



AI-Integrated Learning in Society 5.0: Advancing Critical Thinking in English Language Education

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ABSTRACT

The rapid integration of artificial intelligence (AI) in education has transformed learning environments in the era of Society 5.0, particularly in English language education, where critical thinking skills are increasingly required to support learners' academic and digital competencies. This study investigated the relationship between AI-integrated English for Academic Purposes-Based Learning (EAPBL) and students' critical thinking performance among English Language Learners (ELLs). The study employed a mixed-method explanatory sequential design involving 64 undergraduate students enrolled in English-related courses at Universitas Muhammadiyah Tangerang, Indonesia. Data were collected through questionnaires, performance-based assessments, AI-supported learning tasks, students' reflective responses, and semi-structured interviews. The questionnaire measured AI engagement, AI literacy, cognitive engagement, and perceived critical thinking skills using a five-point Likert scale, while rubric-based assessments evaluated students' written academic outputs. Quantitative data were analyzed using descriptive statistics, paired sample t-tests, multiple regression analysis, and Partial Least Squares Structural Equation Modeling (PLS-SEM). In contrast, qualitative data were analyzed through thematic analysis to support the interpretation of the quantitative findings. The findings revealed a moderate but statistically significant improvement in students' critical thinking performance, with an overall post-test score of 46%. Among the five dimensions of critical thinking, interpretation demonstrated the highest performance, followed by argumentation, while analysis, evaluation, and synthesis remained relatively underdeveloped. The PLS-SEM analysis indicated that AI engagement significantly influenced cognitive engagement, which in turn contributed to students' critical-thinking performance. In addition, AI literacy strengthened the relationship between cognitive engagement and critical thinking outcomes. Qualitative findings further revealed that AI-supported learning helped students organize ideas, generate initial responses, and improve learning efficiency; however, several participants demonstrated dependence on AI-generated responses, limited critical evaluation of AI outputs, and difficulty synthesizing multiple perspectives. These findings suggest that AI-supported learning can foster critical thinking when accompanied by active cognitive engagement and adequate AI literacy. The study highlights the importance of integrating digital, cognitive, and ethical AI literacy into English language education in the context of Society 5.0.

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■ INTRODUCTION

The rapid evolution of digital technologies, particularly artificial intelligence (AI), has fundamentally transformed the educational landscape in the era of Society 5.0, a human-centered paradigm that integrates advanced technologies to address complex societal challenges. This paradigm emphasizes

the synergy between technological innovation and human values, where AI is utilized to enhance human capabilities rather than replace them (Alaqad et al., 2026; Batubara, 2025; Hs et al., 2025; Kumar, 2025; Soelistiono & Wahidin, 2023). In this context, education is positioned as a central mechanism for preparing individuals to navigate and contribute

to increasingly complex, technology-driven environments. Consequently, educational systems are required to move beyond traditional practices and embrace innovative, adaptive, and students-centered approaches.

The emergence of Society 5.0 has significantly influenced the direction of educational transformation worldwide, including in higher education institutions. Universities are increasingly expected to integrate digital technologies into teaching and learning processes to prepare students for academic, professional, and social challenges in the digital era. In language education, this transformation has accelerated with the rapid development of AI-powered technologies, including generative AI systems, intelligent tutoring platforms, automated writing evaluation tools, and conversational chatbots. These technologies have become increasingly accessible to students and educators, enabling more interactive, personalized, and flexible learning activities. AI-supported learning environments allow learners to receive immediate feedback, access authentic materials, improve language accuracy, and engage in self-directed learning beyond classroom boundaries (Aryusmar, 2025; Dix & Naar, 2025; Ghosh & Kumar, 2026; Zakaria et al., 2025).

In English as a Foreign Language (EFL) contexts, the integration of AI has become particularly relevant because language learning requires continuous interaction, feedback, and communication practice. AI tools such as ChatGPT, Grammarly, QuillBot, and AI-based learning management systems are increasingly used in English classrooms to support writing, speaking, reading, and vocabulary development. For example, generative AI tools assist students in generating essay outlines, revising sentence structures, paraphrasing academic texts, and organizing arguments in academic writing tasks. AI-supported chatbots also provide opportunities for learners to practice conversational English and receive immediate linguistic feedback without the limitations of classroom time. Furthermore, AI technologies can facilitate personalized learning by adapting instructional materials to students' language proficiency levels and learning needs. These developments demonstrate that AI has become an influential component of contemporary English language education.

Despite these advantages, the integration of AI into language education also presents significant pedagogical and cognitive challenges. One of the major concerns is students' increasing reliance on AI-generated

responses without critically evaluating the information they produce. In many academic writing tasks, students tend to adopt AI-generated content directly without independently analyzing arguments, verifying evidence, or critically reconstructing ideas. This phenomenon may encourage surface-level learning and reduce opportunities for students to engage in deeper cognitive processes. As a result, although AI can support linguistic performance and task completion, it does not automatically guarantee the development of higher-order thinking skills (Kasneci et al., 2023; Dwivedi et al., 2023). The effectiveness of AI-supported learning, therefore, depends heavily on how AI is pedagogically integrated into instructional practices.

