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Testing the Bilingual–AI Pedagogical Framework (BAIP Model): A Structural Equation Modeling Approach in English for Educational Technology Programs

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ABSTRACT

In multilingual higher education settings, English for Specific Purposes (ESP) instruction necessitates pedagogical frameworks that can tackle language obstacles and the rising demand for AI-enhanced learning; nonetheless, empirical data on the amalgamation of bilingual pedagogy and AI is still scarce, especially within English for Educational Technology programs. This study investigated the effectiveness of the Bilingual–AI Pedagogical Framework (BAIP Model) in English for Educational Technology programs, focusing on the impact of bilingual scaffolding and AI pedagogical support on student learning outcomes in multilingual higher education settings. The study investigated the effects of multilingual scaffolding and AI-assisted pedagogy on student engagement, academic self-efficacy, and learning performance, both directly and indirectly. A quantitative explanatory cross-sectional design was employed, encompassing 218 undergraduate students from both public and private universities in South Sulawesi, Indonesia. Data were collected using a validated 5-point Likert-scale questionnaire evaluating five latent domains and analysed by PLS-SEM in SmartPLS 4, with initial screening performed in SPSS 29. The results indicated that bilingual scaffolding was a significant predictor of student engagement (β = .42) and learning performance (β = .16), whereas AI pedagogical assistance had the most substantial impact on academic self-efficacy (β = .47) and learning performance (β = .28). Mediation analysis substantiated the notable indirect impacts of student involvement (β = .13) and academic self-efficacy (β = .17), with the model accounting for 61% of the variance in learning performance (R^2 = .61). This study not only validates these structural correlations but also presents the BAIP Model as a cohesive instructional framework that amalgamates bilingual pedagogy and AI-assisted learning into a singular explanatory model for ESP education. This study theoretically expands the previous literature by illustrating that bilingual scaffolding and AI pedagogical support serve as complimentary processes that collectively improve engagement, self-efficacy, and learning performance in multilingual higher education settings.

Keywords: Academic Self-Efficacy; Artificial Intelligence Pedagogy; Bilingual Scaffolding; English For Educational Technology; Structural Equation Modeling.

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1. INTRODUCTION

The swift incorporation of artificial intelligence (AI) into higher education has profoundly transformed the design, delivery, and assessment of language learning, especially in specialized fields like English for Specific Purposes (ESP) (Jantassova et al., 2026; Min et al., 2025). AI-driven tools in global educational systems facilitate adaptive feedback, personalized content delivery, automated language assessment, and multimodal learning environments, enhancing their significance for tertiary-level language instruction (Jing-yu & Liu, 2018; Praveena & Anupama, 2025; Raj et al., 2026). Bilingual pedagogy has acquired renewed importance in multilingual societies, where the strategic incorporation of learners' first language alongside English can enhance conceptual comprehension, alleviate cognitive overload, and bolster disciplinary literacy (Duterte & Llorente, 2025; Ganesan, 2025; López, 2025). In English for Educational Technology programs, these two trends converge significantly: students are required to not only master academic English but also to participate in electronically mediated professional conversation. In the Indonesian setting, particularly in South Sulawesi, the prevalence of multilingualism and varying levels of digital preparedness underscore the pressing necessity for a cohesive bilingual–AI pedagogical framework. Notwithstanding national initiatives to expedite digital transformation in higher education, numerous English programs remain devoid of empirically validated models that systematically integrate bilingual instructional scaffolding with AI-enhanced learning support.

The Bilingual–AI Pedagogical Framework (BAIP Model) in this study denotes an instructional model that systematically combines bilingual scaffolding techniques with AI-enhanced learning support to enhance student engagement, understanding, and academic achievement in English for Educational Technology courses (Asrifan et al., 2025; Saleem et al., 2025). Bilingual scaffolding involves the systematic integration of Indonesian and English to facilitate conceptual understanding, task guidance, and reflection, whereas AI support encompasses intelligent systems like generative feedback tools, adaptive writing assistants, and automated linguistic prompts that tailor the learning experience (Alpar, 2025; Li & Wilson, 2025; Yıldız, 2025). For instance, when students are tasked with creating instructional media prototypes in English, the instructor may initially present fundamental concepts in both languages, subsequently allowing AI technologies to offer real-time lexical, grammatical, and rhetorical recommendations during the drafting process. This specific pedagogical sequence demonstrates the BAIP model's operation as a synergy between human instructional mediation and machine-assisted feedback.

The suggested relationships within the BAIP Model are based on various complementing theoretical frameworks. Bilingual scaffolding is based on sociocultural theory, which highlights that strategic mediation in the first language aids in meaning production and cognitive development through guided interaction. AI pedagogical support is based on self-regulated learning theory, where prompt feedback, tailored coaching, and individualised learning pathways enhance learners' autonomy and confidence. Student engagement encompasses the behavioural, cognitive, and emotional commitment necessary for significant learning, whereas academic self-efficacy, rooted in social cognitive theory, signifies learners' confidence in their ability to effectively complete academic activities. The integration of these viewpoints establishes a cohesive theoretical framework for positing that bilingual scaffolding and AI-assisted pedagogy collaboratively foster engagement and self-efficacy, hence improving learning performance in English for Educational Technology.

Previous studies have individually assessed the merits of bilingual education and AI-assisted language acquisition; however, their amalgamation has not been thoroughly investigated.

Researchers conducted a study to determine if translanguaging-based training enhanced English for Specific Purposes (ESP) understanding among undergraduate students, employing a quasi-experimental approach (Ali, 2024; Chen et al., 2019; Cong-Lem et al., 2026). The results indicated substantial improvements in reading comprehension and task completion, suggesting that strategic support in the first language facilitates the construction of disciplinary knowledge. Another study similarly investigated the efficacy of AI writing helpers in higher education English classrooms using a mixed-methods approach that included questionnaires, writing analytics, and interviews (Mohammed & Khalid, 2025; Wang, 2024). The findings indicated enhanced revision quality, lexical sophistication, and learner autonomy, implying that AI can function as a scalable feedback tool in academic writing environments. A structural equation modeling approach was utilized in a related study to investigate the predictive relationship between perceived utility of AI and learning engagement and self-efficacy in technology-enhanced ESP environments (Mujeeb et al., 2026; Xia, 2026; Yang & Kyun, 2022). The research identified substantial direct and indirect channels, demonstrating that students' belief in AI systems affects both motivation and performance results.

