for high, intermediate, and low proficiency learners should be created to provide tailored guidance.Specifically:

For low-proficiency learners, teachers can use Pigai's backend to download error reports

and manually push customized resource packages for common grammatical errors, including error attribution cards, grammar charts, and practice templates to improve accuracy. For intermediate learners, teachers can embed text structure diagrams and revision templates in Pigai's annotations, requiring students to revise and resubmit to enhance argument coherence.For high-proficiency learners, teachers can link advanced resources like academic literature and interdisciplinary cases in Pigai's annotations to promote innovative thinking and depth in content.

Trend 3: Research on Equalization of Teaching Resources Oriented by Educational Equity

Existing research has revealed the imbalance in educational resource allocation, especially in rural and township areas, where the deficiency of educational resources severely affects the effectiveness of Pigai utilization and educational equity. Future research should focus on how to provide technical training and support to help students (especially ethnic minority students) increase their familiarity with digital tools and enhance their behavioral, cognitive, and affective engagement, thereby narrowing the gap between urban and rural education and ensuring that Pigai can access more students.

Trend 4: Integrating Generative AI, and constructing Dual-AI Writing Feedback Model

As generative AI technologies advance, their potential in education is becoming evident. These tools can provide personalized feedback, offer writing examples and prompts that stimulate students' writing inspiration[23], and improve students' writing proficiency[24]. Future research could therefore explore integrating Pigai with generative AI to construct a "Pigai + Generative AI" feedback model. This model would combine generative AI's strengths in content creation and creativity stimulation with Pigai's capabilities in linguistic error correction and real-time feedback to offer students more comprehensive and in-depth writing guidance.

3.2 Research on Pigai's Impact Across Different Learner Groups

3.2.1 Commonalities and Differences of Pigai's Impact Across Different Learner Groups

Current research has investigated the effects of Pigai on various learner groups, including those with different language proficiency, academic majors, and educational levels. The findings reveal several commonalities and differences in how Pigai is utilized and perceived across these groups.

All groups recognize Pigai's value in providing instant feedback and correcting basic errors, which enhances writing efficiency, but they dissatisfied with Pigai's limited ability to optimize content logic and overall structure. Besides these commonalities, there are still some differences.

In the terms of different language proficiency levels, lower Proficiency Learners are benefit from surface-level error correction (spelling and grammar) [25], which reduces writing anxiety and boosts confidence [7][26]. They can also optimize paragraph and sentence logic during revisions [27]. However, they struggle with complex feedback[28] and need more support to improve writing skills based on feedback [29].

Higher Proficiency Learners utilize Pigai's vocabulary and syntactic correction features to enhance lexical and syntactic proficiency[30][31]. With teacher guidance, they refine composition logic and content[16]. However, they have limited gains in writing sophistication, are skeptical of feedback accuracy, and seek more higher-level linguistic feedback [19].

In the academic majors aspect, English majors demand higher-order writing instruction, such as clear feedback on content and organization[30], and language form and genre adaptation[6]. Non-English Majors focus on basic error correction and personalized feedback

for writing efficiency[15][32]. They require teacher assistance for complex issues like organization and rhetoric [3] and need personalized, discipline-adapted feedback.

In different educational levels, college students recognize Pigai's value in correcting basic errors[11] but find it less effective in enhancing syntactic complexity and discourse coherence. Lower-year undergraduate students rely on basic error correction[27], while upper-year students focus on optimizing content logic and overall structure[33]. English major undergraduates need more stylistic guidance[16], whereas non-English majors value user-friendliness and immediate feedback[20]. Graduate Students can quickly identify errors with Pigai but need multiple feedback sources due to high academic writing demands[34].

3.2.2 Future Research Directions

Based on the findings, future research and optimization of Pigai should focus on developing personalized feedback plans. Personalized feedback plans should be developed by tailoring writing standards and genre training to different majors and proficiency levels.Focus on students' strengths by optimizing argument structure for logical thinkers[35] and improving word choice and sentence structure for those proficient in language expression[36].

