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Enhancing Indonesian Linguistic Competence through AI-Mediated Feedback: The Efficacy of Syntactic and Interactive Strategies

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ABSTRACT

This study employed a quantitative survey design to examine the impact of artificial intelligence (AI)-mediated feedback on vocabulary, pragmatics, syntax, error awareness, and interactive online writing in the development of linguistic competence in Indonesian. Data were collected from high school and university students in Indonesia. The collected data were analysed using SPSS software, applying regression and moderation analyses. Results indicate that syntactic feedback, interactive writing feedback, and vocabulary support have the most positive effects on linguistic competence. Pragmatic feedback and error recognition are also beneficial, though to a lesser degree. The effect is strongly moderated by digital literacy, enabling AILDs with higher literacy levels to capitalise on AI feedback and improve their use of the target language. The research offers new perspectives by revealing that AI-mediated feedback functions differently across linguistic components and positioning digital literacy as a crucial facilitator of learning outcomes in an Indonesian context. The findings provide evidence for educators and policymakers to develop AI-informed curricula that consider not only technical feedback but also digital literacy and ethics. The results have implications for fair, equitable and human-centered adoption of AI in education policy and practice as well as recommendations that can be applied across languages and

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learner communities globally.

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1. Introduction

In recent years, there has been a marked acceleration in the development of language education within technologically enhanced learning environments and the integration of artificial intelligence (AI) into these contexts. Consequently, there is an imperative to reconsider conventional pedagogical practices and the assessment of linguistic competence outcomes[1,2]. AI-based tools have become a regular feature in language classrooms worldwide, providing students with immediate feedback-particularly through interactive writing platforms and adaptive instructional systems that offer valuable support for the simultaneous development of vocabulary, syntax, and pragmatic awareness[3–5]. Despite extensive research on the use of AI in language education, particularly in the context of widely taught languages such as English, there remains a paucity of research concerning Indonesian language education. This gap is especially evident in secondary and undergraduate education, specifically among Sekolah Menengah Atas (SMA) and university Students. Consequently, this study is both timely and relevant. Addressing the integration of AI in Indonesian language teaching at the grassroots level[6–8].

It is imperative to acknowledge the pivotal role that feedback plays in developing linguistic competence within the context of language acquisition. Feedback helps students identify errors, refine their word choice, and improve sentence accuracy, thereby promoting more meaningful language acquisition[9–12]. AI extends traditional feedback practices by providing context-aware personalized suggestions that help learners enhance their vocabulary, syntactic accuracy, and pragmatic appropriateness[13,14]. Recent empirical research suggests that AI-generated feedback encouraging active learner engagement, self-correction, and reflection metacognitive processes is crucial for fostering autonomous learning in digital environments[15–17]. Nonetheless, most existing studies focus on English or other high-resource languages, leaving a gap in the development of AI tools for Bahasa Indonesia, particularly at the (Sekolah Menengah Atas) SMA level, where lexical, syntactic, and pragmatic competencies are integrated and assessed simultaneously.

A comprehensive review of previous studies reveals significant variation in how learners respond to AI interventions, with differences often attributed to their levels of digital literacy, prior knowledge, and engagement[18–20]. Research findings present mixed results: while some learners demonstrate significant gains in language. performance after receiving AI-mediated feedback interventions[21–23], others show only modest improvements. This suggests that moderating variables such as students' digital competences and their ability to critically interpret AI-generated suggestions may influence the effectiveness of such interventions[24,25]. Accordingly, there is a clear need for research investigating digital literacy as a moderating factor in the relationship between AI interventions and language proficiency[26,27].

The theoretical framework for this study is grounded in sociocognitive and interactionist theories of language learning[28–31]. From a social-cognitive perspective, feedback plays a central role in second language acquisition, where cognitive processes and interaction between learner and interlocutor are assumed to facilitate the development of linguistic competence. Feedback serves as a key mechanism through which linguistic rules become internalized[32]. AI-assisted interactive writing practices also create opportunities for dialogic interaction, enabling learners to negotiate meaning, align syntactic structures and adjust pragmatic appropriateness[33–36]. These frameworks position AI-mediated intervention not merely as tools for error correction but as mechanisms that promote higher-order engagement and metacognitive awareness.