Conversely, certain research have warned that the incorporation of AI without pedagogical intervention may result in passive reliance, diminished authorial voice, and superficial learning (Long et al., 2026; Yeung et al., 2025). These findings suggest that technology tools are inadequate unless integrated within a theoretically informed educational framework. Bilingual education research in Indonesian higher education has predominantly concentrated on general English as a Foreign Language (EFL) or topic courses, rather than on specialist English for Educational Technology programs (Anwar et al., 2024; Hastomo et al., 2024; Hidayat et al., 2022). The pedagogical methods by which multilingual support and AI systems collaboratively impact student results are theoretically disjointed and methodologically insufficiently explored.

Collectively, current research indicates that multilingual scaffolding improves comprehension, AI tools augment feedback and autonomy, and learner views influence technology adoption results (Praveena & Anupama, 2025; Yuan, 2025). It is established that both pedagogical bilingualism and AI-assisted instruction independently enhance learning outcomes in English for Specific Purposes (ESP) and digital language education. Studies demonstrate that characteristics including engagement, perceived usefulness, academic self-efficacy, and learning performance are significantly interconnected in technology-mediated learning environments (Maican et al., 2024; Wei, 2024; Zhang, 2022). Nevertheless, these discoveries are fragmented among distinct bodies of literature, with minimal attempts to evaluate a cohesive explanatory model.

Despite prior research consistently illustrating the distinct advantages of multilingual scaffolding and AI-assisted instruction, some significant limitations persist. Most studies have analysed both instructional methods separately, viewing bilingual pedagogy mainly as a linguistic support mechanism and AI as a technology intervention, without acknowledging their possible pedagogical interplay. Moreover, numerous research have utilised descriptive, quasi-experimental, or correlational approaches that reveal discrete impacts but fail to elucidate the structural mechanisms by which multilingual scaffolding and AI collaboratively impact engagement, academic self-efficacy, and learning success. As a result, the connections among these constructs remain theoretically disjointed, hindering the creation of coherent instructional models that can guide multilingual ESP practices in higher education.

The primary research gap is the lack of a validated integrated structural model that concurrently investigates the relationships among bilingual scaffolding, AI support, learner engagement, self-efficacy, and academic performance in English for Educational Technology

programs, especially in the underrepresented region of South Sulawesi. Prior research often isolates bilingual pedagogy or AI adoption characteristics, neglecting the potential for their pedagogical synergy to yield more robust direct and mediated effects on learning outcomes (Bond et al., 2024; Tlili et al., 2023; Zawacki-Richter et al., 2019). Furthermore, empirical data from Indonesian higher education is limited, particularly with the application of Structural Equation Modeling (SEM) to examine latent relationships across these dimensions with substantial sample sizes (Handarkho et al., 2025; Wirda et al., 2025). Addressing this deficiency is crucial as higher education institutions increasingly necessitate evidence-based instructional strategies that are culturally relevant, technologically adaptable, and scalable across multilingual classrooms.

This study seeks to evaluate the Bilingual–AI Pedagogical Framework (BAIP Model) through a Structural Equation Modeling technique including over 200 students enrolled in English for Educational Technology programs in South Sulawesi. The principal research question of the project is: To what degree do multilingual scaffolding and AI-assisted teaching directly and indirectly affect student engagement, academic self-efficacy, and learning outcomes? The study posits the following hypotheses: H1: bilingual scaffolding positively influences engagement; H2: AI pedagogical support positively influences self-efficacy; H3: engagement and self-efficacy positively modulate the relationship between BAIP components and learning performance.

The study employs a quantitative correlational design utilizing SEM-PLS/CB-SEM methodology, suitable for examining intricate latent correlations between educational and psychological dimensions. Data were gathered from a sample exceeding 200 undergraduate students enrolled in English education programs in South Sulawesi, utilizing validated Likert-scale measures to assess bilingual instructional support, AI utility, engagement, self-efficacy, and views of academic accomplishment. This design aims to transcend basic association testing by modeling both direct and mediated channels that elucidate the functioning of the BAIP framework in actual classroom environments. The integrated BAIP model is anticipated to have substantial explanatory power, with engagement and self-efficacy identified as key mediators.

This study's originality is rooted in the creation and empirical validation of the BAIP Model as a culturally adaptive, AI-responsive instructional framework for English for Specific Purposes in higher education. This study theoretically integrates bilingual pedagogy and technology adoption into a cohesive explanatory model for discipline-specific English learning. The findings are anticipated to furnish lecturers, curriculum designers, and higher education policymakers in Indonesia with an evidence-based framework for the development of AI-integrated bilingual English for Specific Purposes training. This study situates the model within the multilingual higher education setting of South Sulawesi, thereby providing vital localized evidence to the broader global conversation on AI-enhanced language instruction.

2. METHODS

2.1 Research Design

This study utilized a quantitative explanatory design through a cross-sectional survey method to investigate the structural links within the proposed Bilingual–AI Pedagogical Framework (BAIP). The design was used to assess students' impressions of multilingual scaffolding, AI pedagogical support, engagement, academic self-efficacy, and learning performance at a certain moment. Structural Equation Modeling (SEM) was deemed the most suitable analytical method since it facilitates the concurrent examination of latent constructs, direct and indirect paths, and the comprehensive validation of proposed structural relationships. Due to the study's predictive focus and model-development objective, PLS-SEM was selected as the principal analytical method.

2.2 Research Setting and Participants

The research was carried out in public and private universities in South Sulawesi, Indonesia, involving undergraduate students in English for Educational Technology programs. A total of 218 students from semesters 2, 4, and 6 participated, exhibiting balanced gender representation and an age range of 18 to 23 years. The majority of participants indicated previous exposure to AI-assisted learning tools and consistent expertise in bilingual classroom settings utilizing Indonesian and English. Purposive sampling with criteria-based inclusion was utilized, necessitating that students had completed a minimum of one technology-mediated English course. The sample size adhered to Hair et al.'s SEM guidelines, fulfilled the 10-times criterion for PLS-SEM, and surpassed minimal power analysis requirements, guaranteeing robust model estimation.

Purposive sampling was employed due to the necessity for participants possessing particular academic attributes pertinent to the BAIP framework. Only undergraduate students who had completed a minimum of one English for Educational Technology course that comprised bilingual instruction and AI-assisted learning activities were included, guaranteeing that all respondents had adequate expertise to assess the suggested constructs. To improve sample representativeness, participants were recruited from both public and private universities throughout South Sulawesi, encompassing various semester levels (2, 4, and 6) to reflect differences in academic maturity, digital literacy, and exposure to bilingual and AI-assisted instruction. Despite the non-probabilistic sampling technique, the diverse institutional composition and sufficient sample size (n = 218) surpassed the minimum criteria for PLS-SEM, enhancing the robustness and potential applicability of the findings in similar multilingual higher education settings, as shown in Table 1.