Among the competencies emphasized in the Society 5.0 era, critical thinking and problem-solving have become essential skills for navigating information-rich and digitally mediated environments. Critical thinking enables learners to interpret, analyze, evaluate, and synthesize information while constructing logical, evidence-based arguments (Paul & Elder, 2020; Rivas et al., 2023). These competencies are increasingly important in EFL contexts because language learning extends beyond grammatical knowledge and vocabulary acquisition. Students are also expected to communicate ideas critically, respond to academic issues analytically, and engage in meaningful reasoning processes through language use. In academic writing and discussion activities, learners must evaluate sources, organize arguments, justify opinions, and synthesize information from multiple perspectives. Therefore, critical thinking functions as an essential cognitive foundation for effective language learning and academic communication.

Furthermore, the widespread use of AI-generated information has increased the importance of digital and ethical AI literacy among students. Learners must possess the ability to critically evaluate the credibility, accuracy, bias, and limitations of AI-generated content (He et al., 2024; Hong & Guo, 2024; Jurayeva, 2025; Lee et al., 2025; Mohadih et al., 2025; Ruzieva, 2025; Saidi & Tobi, 2025; Samaty, 2025; Thongsan & Anderson, 2025). Without sufficient AI literacy, students may become passive users of technology, relying excessively on automated responses rather than engaging in independent reasoning. This issue is particularly relevant in higher education contexts, where academic integrity, originality, and critical evaluation are central components of scholarly learning. Consequently, educators are increasingly challenged to design

instructional approaches that integrate AI responsibly while simultaneously promoting students' cognitive engagement and critical awareness.

Previous studies have shown that AI-supported learning environments may enhance cognitive and metacognitive engagement through interactive feedback, adaptive learning systems, and opportunities for reflection (Rosmayanti, 2026; Zakaria et al., 2025). AI technologies can help learners organize ideas, identify errors, and improve their understanding of complex materials. However, other studies also indicate that excessive reliance on AI may weaken learners' independent thinking, creativity, and analytical reasoning if technology use is not accompanied by structured instructional guidance (Hs et al., 2025; Kotamjani et al., 2026). These contradictory findings suggest that the role of AI in fostering critical thinking remains complex and warrants further investigation, particularly in language learning contexts where communication and reasoning are closely interconnected.

To address these challenges, there is a growing need for an integrative pedagogical framework that combines language learning, the development of critical thinking, and AI-supported learning. English for Academic Purposes-Based Learning (EAPBL) offers such a framework because it emphasizes authentic academic tasks requiring learners to analyze, evaluate, and synthesize information while using language as a tool for reasoning and communication (Hyland, 2009). Through EAPBL, students are encouraged to engage with academic texts, construct arguments, evaluate evidence, and produce coherent academic outputs. When integrated with AI-supported learning, EAPBL has the potential to create dynamic and adaptive learning environments that support both linguistic and cognitive development. AI technologies can serve as learning support tools that facilitate idea generation, language assistance, and access to information while students remain actively involved in academic inquiry and reasoning.

Although studies on AI in language education continue to grow, empirical evidence on the relationship between AI-integrated EAPBL and the development of students' critical-thinking dimensions remains limited, particularly in Indonesian higher education contexts. Existing studies predominantly focus on language achievement, students' perceptions of AI use, or general digital learning experiences, while fewer studies specifically examine how AI-supported learning relates to

the skills of interpretation, analysis, evaluation, argumentation, and synthesis. In addition, limited attention has been paid to the challenges and pedagogical implications arising from students' interactions with AI-supported learning environments. Therefore, further investigation is necessary to understand how AI integration affects students' critical-thinking performance and digital literacy in English language education.

Based on these considerations, this study investigates the relationship between AI-integrated English for Academic Purposes-Based Learning (EAPBL) and English Language Learners' critical thinking skills in the context of Society 5.0. Specifically, this study addresses the following research questions:

1. To what extent does AI-integrated English for Academic Purposes-Based Learning (EAPBL) enhance English Language Learners' critical thinking skills in the context of Society 5.0?
2. How do the key dimensions of critical thinking (interpretation, analysis, evaluation, argumentation, and synthesis) develop through AI-supported learning activities?
3. What challenges and pedagogical implications emerge from the use of AI in fostering critical thinking and digital literacy among English Language Learners?

■ **METHOD**

Research Design

This study employed a mixed-method research design using an explanatory sequential approach to examine the effectiveness of AI-integrated English for Academic Purposes-Based Learning (EAPBL) in enhancing English Language Learners' critical thinking skills within the context of Society 5.0. Mixed-method research enables the integration of quantitative and qualitative data to provide a more comprehensive understanding of complex educational phenomena (Grace et al., 2023; Mondal & Alam, 2025; Oranga, 2025). In this study, the quantitative phase was conducted first to measure students' critical-thinking performance using questionnaires, rubric-based assessments, and statistical analysis. The quantitative findings were then followed by a qualitative phase involving students' reflective responses and interviews to explain why particular statistical patterns emerged, especially regarding students' strengths and difficulties across the dimensions of critical thinking. This explanatory sequential design allowed the researchers to connect numerical findings with learners' experiences,

perceptions, and cognitive challenges during AI-supported learning activities. Such a design is particularly appropriate for studies that seek not only to identify statistical relationships but also to interpret the underlying reasons behind the findings through qualitative insights (Hafsa, 2019).