3.3 Diversity of Research Methods

The current research on Pigai in English writing instruction has employed a wide range of research methods, reflecting the complexity and multifaceted nature of the field.

3.3.1 Research Approaches and Methodological Diversity in Pigai Studies

The literature review reveals a diverse use of research methods, including mixed methods, quantitative research, and qualitative research. Mixed methods were employed in 18 studies (48.6%), combining quantitative data (e.g., writing test scores, questionnaire ratings) and qualitative insights (e.g., semi-structured interviews) to provide a comprehensive understanding of research problems. Quantitative research was used in 16 studies (43.2%), focusing on data analysis to evaluate aspects such as the accuracy of feedback from the Pigai system through statistical methods like paired sample t-tests. Qualitative research, featured in five studies (13.5%), explored phenomena in depth through methods like interviews and classroom observations, examining how teachers' feedback practices changed with AWE and students' engagement with AWE feedback.

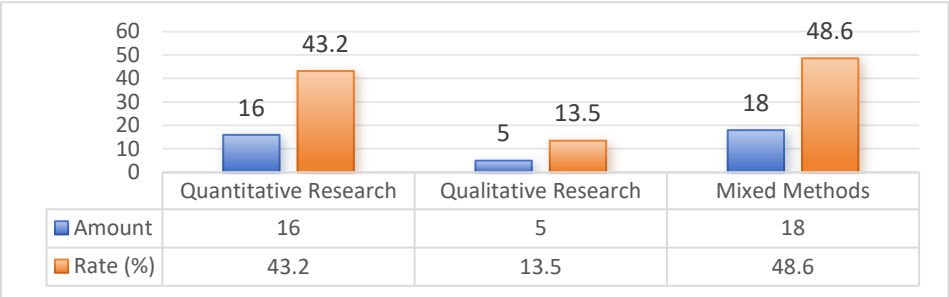

Figure 3. Classification of Research Methods

In terms of experimental design, quasi-experimental designs were most common, used in 21 studies (56.8%). These designs often utilized existing classes or groups without random assignment, comparing pre- and post-intervention outcomes to assess the effectiveness ofWE

A tools or different feedback methods. Non-experimental designs, used in 10 studies (27.0%), involved surveys and case studies to analyze factors like students' cognitive responses to AI feedback or syntactic complexity in writing. Four naturalistic experiments observed student responses to feedback in real classroom settings without controlled variables.The experimental method, used in only one study (2.7%), involved strict control of variables to assess the impact of different feedback types on metacognitive strategies. Additionally, nine studies (24.3%) did not specify an experimental design, focusing on educational practices, surveys, or case studies to explore the practical application of Pigai in writing instruction.