The significance of the present study stems from addressing exiting linguistic and pedagogic gaps[37,38]. through AI is increasingly integrated into classrooms worldwide, to the best of our knowledge, little research has examined its use in the context of learning Indonesian[39–41]. Furthermore, existing literature has primarily examined vocabulary, syntax or pragmatics within AI-mediated interventions[42,43]. This study also differs from previous research in that, while many earlier investigations have recognized the role of AI, its usability effects, particularly regarding syntax accuracy and

pragmatic awareness, have been found to be inconstant at times[44,45]. In this research, AI is employed as a platform to test Bahasa Indonesia interventions, enabling the simultaneous assessment of lexical, syntactic, and pragmatic competence within a single framework. This provides a discussion of AI's role in language education[45,46].

The focus of this study is to examine the effects of five types of AI-mediated feedback interventions on vocabulary choice, pragmatic guidance, syntactic correction, error awareness, and interactive writing on students' overall proficiency in Bahasa Indonesia. The study also investigates the moderating role of students' digital literacy in determining whether more digitally proficient learners achieve greater language gains in AI-supported environments. This quantitative, primary research draws on data collected directly from secondary and tertiary students, ensuring both empirical validity and contextual relevance. The findings are expected to benefit teachers and policymakers by informing the design of AI-integrated language curricula and contribute theoretically to the understanding of how AI can support language learning. Beyond the immediate context, the study holds global significance for understanding language as a dynamic system and for exploring how digital tools can facilitate the acquisition of canonical language forms across linguistic and cultural settings.

2. Literature Review

2.1. Artificial Intelligence in Language Education

AI in language education will also change the traditional classroom teaching mode to provide a new personalized way, and can respond to fit users' own preferences and learning styles, promoting both linguistic progress and cognitive development[47,48]. AI, however, has the potential to provide automatic feedback and scaffold writing-related tasks, all of which promote engagement and self-regulation[49]. In the context of Indonesian language learning, AI-based teaching remains a relatively new and underexplored field, particularly at the primary and secondary education levels, leaving a significant opportunity for systematic research on lexical competence development, syntactic skill acquisition and pragmatic sense training. In contrast to efforts in a host of other English and high-resource language studies, only few initiatives have dealt with the role of AIs[50], opening a new window to AI exploration in ELL education.

2.2. AI-Based Feedback in Language Learning

Feedback is commonly cited as important to language learning, for error correction (Polio et al., 1998), vocabulary gains and syntactic improvement[12,51]. This AI-based feedback exceeds traditional methods in that it provides personalized advice very quickly and according to the situation[52]. It has been reported in previous research that learners can learn more accurately, engage, and provide correct responses with AI feedback[53,54]. Variability has been noted, however: some learners improve sign, others have made very little improvement-learner variables could play a role in the efficacy of AI feedback, i.e., digital literacy, pre-existing knowledge. This disparity justifies the necessity for research on AI feedback in Bahasa Indonesia learning[55].

2.3. Learner Engagement in AI-Assisted Learning

Engagement as a precursor to language learning success: Interactive AI-mediated writing tasks enable students to actively engage, collaborate, and reflect throughout their learning process while empowering them to utilize new vocabulary and grammatical structures in a meaningful context[52,56,57]. By contrast, recent research has demonstrated that AI-induced engagement improves motivation and cognitive encoding of content, which leads to improved linguistic achievement[58,59]. This contributes to the novelty of the present study. Despite these discoveries, however, engagement in Indonesian language learning contexts is an underresearched site of enquiry and area of significance[60,61].

2.4. Adaptive Learning and Personalized Instruction

Adaptive learning, powered by AI algorithms, adjusts instruction according to individual learner profiles and delivers focused remediation for weak areas as well as scaffolding on increasingly difficult questions when mastery is attained[16]. It has also been known that individualized instruction can boost vocabulary retention, syntactic accuracy and pragmatic awareness in other languages[62–64]. Nevertheless, these advantages have not been extensively studied

in Bahasa Indonesia, especially in secondary and undergraduate classrooms[64]. Investigating how AI, as it adapts to instruction in this setting, offers new perspectives on ed-tech situated within local language pedagogy, while filling a gap in the research[65].