Participants and Sampling Technique

The participants in this study comprised 64 undergraduate students enrolled in English-related courses at Universitas Muhammadiyah Tangerang, Indonesia. The participants were selected using purposive sampling, which allows researchers to select individuals who are most relevant to the research objectives (Oranga, 2025). The selection criteria included enrolment in English for Academic Purposes courses, active participation in AI-supported learning activities, and familiarity with digital learning tools. In this study, “familiarity with digital tools” was operationally defined as students who had used digital learning applications or AI-assisted platforms, such as ChatGPT, Grammarly, Google Classroom, or similar educational technologies, for at least six months prior to the study. This criterion was confirmed through a preliminary survey administered before data collection, which examined students’ frequency of technology use, the duration of their AI-assisted learning experiences, and their level of confidence in using digital learning platforms. These criteria ensured that participants had sufficient exposure to AI-integrated learning environments and were capable of engaging in academic tasks that require higher-order thinking skills. The sample size was considered adequate for both descriptive and inferential statistical analysis in educational research contexts (Cohen et al., 2007; Elen & Bishop, 2020; Pócza & Dobos, 2018).

Instruments

Data were collected using three main instruments: a questionnaire, a performance assessment rubric, and AI-supported learning tasks. The questionnaire was designed to measure students’ perceived critical thinking skills, AI engagement, and AI literacy using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), a widely used instrument for measuring attitudes and perceptions in educational research (Hussein, 2009; Kreuder et al., 2024). The instrument was adapted from established critical thinking frameworks (Glaser & Watson, 2002; Glaser, Goodwin; Watson, 2015; Hassan & Madhum, 2007; Possin, 2014) and extended to include dimensions of AI engagement and digital

literacy (Ng, 2021).

In addition to AI engagement and AI literacy, this study also measured students’ cognitive engagement as a mediating variable in the SEM analysis. Cognitive engagement refers to students’ level of mental effort, reflective thinking, and active participation during AI-supported learning activities. The cognitive engagement instrument was adapted from student engagement frameworks in digital learning contexts. It consisted of indicators such as sustained attention during learning tasks, reflective evaluation of AI-generated information, independent reasoning, and active participation in problem-solving activities. The instrument used a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Reliability analysis indicated acceptable internal consistency for the cognitive engagement variable ($\alpha = .83$).

To facilitate the interpretation and presentation of findings, Likert-scale scores were converted to percentages using the formula: Percentage Score = (Obtained Score / Maximum Score) \times 100. The percentage ranges were categorized as follows: 80–100 = Very High, 60–79 = High, 40–59 = Moderate, 20–39 = Low, and 0–19 = Very Low.

In addition, a performance-based rubric was used to assess students’ actual critical thinking abilities through their written outputs, as a rubric-based assessment provides a reliable method for evaluating complex cognitive skills (Giannikas et al., 2022; Joseph et al., 2024; Normuratova, 2024; Sá et al., 2021; Son, 2024; Spires et al., 2018). The rubric evaluated five dimensions of critical thinking, namely interpretation, analysis, evaluation, argumentation, and synthesis. Students also completed AI-supported EAPBL tasks, including text analysis, argument construction, and synthesis writing, which served as authentic measures of their critical thinking processes (Hyland, 2008).

One example of an AI-supported task involved students interacting with ChatGPT to critically analyze academic issues in digital education. The prompt provided to students was: “Using AI assistance, analyze the positive and negative impacts of artificial intelligence on English language learning in higher education. Evaluate the credibility of the arguments generated and develop your own conclusion based on at least two academic perspectives.” Students were required not only to generate responses using AI tools but also to critically evaluate, revise, and synthesize the generated information into their own academic writing. This task was designed to encourage active cognitive engagement rather than passive

acceptance of AI-generated content.

Data Collection Procedure

The data collection procedure was conducted in three stages. The first stage involved the development and validation of research instruments, including expert review to ensure content validity, which is essential for accurate measurement of intended constructs (Elen & Bishop, 2020; Prot & Anderson, 2013). During this stage, students were also introduced to ethical and effective use of AI tools, aligning with current recommendations on AI literacy in education (Iskandar et al., 2025; Joseph et al., 2024; Walter, 2024). This orientation session was conducted prior to the intervention to ensure that students understood the principles of responsible AI use, academic integrity, and critical evaluation of AI-generated content. The second stage involved implementing AI-integrated EAPBL activities over eight weeks of classroom instruction. The intervention consisted of one meeting per week, with each instructional session lasting approximately 120 minutes. During these sessions, students engaged in structured AI-supported academic tasks, including text analysis, argumentative writing, evaluation of AI-generated responses, and synthesis-based academic writing activities. AI technologies such as ChatGPT and digital writing assistance tools were integrated into classroom activities to support idea generation, language development, and critical discussion. Throughout the intervention, students were encouraged to critically evaluate AI-generated outputs rather than passively accept the information provided. The final stage involved the collection of quantitative and qualitative data, including questionnaire administration, rubric-based assessment of students' written outputs, and students' reflective responses regarding their experiences using AI-supported learning environments. These reflective responses were used to provide qualitative explanations for the quantitative findings, particularly concerning students' cognitive engagement, perceived benefits of AI use, and challenges encountered during the learning process.