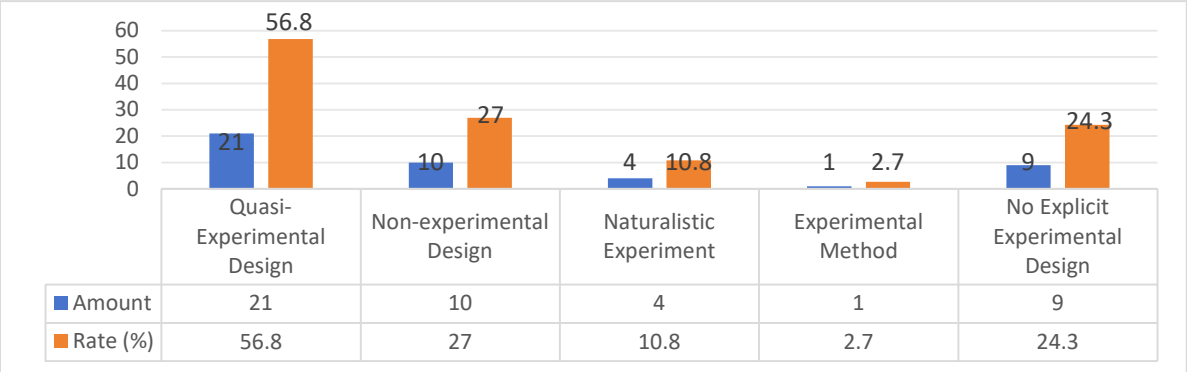

Figure 4. Classification of Experimental Designs

3.3.2 Data Collection and Processing Techniques

Current research on Pigai has constructed a data-collecting and analyzing system that is "quantitatively oriented, qualitatively complementary, and technology-driven." Data collection involves three dimensions: "product—process—perception." Pigai has become the core technical carrier for collecting writing samples and analyzing error types[20]. In addition, studies have provided insights into learners' psychological states (including somatic anxiety, cognitive anxiety, and avoidance behaviors) through psychological scales (e.g., Second Language Writing Anxiety Inventory [SLWAI])[6]. Platform data is also used to record behavioral trajectory data (such as submission frequency and revision time)to reflect learners' writing processes and habits[2][28][37]. Qualitative data were collected mainly through semi-structured interviews[10], reflective texts, and text revision analysis[28].

3.3.3 Analytical Methods and Tools

During the data analysis phase, a diverse and innovative range of methods was employed to ensure the reliability and comprehensiveness of the research findings. These methods included both quantitative and qualitative analyses, as well as mixed methods.

Quantitative analyses were conducted using SPSS for basic statistical testing (e.g., descriptive and inferential statistics), AMOS/Mplus for structural equation modeling (SEM), and Python, which ran the Lexical Complexity Analyzer (LCA) and the Second Language Syntactic Complexity Analyzer (L2SCA), for automated analysis of lexical and syntactic complexity. These methods focused on examining causal relationships between variables, such as the impact of feedback types on writing complexity. For example, Sun and Fan (2022) used SPSS to verify the effect of AWE-assisted assessment on writing performance[6], while Zhang and Zhang (2024) applied it to analyze the role of different feedback modes on metacognitive strategies [31].

Qualitative analyses primarily involved NVivo coding and thematic analysis to explore

students' perceptions and attitudes toward feedback, as well as their acceptance, trust, and use behaviors. For example, qualitative insights were used to explore how students processed Pigai feedback across dimensions such as understanding feedback, managing emotions, and taking actions[29].

In mixed-method research, qualitative insights were combined with quantitative validation to provide a more robust understanding of the research phenomenon. For example, Han et al. (2021) used concurrent triangulation through writing tests, questionnaires, and interviews to compare writing performance across different platforms [32]. This approach demonstrated the innovative integration of multiple data sources and analytical techniques to provide a more robust understanding of the research phenomenon.

3.3.4 Strengths and Limitations of Current Research Methods

Current research on Pigai has both strengths and limitations. The deep integration of mixed research methods, the expansion and application of interdisciplinary theoretical models, and the multi-dimensional evaluation and optimization of effects and tools are three main strengths.

Several studies have achieved a comprehensive analysis of complex educational phenomena by integrating multiple research methods and validation techniques. These techniques include multimodal data validation, quantitative-qualitative synergy, and theoretical-data cyclical validation. For example, Shao (2024) used think-aloud protocols, interviews, and classroom observations to analyze how secondary students processed Pigai feedback across three dimensions: understanding feedback, managing emotions, and taking actions [32]. Han et al. (2021) employed a synergy of quantitative and qualitative validation methods, integrating quasi-experimental designs (quantitative data, such as writing scores and lexical complexity) with semi-structured interviews (qualitative data, such as self-regulation strategies) [32]. Jiang & Yu (2022) employed theoretical-data cyclical validation to iteratively refine their understanding of the phenomena [28]. These approaches effectively circumvent the one-sidedness of a single perspective, allowing for a more comprehensive analysis of complex educational phenomena.

Researchers have expanded the explanatory power of traditional language teaching and learning research by integrating interdisciplinary theories into their analytical frameworks. For example, Zhai and Ma (2022) incorporated environmental, individual, educational, and systemic factors into the Technology Acceptance Model (TAM) and analyzed college students' acceptance of AWE feedback through Structural Equation Modeling (SEM) [3]. Xu and Zhang (2022) compared the response differences of high/low-level learners to AWE feedback based on Vygotsky's Zone of Proximal Development (ZPD) theory [2]. Zhang and Hyland (2023) divided digital literacy into dimensions such as "technical operation, information evaluation, and collaborative innovation" to confirm that digital literacy is positively correlated with AWE feedback utilization rate [39].