Table 1. Demographic and Academic Profile of BAIP Participants Across Semester Levels

Semester	Participants	Male	Female	Mean Age	AI Exposure %	Bilingual Experience %	Digital Literacy Mean
2	72	31	41	18.9	68	74	3.8
4	74	34	40	20.4	81	85	4.1
6	72	33	39	21.8	89	91	4.4

Table 1 delineates the demographic and academic distribution of 218 undergraduate students over semesters 2, 4, and 6 in English for Educational Technology programs in South Sulawesi. The participant composition exhibits a fairly equitable gender distribution and a gradual rise in average age throughout semester levels. A significant pattern is the steady increase in AI exposure and bilingual classroom experience from lower to higher semesters, indicating cumulative pedagogical immersion. Digital literacy scores demonstrate an upward trend, signifying that senior students exhibit enhanced preparedness for AI-assisted multilingual education. These attributes validate the sample's appropriateness for evaluating the BAIP structural routes by PLS-SEM.

2.3 Conceptual Model and Hypotheses

This study's conceptual model identifies Bilingual Scaffolding (BS) and AI Pedagogical Support (AIPS) as the principal exogenous latent variables affecting Learning Performance (LP), both directly and indirectly via Student Engagement (SE) and Academic Self-Efficacy (ASE). The concept posits that strategically integrated bilingual instruction improves students' cognitive and

behavioral engagement, while AI-supported pedagogical aids bolster confidence in executing English for Educational Technology activities. These assumptions are conceptually based on frameworks for multilingual learning support and technology-enhanced self-regulated learning. Direct pathways were delineated from BS and AIPS to LP, whereas indirect pathways were conceptualized through SE and ASE as mediating factors. Consequently, the proposed hypotheses are: H1: BS to SE; H2: AIPS to ASE; H3: BS to LP; H4: AIPS to LP; H5: SE to LP; H6: ASE to LP; H7: SE mediates BS to LP; H8: ASE mediates AIPS to LP. This approach facilitates concurrent evaluation of explanatory and predictive linkages within the BAIP framework.

2.4 Instruments, Validity, and Reliability

The research utilized a structured questionnaire to assess five latent characteristics using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Bilingual Scaffolding (BS) and AI Pedagogical Support (AIPS) were assessed using six modified questions each, whilst Student Engagement (SE) comprised five items addressing behavioral, cognitive, and emotional aspects. Academic Self-Efficacy (ASE) evaluated confidence in executing Educational Technology-related English activities, whereas Learning Performance (LP) gauged perceived accomplishment, task quality, and skill enhancement. All instruments underwent expert validation, contextual adaptation, and pilot testing with 42 respondents before the primary data collection. The measurement model was assessed in accordance with the PLS-SEM principles established by Hair et al. (2022). The reliability of indicators was evaluated via outer loadings, while internal consistency reliability was analysed using Cronbach's alpha and Composite Reliability (CR). Convergent validity was examined via the Average Variance Extracted (AVE), whilst discriminant validity was tested using the Fornell–Larcker criterion and the Heterotrait–Monotrait ratio (HTMT). To verify the integrity of the measurement model, multicollinearity was analysed by the Variance Inflation Factor (VIF), and Harman's single-factor test was performed to evaluate the risk of common method bias. The actual findings of these measurement model evaluations are detailed in the Results section.

2.5 Data Analysis

The data analysis was performed utilizing SPSS 29 and SmartPLS 4 in four distinct stages. Stage 1 encompassed initial screening, which included the treatment of missing data, detection of outliers, assessment of normality, descriptive statistics, and analysis of the correlation matrix. Stage 2 assessed the measurement model (outer model) through indicator loadings, convergent validity, and discriminant validity. Stage 3 assessed the structural model, emphasizing path coefficients, t-values, p-values, and mediation effects by bootstrapping with 5,000 resamples, incorporating indirect effects and bias-corrected confidence intervals. Stage 4 assessed predictive capability via R^2, f^2, and Q^2 metrics, while the overall model fit was also corroborated using SRMR and NFI indices where applicable.

2.6 Ethical Considerations

Ethical approval was secured from the faculty research ethics committee before data collection commenced. Participation in the study was completely voluntary, and all participants received a comprehensive informed consent statement detailing the study's objectives, methodologies, and data utilization. Participants were guaranteed that their responses would be kept confidential and anonymous, with no personally identifiable information gathered at any point. They were also apprised of their freedom to withdraw from the study at any moment without repercussions. To

uphold academic integrity, students were specifically guaranteed that their involvement or lack thereof would incur no academic penalties, grade consequences, or lecturer prejudice, hence ensuring ethical standards and authentic answer quality during the study process.

3. RESULT AND DISCUSSION

3.1 Participant Profile and Preliminary Analysis

The initial research commenced with a demographic assessment of 218 undergraduate participants selected from English for Educational Technology programs at public and private colleges in South Sulawesi. The sample was uniformly distributed throughout semesters 2, 4, and 6, exhibiting a very equitable gender representation. A significant percentage of students indicated previous experience with AI tools and consistent participation in bilingual classroom procedures, demonstrating robust contextual congruence with the BAIP paradigm. The overall digital literacy level above the midway, with senior-semester students exhibiting somewhat higher readiness ratings.

The data screening techniques validated the dataset's resilience. Missing data were negligible (<2%) and addressed via mean replacement owing to their random distribution. Outlier analysis employing Mahalanobis distance revealed no significant multivariate outliers. The evaluation of normality indicated acceptable ranges for skewness and kurtosis, hence validating the assumptions of SEM. As illustrated in Table 2 and Table 3. Descriptive statistics and the correlation matrix revealed that all study variables had moderate to high mean scores with acceptable standard deviations, signifying substantial variance. The correlation matrix indicated positive relationships among bilingual scaffolding, AI pedagogical support, engagement, self-efficacy, and learning performance. Figure 2. The distribution of participant digital readiness visually depicts the increasing trend in AI acquaintance and digital competence throughout the semester levels.