Data Analysis

Data analysis was conducted using both quantitative and qualitative techniques. Quantitative data obtained from the questionnaire and rubric-based assessments were analyzed using descriptive statistics, including mean, percentage, and standard deviation, as well as inferential statistics such as paired sample t-tests, multiple regression

analysis, and Partial Least Squares Structural Equation Modeling (PLS-SEM) to examine the relationships among AI-supported learning, cognitive engagement, AI literacy, and students' critical thinking performance (Jurayeva, 2025; Ruzieva, 2025). PLS-SEM was selected because it is considered more suitable for studies with relatively small sample sizes and predictive structural models. The analysis also examined the mediating role of cognitive engagement and the moderating effect of AI literacy on students' critical thinking outcomes.

Instrument reliability was assessed using Cronbach's alpha to ensure internal consistency. The results showed acceptable reliability values for all variables, including critical thinking skills ($\alpha = .87$), AI engagement ($\alpha = .84$), and AI literacy ($\alpha = .81$), indicating that the instruments were sufficiently reliable for data collection and analysis (Elen & Bishop, 2020; Prot & Anderson, 2013).

Qualitative data obtained from students' reflective responses and semi-structured interviews were analyzed using thematic analysis, which involves identifying, analyzing, and interpreting patterns within qualitative data (Guest et al., 2020). The qualitative phase was conducted after the quantitative analysis to explain the statistical findings, particularly students' strengths and difficulties across the dimensions of critical thinking. Several themes emerged from the analysis, including "AI-assisted idea organization," "dependence on AI-generated responses," and "difficulty in synthesizing multiple perspectives." To strengthen the integration of mixed-method findings, selected interview excerpts and reflective statements were incorporated into the Results and Discussion section to illustrate students' experiences and explain why particular quantitative patterns emerged. In addition, a thematic network graph was developed to visually map the interconnected patterns of students' reliance on AI during learning activities and its influence on cognitive engagement and critical thinking performance.

To ensure rigor and consistency in rubric-based assessment, the study employed inter-rater reliability procedures with two independent evaluators who assessed students' written outputs using the same critical-thinking rubric. Inter-rater agreement was calculated using Cohen's Kappa coefficient, which produced a value of .82, indicating strong agreement between raters and demonstrating that the scoring process was sufficiently consistent and reliable (Cohen et al., 2007). In addition, triangulation was applied by

integrating questionnaire results, performance assessments, and qualitative reflections to enhance the credibility and validity of the findings.

- Ethical Considerations

Ethical considerations were addressed by obtaining informed consent from all participants prior to data collection. Participation was voluntary, and students were informed that their responses would be kept confidential and used solely for research purposes. The study also emphasized academic integrity and ethical AI use throughout the research process.

■ RESULT AND DISCUSSION

The results of this study provide important insights into the role of AI-integrated EAPBL in fostering critical thinking skills within the context of Society 5.0. The overall moderate score 46% suggests that AI-supported learning environments have the potential to enhance students' cognitive development, but their effectiveness depends heavily on pedagogical design. AI appears to function effectively as a cognitive scaffold, particularly in supporting comprehension and initial reasoning processes, which explains the relatively higher performance in interpretation.

However, the lower scores in evaluation, analysis, and synthesis indicate that AI alone is insufficient to develop higher-order thinking skills. These findings support the argument that without structured guidance, learners may engage in surface-level interaction with AI-generated content rather than deep critical engagement (Shakib Kotamjani et al., 2026). This highlights the importance of integrating AI within a pedagogical framework, such as EAPBL, that emphasizes active learning, reflection, and critical inquiry.

The low performance in synthesis is particularly significant, as it reflects students' difficulty in integrating multiple perspectives into coherent academic outputs. This suggests that learners may rely heavily on AI-generated responses without fully processing or reconstructing the information. From the perspective of cognitive engagement theory,

Table 1. Descriptive statistics of students' critical thinking performance based on rubric assessment

Dimension	Mean (%)	Category
Interpretation	63%	High
Analysis	45%	Moderate
Evaluation	40%	Moderate
Argumentation	53%	Moderate
Synthesis	29%	Low
Overall Score	46%	Moderate

this indicates insufficient deep processing, which is essential for higher-order thinking (Iskandar et al., 2025; Jurayeva, 2025; Kholdaralievna, 2025a, 2025b; Lawasi et al., 2024; Mitrulescu, 2025; Rosmayanti, 2026; Ruzieva, 2025; Samaty, 2025; Zablotska et al., 2026; Zakaria et al., 2025). Therefore, instructional strategies should explicitly target synthesis skills by requiring students to compare, evaluate, and combine information from multiple sources.

Furthermore, the challenges observed in evaluation and assumption analysis highlight the need for developing digital and ethical AI literacy. Students must be trained to critically assess the credibility, bias, and limitations of AI-generated content (Iskandar et al., 2025; Joseph et al., 2024; Subrahmanyam, 2025; Sunarti, 2025; Walter, 2024). Without such competencies, learners may become passive users of AI rather than critical thinkers. This reinforces the importance of incorporating AI literacy into language education as a core component of learning in Society 5.0.