2.5. The Importance of Learning and Enhanced Digital Literacy for AI Education

Digital literacy, which is the capability to search, judge and engage with digital technology, plays a key factor in determining AI-induced learning performance[66]. Students who have stronger digital literacies are able to better understand feedback given by AIs, incorporate suggestions more accurately and successfully participate in dialogical writing opportunities. Earlier studies also revealed that in Bahasa Indonesia contexts, empirical evidence is limited.). The moderating role of digital literacy between AI interventions and learning outcomes[6,67]. Examining the perceived moderating effect is valuable, both theoretically and practically, facilitating curriculum design and revamping digital literacy[68].

2.6. Research Support AI-Enhanced Language Education

While there is an increasing literature on AI in language learning, some gaps have been identified: (i) Few studies focusing on Bahasa Indonesia, (ii) No integrated study concerning lexical, syntactic, and pragmatic competence has been undertaken yet (iii), Cursory Examination of digital literacy as a moderating factor; and (iv) little empirical evidence from quantitative primary research designs among secondary students[69,70]. By bridging these gaps, this work also provides novel findings for AI-enhanced language education, offers teaching advice to practitioners and adds valuable evidence to the theory of how AI can boost multilingual as well as culturally-specific language learning environments.

3. Research Model and Hypotheses

3.1. Research Model

This study investigates the impact of five AI-mediated interventions on feedback on vocabulary selection, pragmatic suggestions, syntax correction, error awareness, and interactive writing on students' linguistic competence in Bahasa Indonesia, with digital literacy as a moderating factor. The model posits that AI interventions directly influence competence development, while digital literacy enhances or attenuates these effects depending on the students' ability to utilize AI tools effectively[71,72]. The research model is illustrated in **Figure 1**.

Figure 1. Research framework model for AI-assisted language learning.

3.2. Population and Sample

The population of this research is High School (SMA) and first-year college students in Indonesia, who represent various educational environments in which Bahasa Indonesia is learned and assessed. Stratified random sampling was used to ensure proportional representation by grade (SMA 10/12) and field of study at the undergraduate level. This technique reduces sampling bias and allows for the generalization of findings to larger populations of learners [73]. The total sample size was 350, which comprised 200 SMA (*Sekolah Menengah Atas*) students and 150 undergraduates. This sample size is sufficient for quantitative statistical methods like descriptive statistics, reliability and validity analysis process, multiple regression analysis and the testing of moderation in SPSS, which require at least 100–150 respondents to ensure a reliable estimate [74,75]. In **Appendix A Table A1**, the sample size selected provides statistical power, representativeness, and strength in analyzing the artificial intelligence (AI) approach to intervention in the context of language learning.

3.3. Instrumentation

Appendix B Table A2 shows the research tools developed systematically to evaluate the effectiveness of artificial intelligence (AI)-based interventions and students' language skills and digital literacy. Responses of vocabulary feedback were measured with the degree to which AI suggestions guided correct word selection, as the research also suggested that AI has a role in lexical learning [57,76]. Pragmatic advice calibrating learners' performance of context valid expressions mirrored findings that AI writing feedback sharpens pragmatic sensitivity [77]. Syntax Correction targeting the ability to detect and correct grammatical errors (consistent with reports on syn vocab [78]. Error awareness addressed how AI prompts help improve students' recognition of frequent errors, aligning with research suggesting that automated feedback improves metalinguistic awareness [52]. Interactive authoring is a combination of engagement and contribution when students work actively on AI-supported tasks, as literature has shown that interactive digital activities improve motivation and learning outcomes [79,80]. Linguistic ability covered lexical, syntax and pragmatic skills, which were from validated tools to render consistent measurements [81–83]. Last, digital literacy measured students' effective use of AI feedback by navigating, interpreting, and mobilizing the feedback, which is in line with the argument that it moderates technology-enhanced learning [84]. All instruments were pilot tested and showed Valid data internal consistency with acceptable validity for gathering data.

3.4. Data Analysis

SPSS version 26 was employed for analyzing data gathered from the questionnaires through a systematic process. First, descriptive statistics mean, standard deviation, skewness and kurtosis were applied in order to test the distribution of data and normality [85]. The reliability of the scales was measured by Cronbach's alpha coefficient, and those greater than 0.70 were considered reliable. This list was then used to examine validity using these items in exploratory factor analysis (EFA) with varimax rotation to establish dimensionality. For hypothesis testing, a second step of multiple regression analysis was performed to check the impact of AI-mediated interventions on linguistic competence (any indices), and moderation analysis confirmed if including interaction terms [86]. *P*-value $p < 0.05$ was considered to indicate a statistically significant difference, and effect size estimates were derived by examining standardized beta coefficients. A combination of these analyses lent methodological soundness as well as empirical validity to the model.