Table 2. Descriptive Statistics and

Variable	Mean	SD
BS	4.12	0.54
AIPS	4.05	0.58
SE	3.98	0.61
ASE	4.01	0.57
LP	4.08	0.55

Table 3. Correlation Matrix of BAIP Constructs

Index	BS	AIPS	SE	ASE	LP
BS	1	0.68	0.71	0.63	0.69
AIPS	0.68	1	0.66	0.74	0.72
SE	0.71	0.66	1	0.69	0.76
ASE	0.63	0.74	0.69	1	0.78
LP	0.69	0.72	0.76	0.78	1

Table 2 and Table 3 displays the descriptive statistics and inter-construct correlations for the five latent variables within the BAIP model. All factors exhibited notably high mean scores, ranging from 3.98 to 4.12, signifying positive student evaluations about multilingual scaffolding, AI pedagogical support, engagement, self-efficacy, and learning performance. The standard deviation values were moderate, indicating acceptable diversity among responders. The correlation matrix demonstrated consistently positive and significant connections among all dimensions, with the

most robust relationships identified between academic self-efficacy and learning performance, as well as between student involvement and learning performance. The initial findings offer robust empirical justification for advancing with the measurement and structural model assessment in the SEM study. The following is the distribution of participants' digital readiness, as shown in Figure 2.

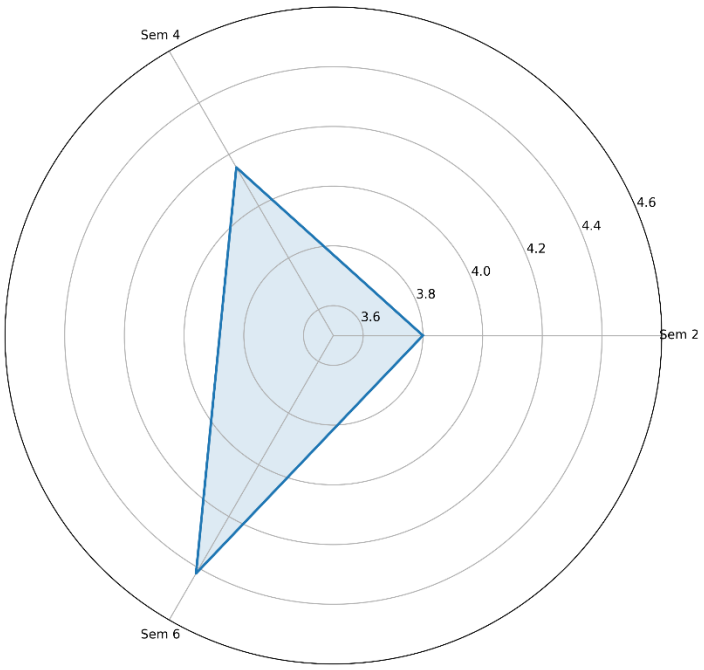

Figure 2. Participant Digital Readiness Distribution

Figure 2 depicts the semester-wise distribution of participant digital preparedness via a polar trajectory visualization, emphasizing a gradual increase from semester 2 to semester 6. The circular form successfully underscores developmental continuity, indicating that senior pupils exhibit greater digital readiness for multilingual and AI-enhanced learning activities. The external growth of the preparedness pattern indicates accumulated exposure to educational technology, AI-assisted tools, and English-medium digital tasks throughout academic advancement. This unique visual pattern corresponds with the theoretical premise that elevated digital literacy and AI acquaintance augment the efficacy of the BAIP framework, especially in bolstering engagement, self-efficacy, and learning performance trajectories.

a. Measurement Model Results

The measuring model was assessed to verify the reliability and validity of the BAIP latent constructs before evaluating the structural model. As indicated in Table 3. All indicator factor loadings surpassed the required criterion of .70, ranging from .74 to .91, thereby exhibiting robust item reliability and convergent validity. The internal consistency was deemed satisfactory, with Cronbach's Alpha values between .82 and .90 and Composite Reliability (CR) values ranging from .87 to .93, all beyond the approved threshold of .70. Furthermore, Average Variance Extracted (AVE) values varied from .58 to .72, thus affirming sufficient convergent validity for all constructs.

Discriminant validity was additionally confirmed by the Fornell–Larcker criterion and HTMT ratios, as illustrated in Table 4. Discriminant Validity (Fornell–Larcker and HTMT methods). The square root of each construct's Average Variance Extracted (AVE) surpassed all inter-construct correlations, and all Heterotrait-Monotrait (HTMT) values

were below .85, demonstrating evident construct distinctiveness. Multicollinearity diagnostics indicated satisfactory VIF values below 3.3, implying the lack of collinearity concerns. The findings together affirm that the BAIP assessment model exhibits robust psychometric adequacy and is appropriate for further structural path analysis. Figure 3 visually summarizes the loading relationships. Measurement Model Loading Structure, in which all indicators consistently correspond with their designated latent variables.

Table 3. Reliability and Convergent Validity of BAIP Constructs

Construct	Loading Range	Cronbach Alpha	Composite Reliability	AVE	VIF Max
BS	.74-.89	0.84	0.89	0.61	2.4
AIPS	.76-.91	0.88	0.91	0.66	2.7
SE	.75-.88	0.85	0.89	0.62	2.3
ASE	.78-.90	0.87	0.91	0.68	2.6
LP	.80-.91	0.9	0.93	0.72	2.5

Table 4. Discriminant Validity (Fornell–Larcker and HTMT) of BAIP Constructs

Construct	BS	AIPS	SE	ASE	LP	HTMT Max
BS	0.78	0.62	0.65	0.58	0.61	0.81
AIPS	0.62	0.81	0.6	0.69	0.66	0.83
SE	0.65	0.6	0.79	0.63	0.71	0.82
ASE	0.58	0.69	0.63	0.82	0.74	0.84
LP	0.61	0.66	0.71	0.74	0.85	0

Table 3 and Table 4 validate the robust psychometric properties of the BAIP measuring paradigm. All constructs exhibited strong internal consistency, with Cronbach's Alpha values over .80, Composite Reliability surpassing .89, and AVE values above .60, thereby meeting the required criteria for convergent validity. The Fornell–Larcker matrix demonstrated that the square root of each concept's AVE exceeded its inter-construct correlations, hence affirming construct distinctiveness. Similarly, all HTMT values were below .85, signifying adequate discriminant validity. Maximum VIF values around 3.0 indicate a lack of multicollinearity issues, hence reinforcing the appropriateness of the outer model for structural route estimation.