From a pedagogical perspective, the findings suggest that AI-integrated EAPBL should be designed to promote human-AI collaboration, where AI serves as a tool for inquiry rather than a source of answers. Tasks should require students to question AI outputs, justify their reasoning, and produce original responses. By doing so, educators can ensure that AI enhances rather than diminishes students' cognitive engagement. Ultimately, this study demonstrates that while AI has

Table 2. Summary of Critical Thinking Performance

Score Range	Category	Interpretation
80–100	Very High	Advanced critical thinking
60–79	High	Good critical thinking
40–59	Moderate	Developing critical thinking
20–39	Low	Limited critical thinking
0–19	Very Low	Minimal critical thinking

significant potential to support critical thinking, its effectiveness depends on how it is pedagogically framed and implemented.

Table 2 presents the classification of students' critical thinking performance based on predefined score ranges. The overall score of 46% falls within the "moderate" category, indicating that students have begun to develop critical thinking skills but have not yet achieved a high level of proficiency. This suggests that learners are capable of engaging in basic higher-order thinking processes; however, their ability to consistently apply these skills in complex academic contexts remains limited. The moderate classification reflects a transitional stage of cognitive development, where students require further instructional support to advance toward more sophisticated levels of critical thinking. This finding aligns with the notion that the development of higher-order thinking skills is gradual and requires sustained practice, structured guidance, and meaningful learning experiences, particularly in AI-supported environments.

Table 3. Dimension ranking

Rank	Dimension	Score (%)
1	Interpretation	63%
2	Argumentation	53%
3	Analysis	45%
4	Evaluation	40%
5	Synthesis	29%

Table 3 ranks the five dimensions of critical thinking based on students' performance scores, revealing notable variation across dimensions. Interpretation ranked highest with a score of 63%, indicating that students were relatively proficient in understanding and explaining information. This suggests that AI-supported learning effectively facilitated comprehension and initial meaning-making processes. Qualitative reflections further revealed that students perceived AI tools as helpful for clarifying difficult concepts and organizing ideas during academic tasks.

Argumentation followed with a score of 53%, demonstrating that students were able to construct basic arguments, although these often

lacked deeper justification and critical elaboration. Analysis (45%) and evaluation (40%) remained within the moderate category, reflecting students' difficulties in examining relationships between ideas and critically assessing the credibility of information. Several students admitted that they tended to accept AI-generated responses without conducting deeper verification or independent reasoning.

The lowest-ranked dimension, synthesis (29%), highlights a significant challenge in integrating multiple sources into coherent and original responses. Reflective responses indicated that many students relied heavily on AI-generated summaries rather than reconstructing information independently. This finding suggests that although AI-supported learning may assist comprehension and idea generation, higher-order integrative thinking still requires stronger instructional guidance and active cognitive engagement. Overall, the findings demonstrate that students performed better in lower-order and intermediate cognitive processes than in higher-order analytical and integrative thinking skills.

While Tables 1–3 provide a descriptive and interpretative overview of students' critical thinking performance, these findings alone do not indicate whether the observed differences are statistically significant. The descriptive results suggest variations in students' abilities across dimensions; however, it is necessary to further examine whether implementing AI-integrated EAPBL leads to measurable and meaningful improvements. Therefore, to validate the effectiveness of the intervention, an inferential statistical analysis was conducted using a paired-samples t-test. This analysis allows for a comparison of students' pre-test and post-test scores, thereby determining whether the observed changes in critical-thinking performance can be attributed to the AI-supported learning intervention. The results of this analysis are presented in Table 5.

Table 4 presents the results of the paired samples t-test comparing students' critical thinking scores before and after the implementation of AI-integrated EAPBL. The findings indicate a statistically significant improvement in students' performance, with the mean score increasing from 38.12 in the pre-test to 46.00 in the post-test. The t-value of 8.74, with a p-value < .001, confirms that the

Table 4. Paired samples t-test for overall critical thinking)

Variable	Mean	SD	t	df	Sig. (2-tailed)	Cohen's d
Pre-test	38.12	7.95				
Post-test	46.00	8.21	8.74	63	.000	1.09

Table 5. Paired samples t-test for all dimension of critical thinking

Dimension	Pre Mean (SD)	Post Mean (SD)	Percentage Increase	t	p-value
Interpretation	2.60 (0.52)	3.15 (0.57)	52% → 63%	6.45	.000
Analysis	1.90 (0.48)	2.25 (0.51)	38% → 45%	5.21	.000
Evaluation	1.70 (0.46)	2.00 (0.49)	34% → 40%	4.87	.000
Argumentation	2.25 (0.50)	2.65 (0.54)	45% → 53%	5.98	.000
Synthesis	1.20 (0.41)	1.45 (0.44)	24% → 29%	3.76	.001

difference is statistically significant. In addition, the effect size (Cohen's $d = 1.09$) suggests a substantial increase in students' scores following the intervention.

Despite the strong statistical significance and large effect size, the overall post-test score of 46% remained in the moderate category, indicating that students' critical thinking abilities were still relatively limited. This finding suggests that the observed improvement did not necessarily reflect advanced mastery of higher-order thinking skills. Students demonstrated progress primarily in interpretation and basic argumentation, while more complex dimensions such as evaluation and synthesis remained comparatively low. One possible explanation is that AI-supported learning may help students organize ideas and understand information more efficiently, yet it may not automatically promote deeper analytical reasoning or integrative thinking. Several qualitative reflections also indicated that students frequently relied on AI-generated responses when completing academic tasks, potentially reducing opportunities for independent cognitive processing and critical evaluation.