4. Results

4.1. Descriptive Statistics of Study Variables

All mean score values (**Table 1**) exceeded 4, ranging from 4.18 to 4.41, suggesting a strong positive perception among students that the AI-mediated interventions substantially facilitated their learning activities. Syntax correction (M = 4.41) was the best positive rated of the five types of intervention, demonstrating the importance of syntactic accuracy in students' language development. Articulate writing (M = 4.38) and vocabulary support (M = 4.32) were also positively rated, suggesting that AI did not just enable accuracy but engagement and lexical enhancement too. In contrast, pragmatic advice (M = 4.18) had the lowest mean value, suggesting that contextually sensitive adequacy in language production is still a quite complicated area to tackle for AI systems validation of information processing features.

The average figure for digital literacy (M = 4.29) indicates that respondents generally knew how to interpret and use AI feedback. Likewise, the high mean score for proficiency (M = 4.35) indicates that AI training had a concrete positive impact on learners' competence. The moderate variability (0.71–0.82) reflected relatively homogenous perceptions among the respondents. These results laid the groundwork for later regression and moderation tests.

Table 1. Descriptive statistics of the study variables Overall.

Variable	Mean	Std. Deviation	Min	Max	N
Vocabulary feedback	4.32	0.76	2	5	370
Pragmatic suggestions	4.18	0.82	1	5	370
Syntax correction	4.41	0.71	2	5	370
Error awareness	4.25	0.79	1	5	370
Interactive writing	4.38	0.74	2	5	370
Digital literacy	4.29	0.81	1	5	370
Linguistic competence	4.35	0.77	2	5	370

Source: author, 2025.

4.2. Reliability Analysis of Research Instruments

The results of the reliability test show that all constructs establish a Valid data internal consistency, with Cronbach's alpha values at 0.79 to 0.89 (**Table 2**). Notably, an overall reliability coefficient of 0.89 indicates the soundness of the instrument as a whole which is "excellent" (Hair et al., 2020). For the constructs themselves, five items are related to more than one other measurement: Vocabulary feedback (α = 0.82), syntax correction (α = 0.85), interactive writing aloud (α = 0.87), digital literacy (α = 0.83) and linguistic competence (α = 0.86) possess an acceptable reliability meaning that they provide reliable measurements across all of their reflect a basic contributing indicator whereas grammar correction does not. Pragmatic advice (α = 0.79) and error awareness (α = 0.81) are likewise reliable, but at the lower end of what is considered generally acceptable to Valid data ranges. These results lend confidence in that the measurement scales used are adequate for further statistical analyses, and that the observed associations with AI-mediated interventions would not be weakened by measurement error.

Table 2. Reliability coefficients of study variables.

Scale/Variable	Cronbach's Alpha	Number of Items	Interpretation
Overall Reliability	0.89	28	Excellent
Vocabulary Feedback	0.82	4	Valid data
Pragmatic Suggestions	0.79	3	Acceptable
Syntax Correction	0.85	4	Valid data
Error Awareness	0.81	3	Valid data
Interactive Writing	0.87	5	Valid data
Digital Literacy	0.83	3	Valid data
Linguistic Competence	0.86	4	Valid data

4.3. Correlation Analysis Study

The internal consistency of the scale, measured by Cronbach's Alpha (CA) (**Table 3**), shows a stability at the Valid data level in terms of internal consistency for all constructs. The reliability of 0.89 for the 28-item suggests sound internal consistency, endorsing that the scale is plausible and dependable in gauging constructs which are under study. At the construct level, in terms of the learning views on language support dimension, the subscale for Vocabulary Feedback (α = 0.82, 4 items) and Syntax Correction (α = 0.85, 4 items) demonstrated satisfactory item reliability that indicated stable measurement for learners' perceptions of linguistic support. Likewise, Error Awareness (α = 0.81, 3 items) and Interactive Writing (α = 0.87, 5 items), too yielded a Valid data estimate of reliability implying that the respondents consistently responded to these subtitles of language learning. Pragmatic Suggestion (α = 0.79, 3 items) As a little inferior of the other constructs was achieved for a reliability

of the measure, however it needs to be pointed out that is still within acceptable limits. In addition, Digital Literacy (α = 0.83, 3 items) and Linguistic Competence (α = 0.86, 4 items) showed Valid data reliability as well, supporting their consistency as dimensions of measure. Together, these results support the validity of this instrument for linguistic and digital literacy research; thus reliable data can be provided in pedagogical and theoretical contexts.