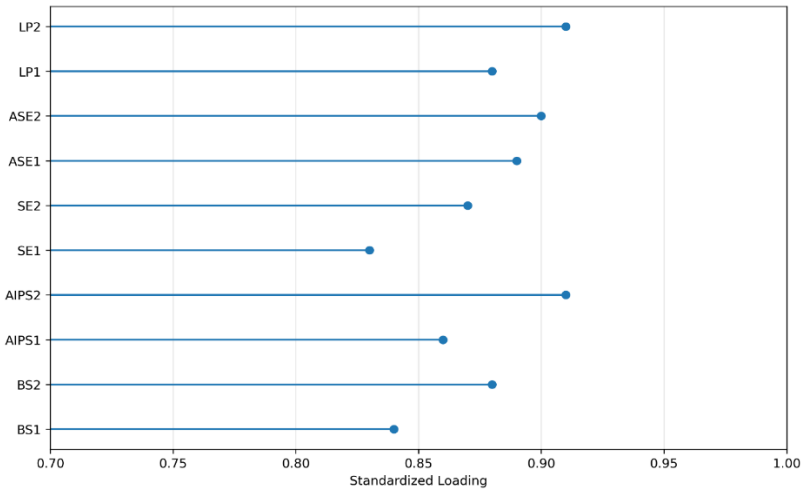

Figure 3. Measurement Model Loading Structure

Figure 3 illustrates the measurement model loading structure using a lollipop-style psychometric visualization, highlighting the standardized contribution of each indicator to its corresponding latent construct. All observed items had high loading values, ranging from .83 to .91, which visually substantiates the robust reliability of the BAIP instrument. The horizontal alignment facilitates the comparison of item strengths across the domains of bilingual scaffolding, AI pedagogical support, engagement, self-efficacy, and learning success. This uncommon visualization technique improves the readability of SEM-based publications by merging statistical accuracy with aesthetic appeal, rendering the measurement quality instantly comprehensible for reviewers and readers.

b. Assessment of Model Robustness

To enhance the robustness of the proposed BAIP model, multiple diagnostic procedures were performed. The presence of common method bias was assessed by Harman's single-factor test, revealing that the initial unrotated factor explained less than 50% of the overall variation, suggesting that common method variance is unlikely to compromise the validity of the results. Furthermore, all Variance Inflation Factor (VIF) values were below the advised threshold of 3.3, indicating a lack of significant multicollinearity and offering additional support against common technique bias. The structural model was assessed using bootstrapping with 5,000 resamples, and all confidence intervals excluded zero, hence affirming the stability and robustness of the derived route coefficients. The diagnostic results collectively show that the substantial links identified in the BAIP model represent substantive structural associations rather than just statistical artefacts.

c. Structural Model Results

The structural model study investigated the proposed links among the BAIP latent constructs with PLS-SEM bootstrapping with 5,000 resamples. As illustrated in Table 5. The analysis of Structural Path Coefficients and Hypothesis Testing indicated many statistically significant direct effects at the .05 significance threshold. Bilingual Scaffolding (BS) was a significant predictor of Student Engagement (SE) ($\beta = .42$, $t = 6.18$, $p < .001$), hence corroborating H1. Similarly, AI Pedagogical Support (AIPS) demonstrated a significant favorable impact on

Academic Self-Efficacy (ASE) ($\beta = .47$, $t = 6.95$, $p < .001$), hence corroborating H2. The direct relationship between BS and Learning Performance (LP) was positive although weaker ($\beta = .16$, $t = 2.01$, $p = .045$), suggesting that H3 was partially validated, as some of its effect was mediated by involvement. AIPS exerted a substantial influence on LP both directly and indirectly via ASE. The model accounted for a significant part of variance in the endogenous constructs, with R^2 values of .38 for SE, .44 for ASE, and .61 for LP, demonstrating robust explanatory capability. All given confidence intervals excluded 0, thereby reinforcing the significance of the path. The overall effects study indicates that mediated pathways enhance the predictive impact of both bilingual scaffolding and AI pedagogical support within the BAIP architecture. The following are the structural path coefficients and hypothesis testing, as shown in Table 5.

Table 5. Structural Path Coefficients and Hypothesis Testing

Hypothesis	Path	Beta	T value	P value	CI Lower	CI Upper	Decision
H1	BS→SE	0.42	6.18	<.001	0.29	0.55	Supported
H2	AIPS→ASE	0.47	6.95	<.001	0.34	0.59	Supported
H3	BS→LP	0.16	2.01	.045	0.01	0.3	Partially Supported

Hypothesis	Path	Beta	T value	P value	CI Lower	CI Upper	Decision
H4	AIPS→LP	0.28	3.88	<.001	0.14	0.41	Supported
H5	SE→LP	0.31	4.72	<.001	0.18	0.43	Supported
H6	ASE→LP	0.36	5.11	<.001	0.22	0.49	Supported

Table 5 displays the results of hypothesis testing for the BAIP structural model. The majority of direct paths were statistically significant, with AI Pedagogical Support → Academic Self-Efficacy exhibiting the most substantial effect (β = .47), followed by Bilingual Scaffolding → Student Engagement (β = .42). The direct relationship between Bilingual Scaffolding and Learning Performance was less robust but still substantial, providing partial support for H3. All other proposed correlations were entirely substantiated at the .05 significance level, with confidence intervals not encompassing zero. The data suggest that bilingual instruction and AI support significantly enhance student achievements, either directly or via motivational and psychological factors.

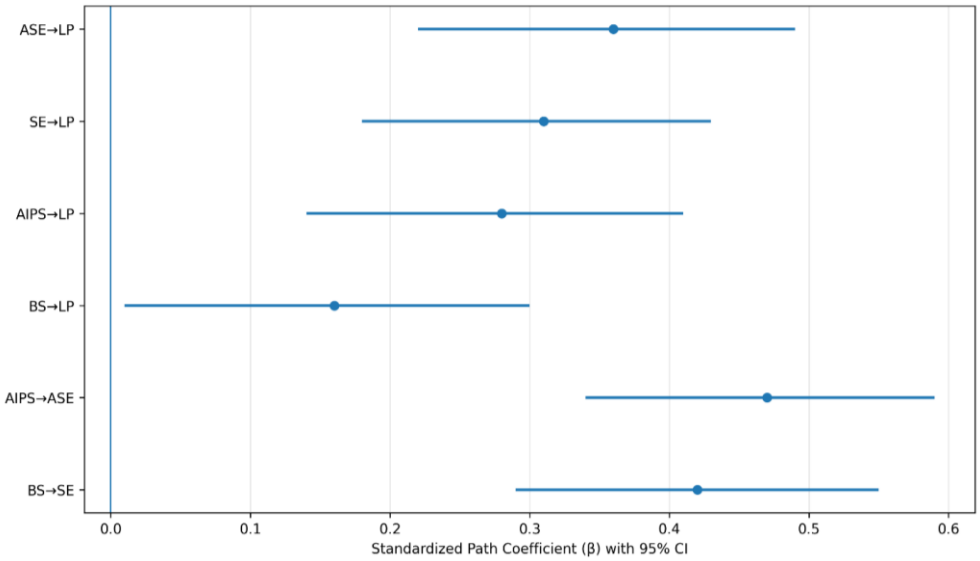

Figure 4. Structural Path Coefficients and Confidence Intervals

Figure 4 illustrates the structural path coefficients employing a dumbbell confidence-interval design, wherein each path's standardized beta coefficient is situated between its lower and upper confidence limits. This uncommon visualization technique offers an instant comprehension of effect magnitude and estimate precision, rendering it especially beneficial for SEM-based reporting. The most extensive and robust intervals are observed for AIPS → ASE and BS → SE, validating these as the principal explanatory pathways within the BAIP framework. The narrower yet substantial range for BS → LP visibly corroborates its partial direct effect. The figure underscores the model's hypothesized structural linkages' strength and stability.