Furthermore, the findings should be interpreted cautiously because this study employed a single-group intervention design without a control group. As a result, the possibility of maturation effects cannot be entirely ruled out. The increase in students' scores may have been influenced in part by natural academic development, increased familiarity with academic tasks, or learning experiences accumulated throughout the semester, rather than solely by the implementation of AI-integrated EAPBL. Therefore, although the findings demonstrate a positive relationship between AI-supported learning and students' critical thinking performance, they do not conclusively establish that AI integration alone caused the observed improvement. Future studies involving control groups or experimental comparison designs are necessary to provide stronger evidence of the

specific contribution of AI-supported learning to the development of critical thinking.

Table 5 presents the paired-samples t-test results across the five dimensions of critical thinking, using both raw rubric scores and percentage conversions. The findings demonstrate statistically significant improvement in all dimensions following the implementation of AI-integrated EAPBL. Interpretation showed the greatest improvement, with the mean score increasing from 2.60 to 3.15, indicating that students benefited from AI-supported activities in understanding and explaining information. Argumentation also showed noticeable improvement, suggesting that AI tools helped students organize and express ideas more effectively.

However, analysis, evaluation, and synthesis remained relatively lower despite statistical improvement. The synthesis dimension showed the lowest post-test mean score (1.45), indicating that students continued to experience difficulty integrating multiple perspectives into coherent academic responses. Qualitative reflections revealed that several students relied heavily on AI-generated summaries and struggled to independently reconstruct information into original arguments. These findings suggest that AI-supported learning may facilitate comprehension and initial reasoning processes more effectively than higher-order analytical and integrative thinking skills.

Table 6 presents the results of the multiple regression analysis examining the predictive role of AI engagement and AI literacy on students' critical thinking performance. The regression model was statistically significant, with an R^2 of .38, indicating that 38% of the variance in critical thinking scores was explained by the two predictors. AI engagement emerged as the strongest predictor ($\beta = .45$, $p < .001$), suggesting that students who interacted more actively with AI-supported learning environments tended to demonstrate higher critical thinking performance. AI literacy also

Table 6. Multiple Regression Analysis

Predictor	B	β	t	Sig.	Tolerance	VIF
AI Engagement	0.42	.45	4.89	.000	.71	1.41
AI Literacy	0.31	.32	3.21	.002	.71	1.41
Model Summary						
$R^2 = .38$	$F = 18.76$		$p = .000$			

showed a significant contribution ($\beta = .32, p = .002$), indicating that students' ability to critically understand and evaluate AI-generated information was associated with better cognitive performance.

To ensure the validity of the regression model, multicollinearity diagnostics were also examined. The tolerance values for both predictors were above .10, while the Variance Inflation Factor (VIF) values remained below 10, indicating that no serious multicollinearity problem was detected. These findings suggest that AI engagement and AI literacy contributed independently to predicting students' critical-thinking performance within the AI-supported learning environment.

While the multiple regression analysis presented in Table 6 confirmed that AI engagement and AI literacy significantly predicted students' critical thinking performance, the analysis primarily explained direct relationships among variables. To further investigate the structural relationships underlying AI-supported learning, Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed, as this approach is considered more appropriate for studies with relatively small sample sizes.

The PLS-SEM model positioned cognitive engagement as a mediating variable to examine whether students' active mental involvement during AI-supported learning contributed to the development of critical thinking. Cognitive engagement in this study

refers to students' reflective thinking, sustained attention, and active cognitive participation during AI-assisted academic tasks. In addition, AI literacy was modeled as a moderating variable to examine whether students' level of AI literacy strengthened the relationship between cognitive engagement and critical thinking performance.

The PLS-SEM analysis enabled simultaneous examination of both direct and indirect relationships among AI engagement, cognitive engagement, AI literacy, and critical thinking performance. The structural model demonstrated acceptable model fit indices, including Standardized Root Mean Square Residual (SRMR) = .04, Normed Fit Index (NFI) = .92, $d_{ULS} = .98$, and $d_G = .42$, indicating that the proposed model adequately represented the observed data. The results further showed that AI engagement significantly influenced cognitive engagement ($\beta = .45, p < .001$) and that cognitive engagement significantly predicted students' critical-thinking performance ($\beta = .53, p < .001$). Furthermore, AI literacy significantly moderated the relationship between cognitive engagement and critical thinking performance ($\beta = .32, p < .01$). The complete results of the PLS-SEM analysis are presented in Figure 1.