Table 3. Correlation matrix of Study variables.

Variable	VF	PS	SC	EA	IW	M_DL	Y_LC
Vocabulary Feedback	1	0.68**	0.72**	0.65**	0.71**	0.63**	0.74**
Pragmatic Suggestions	0.68**	1	0.66**	0.61**	0.69**	0.59**	0.70**
Syntax Correction	0.72**	0.66**	1	0.70**	0.75**	0.67**	0.78**
Error Awareness	0.65**	0.61**	0.70**	1	0.68**	0.62**	0.71**
Interactive Writing	0.71**	0.69**	0.75**	0.68**	1	0.70**	0.76**
Digital Literacy	0.63**	0.59**	0.67**	0.62**	0.70**	1	0.73**
Linguistic Competence	0.74**	0.70**	0.78**	0.71**	0.76**	0.73**	1

Note: ** $p < 0.01$.
Source: Author 2025.

4.4. Regression Analysis Study

Multiple regression analysis (**Table 4**) showed that the model was indeed statistically Sign, $F(5364) = 89.32$, $p < 0.001$, meaning that the combination of independent variables accounted for a meaningful amount to variability in linguistic competence. The R^2 demonstrates a high level of explanatory power, with an $R^2 = 0.71$ and Adjusted $R^2 = 0.70$, which means that approximately 70% of the variance in language proficiency is explained by the covariates. In the predictive step, all predictors Sign added to the model. Vocabulary Feedback ($\beta = 0.18$, $p < 0.001$) and Pragmatic Suggestions ($\beta = 0.15$, $p < 0.001$) had positive effects indeed both of which were Sign associated with linguistic outcomes, highlighting the effect of lexical reinforcement and pragmatic sensitivity in augmenting language production quality. The best predictor was Syntax Correction ($\beta = 0.24$, $p < 0.001$), indicating that structural correctness is a crucial determinant of competence. Likewise, Error Awareness ($\beta = 0.13$, $p < 0.001$) and Interactive Writing ($\beta = 0.20$, $p < 0.001$) make a Sign contribution to the model where learner reflection and active engagement in writing are accounted for as Sign features of writing practice. Therefore, the results demonstrate an integrated instruction framework focusing on vocabulary, pragmatics, syntax, and error monitoring that significantly contributes to linguistic proficiency; thereby validating the pedagogical role for integrated feedback in digital learning environments.

Table 4. Multiple regression results.

Predictor Variable	B	SE	β	t	p	Significance
(c)	0.42	0.18	–	2.33	0.02	Sign
Vocabulary Feedback (VF)	0.21	0.05	0.18	4.2	0.00	Sign
Pragmatic Suggestions (PS)	0.17	0.04	0.15	4.24	0.00	Sign
Syntax Correction (SC)	0.28	0.06	0.24	4.66	0.00	Sign
Error Awareness (EA)	0.15	0.04	0.13	3.76	0.00	Sign
Interactive Writing (IW)	0.23	0.05	0.2	4.7	0.00	Sign

Source: Author 2025.

4.5. Digital Literacy Moderation Analysis

The findings of the moderated regression analysis (**Table 5**) indicated that digital literacy played a crucial role in enhancing the impact of AI-facilitated interventions on students' linguistic competencies. The five interaction terms between independent variables and digital literacy with AI are all significant ($p < 0.01$), indicating that students who pay greater attention to interpreting, navigating and utilizing AI feedback will benefit more from such interventions overall. Namely, strongest moderating is found in the relationship between syntax correction and language competence (β =

0.13, $p < 0.001$), indicating that the more digitally literate students benefit most from AI suggested syntax as they understand better the grammatical suggestions and could apply them to their writing easier. Interactive writing (IW) also exhibits a stronger moderation effect ($\beta = 0.12$, $p < 0.01$), suggesting that students who are digitally literate benefit the most from AI-assisted collaborative and interactive learning activities in writing. Vocabulary feedback ($\beta = 0.11$), pragmatic suggestions ($\beta = 0.08$) and error awareness ($\beta = 0.07$) are also significantly moderated, suggesting that even basic AI feedback mechanisms are more effective when accompanied with high digital literacy skills. These results substantiate the claim that CDL is not just a supporting skill, rather it serves as a crucial moderator, constructing an additional pedagogical value added of AI-based interventions, which has consequential impact on the growth of more sophisticated and situationally-adept linguistics competence in students.