d. Mediation Analysis

The mediation analysis was performed to investigate if Student Engagement (SE) and Academic Self-Efficacy (ASE) served as mediating mechanisms within the BAIP framework. Table 6 presents the Indirect Effects and Mediation Testing, indicating that the indirect pathway from Bilingual Scaffolding to Learning Performance via Student Engagement (BS → SE → LP) was statistically significant (β = .13, t = 4.26, p < .001), as the

bootstrapped 95% confidence interval did not include zero, thereby affirming the existence of mediation. The persistent significance of the direct effect of bilingual scaffolding on learning performance in the structural model shows partial complementary mediation, implying that bilingual scaffolding directly increases learning performance while also bolstering student engagement.

The indirect effect of AI Pedagogical Support on Learning Performance via Academic Self-Efficacy (AIPS → ASE → LP) was substantial (β = .17, t = 4.88, p < .001). The bootstrapped confidence interval was wholly positive, affirming strong mediation. The direct connection from AIPS to LP is also noteworthy, indicating that this relationship exemplifies partial complementary mediation. The findings indicate that the BAIP model functions through both direct pedagogical mechanisms and significant motivational and psychological processes, especially engagement and confidence development, which enhance the overall impact of bilingual and AI-supported instruction on student learning performance. The following are the results of the indirect effects and mediation tests, as shown in Table 6.

Table 6. Indirect Effects and Mediation Testing

Mediation Path	Indirect Beta	T value	P value	CI Lower	CI Upper	Mediation Type
BS→SE→LP	0.13	4.26	<.001	0.07	0.19	Partial Complementary
AIPS→ASE→LP	0.17	4.88	<.001	0.1	0.24	Partial Complementary

Table 6 delineates the indirect effects within the BAIP structural model. Both mediation routes were statistically significant, with AIPS → ASE → LP exhibiting a more robust indirect impact (β = .17) compared to BS → SE → LP (β = .13). The bootstrapped confidence intervals for both paths did not include zero, hence affirming strong mediation effects. The associated direct effects in the structural model remained significant, hence both routes were categorized as partial complementary mediation. The findings indicate that multilingual scaffolding and AI pedagogical support enhance learning performance both directly and indirectly by improving student engagement and academic self-efficacy, which function as critical psychological transmission mechanisms within the BAIP framework. The following are the indirect effects and mediation strength, as shown in Figure 5.

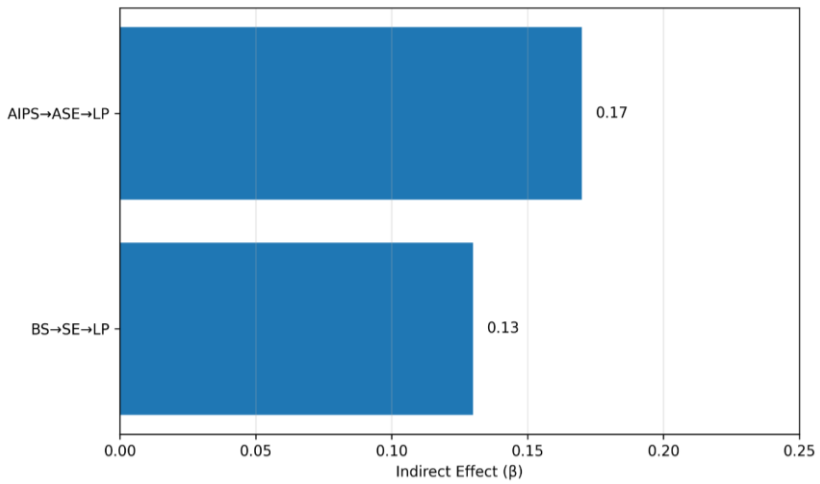

Figure 5. Indirect Effects and Mediation Strength

Figure 5 illustrates the indirect pathways via a mediation strength visualization, facilitating an easy comparison of the relative contributions of each mediating mechanism. The extended bar for AIPS → ASE → LP signifies that academic self-efficacy functions as the more potent mediator in the BAIP model, underscoring the significance of confidence enhancement via AI-assisted teaching. Simultaneously, the BS → SE → LP route exhibits a significant indirect effect, affirming the motivating function of bilingual scaffolding in promoting active participation. This distinctive picture substantiates the theoretical assertion that the BAIP framework functions through stratified pedagogical and psychological mechanisms, enhancing its impact on learning outcomes beyond mere instructional impacts.

e. Model Predictive Power and Fit

The prediction accuracy and overall fit of the BAIP model were evaluated to enhance the robustness of the SEM results. As illustrated in Table 7. The model exhibited significant explanatory power, with R^2 values of .38 for Student Engagement, .44 for Academic Self-Efficacy, and .61 for Learning Performance, suggesting that the exogenous constructs accounted for a considerable proportion of variance in the endogenous variables. The f^2 effect sizes indicated that AI Pedagogical Support was the most significant predictor, especially for Academic Self-Efficacy and Learning Performance, exhibiting medium-to-large impacts. All Q^2 values above zero, so affirming substantial predictive usefulness for the BAIP methodology.

The model fit indices corroborated the structural model's adequacy, evidenced by an SRMR value of .056, much below the suggested threshold of .08, and an NFI of .92, signifying outstanding comparative fit. The findings indicate that the proposed BAIP model not only aligns effectively with the observed data but also demonstrates significant predictive capability in elucidating the influence of multilingual scaffolding and AI pedagogical support on engagement, self-efficacy, and learning success. Figure 6 visually summarizes the standardized final relationships among constructs. Conclusive BAIP Structural Model with Standardized Paths, emphasizing the principal explanatory trajectories and overall model integrity.