While the PLS-SEM analysis in Figure 1 demonstrated the structural relationships among AI engagement, cognitive engagement, AI literacy, and critical thinking performance, the quantitative findings alone could not fully

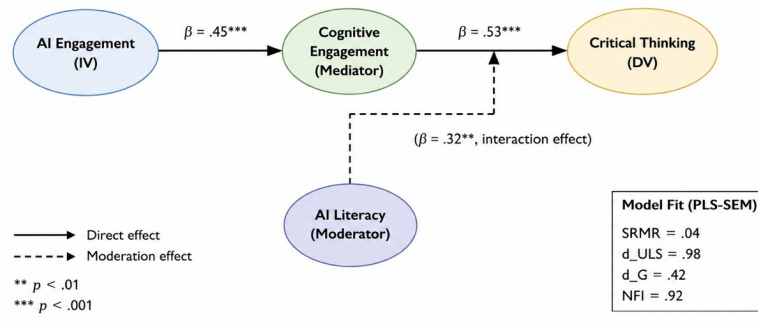


Figure 1. PLS-SEM model of the relationships among AI engagement, cognitive engagement, AI literacy, and critical thinking.

explain how students experienced AI-supported learning in practice. Therefore, the qualitative phase was conducted to explore students' perceptions, learning behaviors, and cognitive challenges during AI-assisted learning activities. The thematic analysis of students' reflective responses and interview data provided deeper insights into the patterns underlying the statistical relationships identified in the quantitative model. To illustrate these patterns more comprehensively, Figure 2 presents a thematic network map of students' dependence on AI and its influence on cognitive engagement and the development of critical thinking.

The findings of this study demonstrate that AI-integrated EAPBL contributes to students' development of critical thinking within the context of Society 5.0. However, the level of improvement remains moderate rather than fully transformative. The statistically significant increase in students' scores indicates that AI-supported learning environments may positively support cognitive development, particularly in tasks involving comprehension, organization of ideas, and initial reasoning processes. Nevertheless, the overall post-test score of 46% suggests that students' critical thinking abilities were still developing and had not yet reached advanced levels of higher-order thinking. This finding implies that the effectiveness of AI integration depends not only on technological access but also on the pedagogical quality of instructional implementation and students' active cognitive engagement during learning activities.

The findings further reveal uneven development across the dimensions of critical thinking, with stronger performance observed in lower- and mid-level cognitive processes than in higher-order integrative thinking.

Interpretation emerged as the strongest dimension, indicating that AI effectively supported students in understanding, explaining, and organizing information during academic tasks. Argumentation also demonstrated moderate improvement, suggesting that learners were able to construct basic claims and supporting ideas with AI assistance. These findings indicate that AI technologies may function effectively as cognitive support tools during the early stages of information processing and idea development.

In contrast, analysis and evaluation remained comparatively weaker, reflecting students' difficulties in critically examining relationships between ideas, assessing credibility, and independently evaluating information generated by AI systems. Several students tended to accept AI-generated responses without conducting deeper verification or engaging in reflective reasoning. This finding suggests that AI-supported learning environments may encourage surface-level engagement when students rely excessively on automated outputs rather than actively interrogating the information provided.

The synthesis dimension demonstrated the lowest performance among all critical thinking components, indicating substantial challenges in integrating multiple perspectives into coherent and original academic responses. This finding may be associated with the technical characteristics of generative AI systems, which typically generate responses by predicting and reproducing statistically probable language patterns rather than constructing genuinely integrative reasoning processes. As a result, students may receive fragmented or overly simplified outputs that appear coherent on the surface but provide

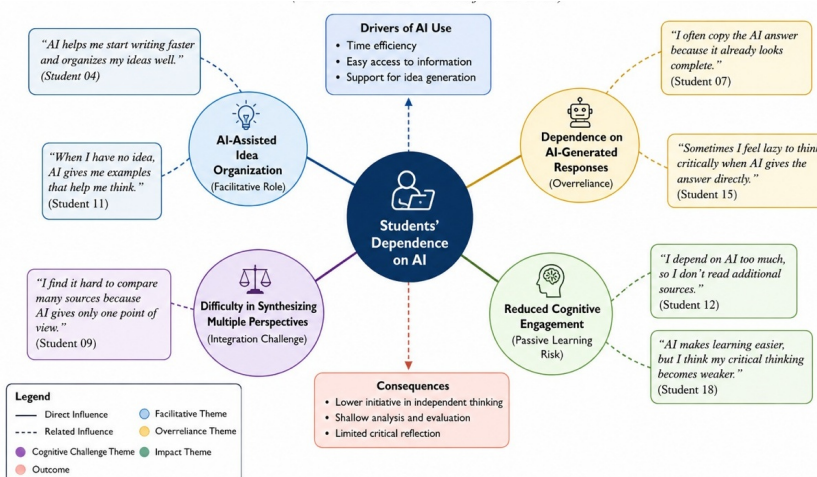


Figure 2. Thematic network mapping patterns of students' AI dependence

limited support for deeper conceptual integration across multiple sources. Consequently, learners may become dependent on AI-generated summaries instead of independently reconstructing arguments and synthesizing ideas critically.

From a cognitive perspective, this pattern aligns with theories of higher-order thinking, which emphasize that synthesis requires active cognitive restructuring, metacognitive reflection, and meaningful integration of knowledge from diverse perspectives. According to cognitive processing theory, higher-order integrative thinking involves deeper mental operations than comprehension or basic reasoning because learners must compare, evaluate, reorganize, and transform information into new conceptual understanding. However, generative AI systems primarily support information retrieval and language generation rather than the reflective cognitive struggle required for advanced synthesis. This may explain why students demonstrated stronger performance in interpretation and argumentation while continuing to experience difficulty in synthesis-oriented tasks.