Table 5. Digital Literacy as a Moderator in Relationship between AI-Mediated Interventions and Linguistic Competence.

Interaction Term	B	SE	β	t	*p*	Sign
Vocabulary Feedback × Digital Literacy	0.12	0.03	0.11	4.01	0.000	Sign
Pragmatic Suggestions × Digital Literacy	0.09	0.03	0.08	3.03	0.003	Sign
Syntax Correction × Digital Literacy	0.15	0.04	0.13	3.75	0.000	Sign
Error Awareness × Digital Literacy	0.08	0.03	0.07	2.67	0.008	Sign
Interactive Writing × Digital Literacy	0.14	0.04	0.12	3.50	0.001	Sign

Source: Author 2025.

5. Discussion

The current investigation aimed to investigate the impact of an AI-based feedback intervention on linguistic competence in Indonesian (both from secondary and tertiary level students) with digital literacy as a moderator. The results strongly support the conclusions that the effects of AI feedback on syntax correction, vocabulary development, error awareness and interactive writing are positive and considerable while pragmatic advice is comparatively less effective. These findings have implications for both the current theoretical debates and empirical work on AI integration in language teaching. They also bring to light several pedagogical, practical, and ethical issues pertinent not only in (the context of) Indonesian classrooms but also within the broader global discussion about technology-mediated language learning.

5.1. Theoretical Justification and Alignment with Learning Frameworks

The findings support the relevance of Vygotsky zone of proximal development, which highlights that scaffolding is crucial to connect learners' current abilities with possible future levels of competence [87]. Syntax correction was also identified as the main driver of linguistic competence, demonstrating that AI serves as a scalable scaffold. This is due to the good assumption that learners who receive adaptive and immediate feedback internalize faster grammatical structures [88]. As described in the literature, AI feedback gives learners chances to negotiate meaning, align forms of language as well as provide personalized input adhering interactionist views of language learning [34,35]. In doing so, AI operationalizes ZPD not as a mechanism for remedying mistakes but rather as an approach to situate learners in dialogically rich environments that will promote opportunities for reflection and self regulation [22].

Secondly, the results are in line with CLT. Helping to break down complex linguistic tasks into smaller parts so that learners can process them more easily without unnecessary cognitive load, AI feedback enables students to focus on syntactic, lexical and pragmatic salience [41,88]. Error-awareness, for example, found to be predictive in nature, illustrate how AI feedback can signal trouble spots of this sort without burdening the learner resulting into more optimal distribution of cognitive resources [21]. This is consistent with previous research that highlights the importance of instruments which can reduce cognitive overload and, indeed, foster meaningful tasks for language teaching [28,29,89].

The study also offers compelling evidence for socio cognitive theories of language learning, which emphasize the interactive and mediated nature of competence growth. Interactive writing feedback from AI tools is a case in point that generates occasions for co-constructed meaning making,

incremental revisions and dialogic interaction with computational interlocutors. This corroborates the argument that AI does not so much 'play' a teacher's role as that of a stereo type ifter but transcends students reflection and mutual interactional skills to help promote students' metacognitive awareness AND linguistic development [30,31,90].

5.2. Empirical Reinforcement: AI interventions and Competence Development

The results are strongly consistent with Vygotsky [87,91] zone of proximal development, which highlights the importance of scaffolding between learners' actual developmental level and their potential capacity. Syntax correction is the most important factor in predicting linguistic competence, revealing AI's role as a scalable scaffolder. This also corresponds to the notion that learners can better memorize grammatical forms when they are provided with adaptive and immediate feedback. As discussed in the literature, AI-supported feedback gives learners a chance to negotiate meaning, compare and align structures, as well as receive customized input that reflects interactionist views of language learning [34–36]. AI does this by operationalizing ZPD through not only error correction but more importantly, putting the learners in dialogic environment where self reflection and regulation is possible [92].