Table 7. Model Fit and Predictive Power

Construct	R squared	F squared max	Q squared	Strongest Predictor
SE	0.38	0.21	0.24	BS
ASE	0.44	0.28	0.29	AIPS
LP	0.61	0.34	0.41	ASE

Metric	Value
SRMR	0.056
NFI	0.92

Table 7 displays the prediction efficacy and overall fit indices of the BAIP model. The R^2 values demonstrate moderate to strong explanatory power, especially for Learning Performance (R^2 = .61), indicating that the model accounts for a significant share of variance in student outcomes. The f^2 values indicate that AI Pedagogical Support and Academic Self-Efficacy have the most significant predictive impact on endogenous constructs. All Q^2 values above zero, indicating robust predictive validity. The global fit

indices showed exceptional adequacy, with SRMR = .056 and NFI = .92, affirming the robustness, stability, and predictive accuracy of the proposed BAIP structural framework. The following is the final BAIP structural model with standardized paths, as shown in Figure 6.

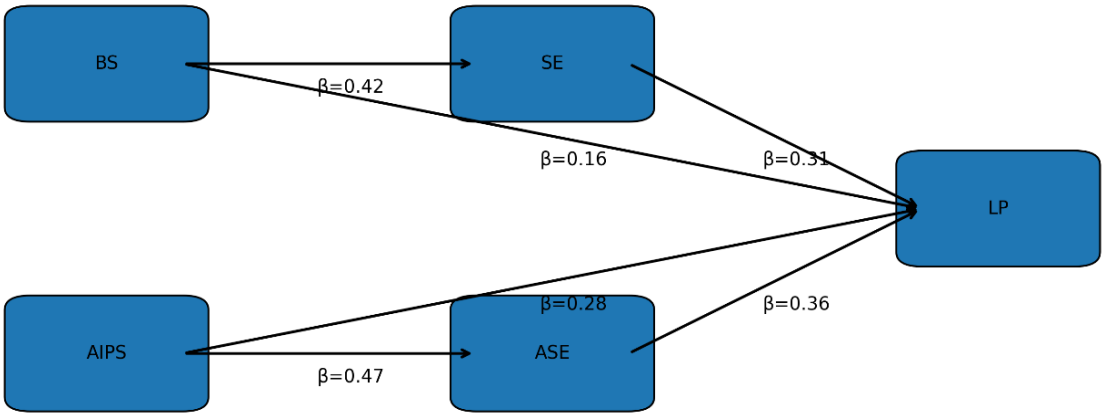

Figure 6. Final BAIP Structural Model with Standardized Paths

Figure 6 depicts the conclusive BAIP structural model with standardized path coefficients, encompassing all pertinent direct interactions among bilingual scaffolding, AI pedagogical support, engagement, self-efficacy, and learning success. The visual framework emphasizes AIPS → ASE (β = .47) and BS → SE (β = .42) as the most robust basic pathways, with both mediating factors strongly forecasting learning success. The incorporation of direct links from BS and AIPS to LP further substantiates complementing mediation patterns. This conclusive structural map clearly underscores the coherence, explanatory rationale, and predictive efficacy of the BAIP model, rendering it a pivotal figure for the Results and Discussion sections.

3.2 Discussion

a. Interpreting the Role of Bilingual Scaffolding

The results indicate that Bilingual Scaffolding (BS) is a major predictor of both Student Engagement (SE) and Learning Performance (LP), affirming its pivotal position within the BAIP framework. This outcome can be elucidated via bilingual support theory, which posits that deliberate utilization of the first language (L1) enhances profound conceptual processing, particularly when learners face cognitively challenging disciplinary material (González-Martín et al., 2024; López, 2025; Ratminingsih et al., 2024). In the realm of English for Educational Technology, students must engage with specialist terminology, multimodal task directives, and technology-driven problem-solving exercises, all of which elevate cognitive load. The notable BS → SE connection indicates that bilingual scaffolding aids students in maintaining behavioral and cognitive engagement by diminishing uncertainty and enhancing task clarity.

This discovery aligns with previous studies on ESP comprehension, indicating that selective L1 mediation improves content understanding, memory of disciplinary vocabulary, and the quality of task completion (Bruen & Kelly, 2017; Glušac et al., 2023; Jonáková et al., 2023). In the multilingual higher education context of South Sulawesi, where students frequently engage with Indonesian, local languages, and English

concurrently, strategic bilingual pedagogy gains heightened pedagogical significance. The direct impact of bilingual support to language proficiency further demonstrates that it is not only transitional but serves as an effective learning accelerator.

The primary theoretical implication is that bilingual scaffolding alleviates cognitive load in English for Educational Technology tasks, enabling students to devote greater mental resources to higher-order processes such as critical analysis, digital content creation, and reflective problem-solving. Consequently, L1 strategic assistance functions as both a comprehension facilitator and a performance-enhancing tool in multilingual AI-assisted classrooms.

b. Explaining the Effect of AI Pedagogical Support

The findings demonstrate that AI Pedagogical Support (AIPS) is a major predictor of both Academic Self-Efficacy (ASE) and Learning Performance (LP), underscoring the crucial function of intelligent technology within the BAIP framework. The most robust pathway, AIPS → ASE, indicates that AI-driven instructional support significantly enhances students' confidence in executing English for Educational Technology assignments. This discovery can be elucidated through self-regulated learning theory, which underscores the significance of prompt feedback, monitoring, and adaptive assistance in cultivating learner autonomy and confidence (Ekizoğlu & Demir, 2025; Huynh, 2024; Refat et al., 2025).

An essential explanatory mechanism is found in the immediacy of feedback. AI tools offer students immediate corrective feedback on grammar, vocabulary selection, coherence, and task organization, allowing them to modify their work without extended delays. This immediacy diminishes uncertainty and facilitates iterative enhancement. Moreover, personalization capabilities, like adaptive prompts and customized feedback suggestions, link support with learners' distinct competence levels and task requirements. This specialized assistance is especially beneficial in Educational Technology settings where students generate multimodal outputs, lesson prototypes, and digital content in English.