Current research provides a multidimensional evidence chain for optimizing Pigai from the perspectives of cognition, emotion, and teaching interaction. For example, Zhai and Ma (2022) analyzed students' perceived usefulness of Pigai feedback through structural equation modeling[3]. Li and Yan (2020) identified a positive correlation (r=0.39) between English majors' writing self-efficacy and the frequency of revisions[40]. The system evaluation found that Pigai has shortcomings in evaluating "writing scenarios" (such as business scenarios) and "rhetorical structures" (such as argument associations). It is recommended to introduce dynamic situational analysis and genre adaptation algorithms to better meet teaching needs.

Despite these strengths, current research on Pigai also has notable limitations. First, the samples are often limited, both in size and scope. For example, 75% of the studies have sample sizes of fewer than 100 participants, with some studies having extremely small sample sizes. Shao (2024) had only 2 middle school students[38], and Zhang (2020) had just 3 college students[10]. Moreover, the research predominantly targets English writing at the undergraduate level (65%), and over 80% of the studies focus on university students, with limited attention to secondary and vocational education stages. This restricts the representativeness and external validity of the findings, particularly for other groups such as vocational college students and minority learners.

Second, there are issues with the duration of the research. 70% of the studies were conducted within a 16-week period (about one semester), with few tracking data spanning multiple academic years. This short time frame makes it difficult to assess the long-term effects of AWE systems on writing ability development. Furthermore, most studies only compare pre-test and post-test scores, rarely analyzing students' behavioral changes during multiple revisions. As a result, the understanding of the dynamic mechanism of “feedback-revision-competence enhancement” remains superficial. Additionally, while a few studies have examined teachers' strategies for integrating AWE feedback, the influence of teachers' intermediary role on students' adoption of feedback still needs further exploration.

3.3.5 Future Research Directions and Methodological Recommendations

For the limitations of current studies, future research can be deepened in the following aspects: Firstly, future research should focus on long-term and dynamic studies to explore the effects of Automated Writing Evaluation (AWE) feedback. A three-stage experiment (pre-test, mid-test, and post-test) over an extended period (such as 2-3 semesters) could be designed to observe the long-term impact of AWE feedback on students' writing development. Using quantitative growth models (e.g., hierarchical linear models) and qualitative interviews can dynamically track how students' cognitive strategies and writing styles evolve.

Secondly, to ensure the generalizability of the findings, the initial sample should be carefully selected to include a diverse range of students in terms of educational stage, language proficiency, and cultural background. This will allow researchers to observe how different student profiles respond to AWE feedback over the long term.

Thirdly, research should be grounded in theories such as self-regulated learning (SRL) and cognitive load theory (CLT). Methods like experiments, quasi-experiments, and case studies, along with tools such as eye-tracking, natural language processing, and cognitive load questionnaires, can be used to investigate how students process AWE feedback and how feedback presentation methods impact learning efficiency over time.

4. Conclusion

This study provides a systematic review of the application of Pigai in English writing instruction from 2020 to 2024. Research has found that existing studies mainly focus on three main themes: technology validation and basic effectiveness evaluation, feedback mode integration and teaching application innovation, and student differences and personalized impact mechanisms. Students with various language levels, professional backgrounds, and educational levels have varying impacts of Pigai on different types of students; diversified research methods are employed.

The scope of the literature search in this study is limited. Firstly, it only covers English databases and does not include Chinese resources, which may affect the completeness and

representativeness of the conclusions. Secondly, the research is limited to literature from 2020 to 2024 and may not cover earlier research findings, thus affecting the comprehensive evaluation of the long-term application effectiveness of Pigai. Future research should cover databases in more languages, especially Chinese resources, to more comprehensively reflect the current status and effectiveness of Pigai's application in English writing instruction. Furthermore, future research should expand the time frame and include earlier research results to more comprehensively evaluate the long-term application effectiveness of Pigai.

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