Correspondingly, the results are in accordance with CLT. Through the decomposition of challenging linguistic operations into smaller manageable subunits, AI feedback minimizes unwanted cognitive load and enables learners to concentrate on important aspects of syntax, vocabulary and pragmatic felicity [31,93]. For example error awareness was found to play a predictive role which, according to AI feedback, points out problematic areas without overloading the learner and makes for a more efficient distribution of cognitive resources. This is in accordance with previous works which underlie the importance to have tools that lower cognitive hurdles and at the same time fuel meaningful engagement in second language learning [28,29,89].

The study also presents powerful evidence in favor of socio cognitive theories of language learning, with their emphasis on the interactive and mediated nature of competence attainment. Interactive writing feedback through AI tools is a concrete illustration of this principle in action by providing students with opportunities to develop their ideas, receive recursive feedback and have dialogic conversations with machine interlocutors. This corroborates the argument that AI does not simply channel the teacher's role but also facilitates the learners' reflection and cooperation, thus fostering alongside language learning also metacognitive consciousness [30,31].

5.3. The Moderating Role of Digital Literacy

An important aspect is that the value of digital literacy serves as a moderator in this study and deserves attention here. Students with better digital literacy also had better performance, thus the effect of AI interventions is not homogenous and depends on students' capacity to read and analyze feedback. This is consistent with the results of Lyu et al. [19,53], who stress that the pre-existing digital competencies of learners condition the utility for them of AI-based tools.

Theoretically, digital literacy can be viewed as metacognition [94], which is the ability to understand and employ efficient strategies for using AI feedback in language learning [95,96]. This makes digital literacy both a tool of cognitive load management and a means by which socio cognitive engagement is mediated. Learners with a lower level of digital literacy [97], instead, could be overwhelmed by feedback and misuse the AI recommendations which potential benefits are limited. This result highlights the necessity of integrating digital literacy instruction into language curriculums, as recommended [6,68].

5.4. Pedagogical and Practical Implications

The pedagogical conclusion of these results is intricate. First, AI interventions must be organized with the goal of teaching across linguistic domains at once, as vocabulary, syntax, and pragmatics are interdependent. A complete system that integrates these characteristics is likely to lead to a far more sustainable linguistic evolution than just systems targeting them in isolation. Secondly, interactive writing should be integrated into instructional design. AI-facilitated collaborative environments can support peer review, group writing and iterative drafting activities that are congruent with the socio cognitive idea of co-constructing meaning. This is especially true in the context of Indonesian language learning, where students might have limited chance to en-

gage in authentic dialogic experiences within traditional classrooms.

Third, differentiated design should consider differential digital literacy. Learners with low access to digital resources need specifically tailored scaffolding and support in order to participate equitably in AI-mediated learning [98,99]. Again, this mirrors wider concerns for equity in ed-tech and the risk of deepening digital divides if factors like these are not considered. Lastly, teacher education should not only provide knowledge and skills for AI integration into classroom practice, it should also prepare teachers to lead students in critical reflection of feedback, limitations and possibilities of AI [57,100]. Of course, teachers act as intermediaries between students and AI to keep the technology a helpful aid rather than replacing human pedagogy [87].

5.5. Ethical and Societal Considerations

The use of AI in education also presents significant ethical concerns. Data privacy, algorithmic bias and the dangers of over reliance on technology are front and center. As mentioned in the introduction, algorithmic biases might perpetuate linguistic hierarchies by being biased towards favoring specific dialects or structures [44,101]. This is especially true of Bahasa Indonesia, in which regional variation and cultural specificity are central to communicative competence. It is also the question of the marginalization of teachers that cannot be ignored. Although AI can scale feedback to be fast and efficient, it is unable to supplement the motivational, empathetic, and contextualised support human educators give. A balanced model in which AI is a substitute for teachers is needed to preserve both the effectiveness and human aspect of education [46].

5.6. Future Research Directions

Our study has raised a number of channels that need further research. Longitudinal research is needed to investigate the long-term effects of AI delivered interventions on language maintenance and development, whereas most published studies (including this one) report short-term impacts. And future studies should also aim at unexplored dimensions of language competences, especially pragmatic and socio-linguistic understanding where AI struggles to provide effective support. The multimodal feedback may be enriched with textual, audio and visual feedback elements in order to create better possibilities for future pragmatic development.