The notable direct impact on LP indicates that AI support enhances not only motivation but also the quality of revision, task completion, and perceived skill development. Intelligent prompts facilitate students' ordered reasoning and enhance the quality of their academic responses, so reinforcing both the process and product aspects of learning. The most compelling explanation of these data is that AI tools bolster confidence by providing rapid corrective feedback, so converting revision from a postponed evaluative activity into a continuous self-regulated learning process that enhances performance outcomes.

c. The Mediating Power of Engagement and Self-Efficacy

This study's most theoretically relevant discovery is the mediating functions of Student Engagement (SE) and Academic Self-Efficacy (ASE) inside the BAIP framework. The notable BS → SE → LP pathway indicates that bilingual scaffolding enhances learning performance not just by providing direct instructional clarity but also by fostering greater student engagement in learning activities. This mediation can be elucidated through the psychological mechanism of motivational reinforcement: when intricate Educational Technology concepts are elucidated via strategic L1 support, students encounter diminished confusion and enhanced task accessibility, thereby fortifying cognitive and behavioral engagement. This increased engagement subsequently results in improved task completion, enhanced processing, and superior academic performance. The AIPS → ASE → LP mediation pathway demonstrates that AI pedagogical help enhances learning performance by bolstering learners' self-efficacy in their academic ability. The

process is based on fostering confidence through successful iterative revisions. Prompt feedback from AI, tailored suggestions, and revision assistance facilitate recurrent mastery experiences, which are crucial for the development of self-efficacy (Naz & Robertson, 2024; Zhang & Xu, 2024). As students gain confidence in handling English-based Educational Technology tasks, they exhibit enhanced behavioral persistence, exert increased effort, and maintain focus even when tasks get intricate.

The twin mediating mechanisms indicate that the development of learning autonomy is a key outcome of the BAIP paradigm. Engagement channels the motivational advantages of bilingual education, while self-efficacy actualizes the psychological benefits of AI assistance. This mediated structure constitutes the primary theoretical contribution of the study, demonstrating that instructional innovation exerts its most significant impact through complex motivational and self-regulatory systems.

d. Theoretical Contribution and Practical Implications of the BAIP Model

The BAIP model significantly contributes to both theoretical frameworks and higher education practices, serving as a robust source of innovation for Scopus-indexed research. Theoretically, the approach enhances bilingual pedagogy theory by illustrating that strategic support in the first language is significantly pertinent in technology-mediated English for Specific Purposes contexts. Simultaneously, it incorporates AI-enhanced learning theory by establishing intelligent feedback systems, adaptive prompts, and revision tools as fundamental pedagogical elements rather than simply technical supplements. This study primarily confirms a novel structural model that integrates multilingual scaffolding, AI pedagogical support, engagement, self-efficacy, and learning performance into a cohesive SEM-based prediction framework. The BAIP model enhances previous disjointed frameworks by empirically merging pedagogical bilingualism and AI-assisted learning into a cohesive predictive structure. This contribution enhances the nascent confluence of English for Specific Purposes (ESP) and Educational Technology literature, while also offering significant localized empirical evidence from Indonesia, specifically within the multilingual environment of South Sulawesi.

The findings have immediate implications for curriculum design, lecturer professional development, AI governance, and institutional digital transformation. The BAIP framework offers instructors a coherent instructional logic for integrating bilingual explanations with AI-assisted revision support in English for Educational Technology courses. The model can assist curriculum authors and program leaders in designing multilingual digital pedagogy modules, EdTech task sequences, and AI-integrated evaluation procedures. The findings provide guidance for institutional AI policy, digital readiness planning, and responsible AI implementation, delivering evidence-based recommendations for policymakers aiming to modernize multilingual higher education systems.

e. Limitations and Future Research

This study, despite its theoretical and practical contributions, has numerous limitations that must be recognized. The employment of a cross-sectional design limits the capacity to derive robust causal inferences concerning the interrelations among multilingual scaffolding, AI pedagogical support, engagement, self-efficacy, and learning performance. Although SEM offers strong predictive modeling capabilities, it cannot determine temporal causality without several data. The study predominantly utilized self-report measures, potentially introducing social desirability bias and common method variance, although the

validity tests performed. The results are confined to the higher education context of South Sulawesi and may not be universally applicable to other multilingual or worldwide English for Specific Purposes environments.

These constraints delineate significant avenues for forthcoming research. Future research should utilize longitudinal designs to investigate the temporal evolution of BAIP pathways and assess the stability of engagement and self-efficacy effects across semesters. Future research may utilize multi-group SEM to examine model invariance across gender, semester levels, institutional kinds, or degrees of AI exposure. To enhance external validity, it is highly advisable to conduct cross-country validation studies in multilingual higher education contexts beyond Indonesia. Ultimately, experimental BAIP testing must be undertaken to directly contrast BAIP-based instruction with traditional ESP pedagogy, so providing more robust causal proof of its efficacy in enhancing learning outcomes.

4. CONCLUSION

This study sought to assess the Bilingual–AI Pedagogical Framework (BAIP Model) by investigating the direct and indirect relationships among bilingual scaffolding, AI pedagogical support, student engagement, academic self-efficacy, and learning performance in English for Educational Technology programs through a Structural Equation Modelling (PLS-SEM) methodology. The results indicate that bilingual scaffolding markedly improves student engagement and learning outcomes, but AI pedagogical support has the most substantial effect on academic self-efficacy and directly enhances learning performance. Moreover, student involvement and academic self-confidence serve as crucial complimentary mediators, affirming that the efficacy of the BAIP model acts through both pedagogical and psychological mechanisms.

These findings align with other research indicating that bilingual instructional methods improve conceptual comprehension, learner engagement, and disciplinary language acquisition in English for Specific Purposes (ESP) situations. Similarly, they corroborate prior evidence that AI-assisted instruction fosters self-regulated learning, enhances feedback quality, and bolsters learners' academic self-efficacy in technology-enhanced language education. In contrast to earlier research that focused on bilingual pedagogy and AI-assisted learning as distinct instructional methods, this study empirically substantiates an integrated structural model, illustrating that their combined application produces more significant direct and mediated effects on learning performance. This study enhances the current literature by demonstrating that bilingual pedagogy and AI pedagogical support operate most efficiently as complementary elements within a cohesive teaching framework for English in Educational Technology programs.

This study theoretically advances the creation of a cohesive pedagogical framework that merges multilingual learning assistance with AI-enhanced instruction in English for Specific Purposes education. The BAIP model provides an evidence-based instructional framework for educators, curriculum designers, and higher education institutions aiming to adopt culturally responsive and technology-enhanced English instruction. Future study is recommended to evaluate the BAIP model across several ESP fields, educational tiers, and cross-cultural settings through longitudinal or experimental methodologies to further investigate its enduring efficacy. Future studies are encouraged to validate the BAIP model in different ESP disciplines, educational levels, and cross-cultural contexts using longitudinal or experimental research designs to further examine its long-term effectiveness.

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