Another important finding concerns the challenges that emerge from students' interactions with AI-supported learning environments. The lower performance in evaluation and synthesis indicates that learners may rely on AI-generated responses without engaging in sufficiently deep cognitive processing. Qualitative reflections revealed that several students perceived AI as a fast and convenient solution for completing academic tasks, which occasionally reduced their motivation to independently verify information or to critically elaborate arguments. This finding aligns with concerns that AI use may encourage passive learning and surface-level engagement when instructional activities do not explicitly require critical evaluation and reflective reasoning (Alaqad et al., 2026; Ghosh & Kumar, 2026).

At the same time, the findings highlight the growing importance of digital and ethical AI literacy in English language education. Students must not only understand how to operate AI technologies but also develop the ability to critically evaluate the credibility, bias, relevance, and limitations of AI-generated content (Iskandar et al., 2025; Joseph et al., 2024; Walter, 2024). Without sufficient AI literacy, learners may become passive consumers of information rather than active participants in knowledge construction. Therefore, AI literacy should be integrated into language learning activities as an essential

component of the development of critical thinking in digitally mediated learning environments.

From a theoretical perspective, these findings support the view that AI functions primarily as a cognitive scaffold rather than a direct driver of higher-order thinking. The results of the regression and PLS-SEM analyses indicate that AI-supported learning contributes to the development of students' critical thinking through cognitive engagement as a mediating mechanism. At the same time, AI literacy strengthens the relationship between cognitive engagement and critical thinking performance. In other words, the effectiveness of AI integration depends not only on students' engagement with AI-supported learning activities but also on their ability to critically understand, evaluate, and utilize AI-generated information. These findings reinforce sociocognitive perspectives emphasizing that meaningful learning occurs through active cognitive participation and critical interaction with information rather than passive reception of content.

However, the findings should also be interpreted cautiously because this study employed a single-group intervention design without a control group. Consequently, the possibility of maturation effects cannot be fully excluded. Improvements in students' critical thinking performance may have been influenced in part by natural academic development, increased familiarity with academic tasks, or learning experiences accumulated throughout the semester, rather than solely by AI-supported learning interventions. Therefore, although the study demonstrates a positive relationship between AI-supported learning and critical thinking performance, it does not conclusively establish that AI integration alone caused the observed improvements. Future studies involving experimental comparison groups are necessary to provide stronger evidence of the specific contribution of AI-supported learning to the development of higher-order thinking.

From a pedagogical perspective, the findings suggest that AI-integrated EAPBL should be designed to promote human-AI collaboration rather than passive dependence on AI. Learning activities should explicitly require students to question AI-generated outputs, compare multiple perspectives, justify arguments with evidence, and construct original responses through reflective reasoning. Educators should also design instructional tasks that encourage students to evaluate the credibility and limitations of AI-generated information rather than merely accepting

automated responses. By doing so, AI can serve as a learning support tool that enhances students' cognitive engagement rather than reducing independent thinking. Ultimately, this study demonstrates that while AI has considerable potential to support English language learning and the development of critical thinking, its educational effectiveness depends fundamentally on how it is pedagogically structured, critically mediated, and cognitively engaged by learners.

■ CONCLUSION

The findings of this study demonstrate that AI-integrated EAPBL has the potential to support students' development of critical thinking in English language learning, particularly in comprehension, interpretation, and the initial construction of arguments. However, the relatively moderate overall achievement and the persistently low performance in synthesis and evaluation indicate that AI-supported learning alone is insufficient to foster advanced higher-order thinking skills. Students frequently benefited from AI assistance in organizing ideas and accessing information, yet many still struggled to critically evaluate information and integrate multiple perspectives into coherent academic arguments.

These findings carry important pedagogical implications for English language educators in the era of Society 5.0. AI should not be positioned merely as an automated answer-generating tool but rather as a cognitive support instrument integrated within reflective and inquiry-based learning activities. To reduce students' dependence on AI-generated responses, lecturers should design instructional tasks that explicitly require learners to compare AI outputs with academic sources, identify potential bias or inaccuracies, justify arguments using evidence, and revise AI-generated ideas through independent reasoning. Classroom activities should also encourage students to question, critique, and reconstruct AI-generated information rather than passively accept automated responses.

Furthermore, English language instruction should incorporate digital and ethical AI literacy as an integral component of learning. Students need practical guidance on responsible AI use, academic integrity, source verification, and critical evaluation of AI-generated content. Lecturers may implement reflective writing tasks, collaborative discussions, and source-validation activities to strengthen students' analytical and evaluative thinking processes during AI-supported learning.

At the institutional level, universities should support the integration of AI literacy into curriculum development and provide professional training for educators regarding effective pedagogical use of AI technologies. Since this study employed a single-group intervention design, future research with control groups and longer intervention periods is recommended to provide stronger evidence of the long-term impact of AI-supported learning on the development of higher-order critical thinking. Ultimately, the effectiveness of AI in English language education depends not only on technological sophistication but also on how critically, ethically, and reflectively the technology is integrated into pedagogical practice.

■ DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the writing of this manuscript, the authors employed ChatGPT (OpenAI) to assist with language refinement, grammatical editing, paraphrasing, and improving academic clarity. The AI tool was used solely to support the writing process and was not used to generate, analyse, or interpret research data, nor to produce scientific conclusions independently. The authors carefully reviewed, revised, and validated all generated content and assume full responsibility for the accuracy, integrity, and originality of the published article.

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