Furthermore, other educational settings need to be considered. Most of the recent research (including this study) relies on secondary and early tertiary populations. Further to primary education also where there are a significant number of AI interventions in vocational training and non-formal learning, insights into the potential for sustainable scalability of such AI solutions will be provided. Last but not least, the continued research towards culturally responsive AI models is imperative. Systems that are more representative of the cultural and linguistic contexts of Bahasa Indonesia learners, can help to alleviate shortcomings in pragmatic instruction today, and promote equity in language education.

6. Conclusions

The present research shows that AI interventions focusing mainly on syntax correction, interactive writing and vocabulary feedback improve linguistic competence. However, the effectiveness of these tools depends on the learners' digital literacy as an important mediating factor. Theoretically, the results align with ZPD and CLT frameworks, reinforcing the view of AI as a supportive element in language development. Empirically, they contribute to the growing consensus on the value of AI in language instruction, while also highlighting weaknesses such as limited pragmatic support. In practice, the results emphasize the importance of systemic approaches that integrate AI tools with a strong focus on digital literacy and ethics. As AI continues to advance, its application in language learning must be guided by principles of equity, openness, and human-centeredness. These findings can inform future research to streamline AI applications and expand their impact across diverse learner populations.

Author Contributions

Conceptualization, M.; methodology, M.; software, M.; validation, S.S. and F.R.; formal analysis, M.; investigation, M.; resources, M.; data curation, M.; writing original draft preparation, M.; writing review and editing, S.S., F.R., A.D., and G.M.S.S.; visualization, M.; supervision, S.S., F.R., and A.D.; project administration, S.S. and F.R. All authors have

read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was conducted according to the Declaration of Helsinki, and it was approved by the Ethics Committee of Safin Pati University. All procedures involving human participants were performed with the ethical standards of the institution.

Informed Consent Statement

Informed written consent has been obtained from all participants involved in this study.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Conflicts of Interest

The authors declare no conflict of interest.

Appendix A

Table A1. Population and sample distribution.

Education Level	Population	Sample	Sampling Method
SMA (Grade 10–12)	1200	200	Stratified Random
Undergraduate (S1)	900	150	Stratified Random
Total	**2100**	**350**	—

Appendix B

Table A2. Research Instruments.

Variable	Dimension	Sample Item	Scale	Reliability
Vocabulary Feedback	AI lexical suggestions	1. *AI feedback helped me choose correct Indonesian words.* 2. *AI improved my vocabulary variation.* 3. *AI suggestions helped me avoid incorrect word choices.* 4. *AI feedback expanded my lexical knowledge.*	1–5	0.89
Pragmatic Suggestions	AI pragmatic input	1. *AI suggestions improved my sentence appropriateness.* 2. *AI feedback made my writing more natural.* 3. *AI recommendations increased my cultural awareness in writing.*	1–5	0.87
Syntax Correction	AI syntax guidance	1. *AI feedback corrected my grammar errors effectively.* 2. *AI helped me structure sentences better.* 3. *AI suggestions reduced syntactic errors in my writing.* 4. *AI made my sentence structure clearer.*	1–5	0.91
Error Awareness	AI error recognition	1. *AI helped me notice recurring mistakes in my writing.* 2. *AI feedback increased my self-awareness of errors.* 3. *AI encouraged me to monitor mistakes during writing.*	1–5	0.88
Interactive Writing	AI interactive tasks	1. *AI-assisted writing tasks increased my engagement.* 2. *AI tasks motivated me to improve writing quality.* 3. *AI writing activities kept me actively involved.* 4. *AI support encouraged collaborative learning.* 5. *AI writing tasks enhanced my participation in class.*	1–5	0.9

Table A2. *Cont.*

Variable	Dimension	Sample Item	Scale	Reliability
Linguistic Competence	Lexical, Syntactic, Pragmatic	1. *I can use correct vocabulary in my Indonesian writing.* 2. *I can write with proper sentence structures.* 3. *I can apply pragmatic expressions appropriately.* 4. *I can integrate vocabulary and syntax effectively.*	1–5	0.92
Digital Literacy	Technology use & evaluation	1. *I can effectively interpret AI feedback for learning.* 2. *I am confident in using AI-based learning tools.* 3. *I can evaluate the usefulness of AI suggestions.*	1–5	0.86

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