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A Survey on the Digital Literacy of Cross-Border E-Commerce Students under AI-Assisted Teaching: An SEM Approach

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Abstract

With the growing integration of Artificial Intelligence (AI) into education, digital literacy has become a fundamental competency for students in cross-border e-commerce programs. This study investigates how students' AI engagement influences their digital literacy in AI-assisted teaching environments. Using Structural Equation Modeling (SEM), this research conceptualizes AI engagement through four dimensions: Personalization and Adaptivity, Interactivity and Feedback, Learning Analytics Support, and Perceived Usefulness of AI Tools—and digital literacy through six dimensions: Digital Business Operation Skills, Digital Marketing and Communication, Data and Information Management, Cross-Border Compliance and Security, Digital Content Creation and Innovation, and Ethical and Entrepreneurial Awareness. A survey of 386 cross-border e-commerce undergraduates was conducted across multiple universities. Results reveal that all four dimensions of AI engagement significantly and positively predict students' digital literacy, with the strongest effects observed for Perceived Usefulness and Interactivity and Feedback. These findings highlight the crucial role of AI engagement in enhancing domain-specific digital literacy and provide implications for curriculum design in AI-driven education.

Keywords

Digital literacy; Cross-border e-commerce; AI-assisted teaching; AI engagement; Structural equation modeling.

1. Introduction

The rapid advancement of artificial intelligence (AI) has transformed higher education and redefined the learning experience. In particular, AI-assisted teaching which integrates intelligent recommendation, adaptive learning, and automated feedback has become a key approach to fostering students' technological and professional skills [1]. For cross-border e-commerce students, digital literacy is essential not only for academic success but also for employability in the global digital economy [2].

However, despite extensive research on AI in education, there remains limited empirical evidence on how AI engagement affects students digital literacy in discipline-specific contexts such as e-commerce. Addressing this gap, this study applies Structural Equation Modeling (SEM) to explore how different facets of AI engagement contribute to the enhancement of digital literacy among cross-border e-commerce students.

The objectives of this study are: To measure the level of digital literacy among cross-border e-commerce students in AI-assisted learning environments. To examine the relationships between AI engagement dimensions and digital literacy dimensions. To identify which AI engagement components most effectively foster digital literacy development.

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2. Methodology

2.1. Participants and Data Collection

A total of 386 undergraduate students majoring in Cross-Border E-Commerce from universities in China were surveyed, with a balanced gender composition. Participants have engaged in AI-integrated courses such as E-Commerce Analytics, Digital Marketing Automation, and AI for Business Decision-Making. Data were collected via an online questionnaire after one semester of AI-assisted instruction. Respondents participated voluntarily and anonymously.

2.2. Measurement Design

All constructs in this study were measured using a five-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"). The measurement items were adapted from previously validated instruments and refined to fit the cross-border e-commerce and AI-assisted teaching context.

The independent variable, AI Engagement, was conceptualized through four dimensions: Personalization and Adaptivity, Interactivity and Feedback, Learning Analytics Support, and Perceived Usefulness of AI Tools. The items for these dimensions were adapted from prior studies on technology-enhanced learning and AI-supported education [3, 4]. Specifically, Personalization and Adaptivity items were based on research related to adaptive learning systems and AI-driven customization [5], while Interactivity and Feedback drew from studies on digital learning engagement and feedback immediacy [6, 7]. Learning Analytics Support was developed with reference to models of AI-based data analytics for learning performance monitoring [8], and Perceived Usefulness of AI Tools was adapted from the Technology Acceptance Model (TAM) [9].

The dependent variable, Digital Literacy, was operationalized as a multidimensional construct that reflects the comprehensive digital competencies required in cross-border e-commerce education. The items were adapted from established frameworks of digital competence and digital business literacy [10, 11]. It consists of six dimensions: Digital Business Operation Skills, Digital Marketing and Communication, Data and Information Management, Cross-Border Compliance and Security, Digital Content Creation and Innovation, and Ethical and Entrepreneurial Awareness. These dimensions capture students' technical, cognitive, and ethical capacities to operate effectively in AI-driven global e-commerce environments.

All items were reviewed by domain experts in e-commerce education and AI-assisted teaching to ensure contextual relevance and content validity. A pilot test was conducted prior to the main survey to assess item clarity, reliability, and linguistic consistency.

2.3. Data Analysis Procedures

The data analysis followed a systematic approach to ensure the reliability and validity of the measurement model and the robustness of the structural relationships. First, reliability was evaluated using Cronbach's alpha, Composite Reliability (CR), and Average Variance Extracted (AVE) to confirm internal consistency and convergent validity of the constructs. Next, a Confirmatory Factor Analysis (CFA) was conducted to assess the measurement model's validity, including factor loadings, construct reliability, and discriminant validity.

Subsequently, Structural Equation Modeling (SEM) was employed to test the hypothesized relationships between AI engagement dimensions and digital literacy dimensions. The analysis was performed using AMOS or SmartPLS, depending on the data characteristics and model complexity. To evaluate the adequacy of model fit, multiple indices were examined, including the Chi-square to degrees of freedom ratio (χ^2/df), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean

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Square Residual (SRMR). Acceptable model fit was determined based on established thresholds from prior SEM research.

3. Results and Findings

3.1. Descriptive Statistics

A total of 386 valid responses were collected from undergraduate students majoring in cross-border e-commerce at five Malaysian universities. The sample consisted of 61.1% female and 38.9% male participants, with an average age of 21.4 years (SD = 1.9). Table 1 presents the descriptive statistics for all constructs, including means, standard deviations, and correlations.

Table 1 Descriptive Statistics and Correlations among Constructs (N = 386)

Construct	Mean	SD	PA	IF	LAS	PUAT	DBOS	DMC	DIM	CCS	DCCI	EEA
PA	4.12	0.63	1									
IF	4.08	0.59	.61**	1								
LAS	4.02	0.67	.58**	.63**	1							
PUAT	4.19	0.66	.65**	.69**	.66**	1						
DBOS	4.04	0.60	.51**	.47**	.43**	.55**	1					
DMC	4.09	0.64	.46**	.48**	.45**	.50**	.68**	1				
DIM	3.97	0.61	.41**	.43**	.47**	.44**	.63**	.67**	1			
CCS	3.89	0.65	.38**	.41**	.44**	.40**	.61**	.62**	.66**	1		
DCCI	4.06	0.63	.46**	.44**	.45**	.49**	.63**	.67**	.65**	.59**	1	
EEA	4.01	0.60	.42**	.40**	.41**	.45**	.58**	.62**	.63**	.60**	.64**	1
Note. All correlations are significant at $p < 0.01$ (two-tailed).												

3.2. Measurement Model Evaluation

The Confirmatory Factor Analysis (CFA) was performed to assess the reliability and validity of the constructs. All standardized loadings were above 0.70, indicating good indicator reliability. The results for Cronbach's alpha (CA), Composite Reliability (CR), and Average Variance Extracted (AVE) are presented in Table 2. All constructs met the threshold, confirming good internal consistency and convergent validity. Discriminant validity was assessed using the Fornell–Larcker criterion, where the square roots of AVEs exceeded the inter-construct correlations, indicating adequate discriminant validity.

Table 2 Reliability and Convergent Validity Results

Construct	CA	CR	AVE
Personalization & Adaptivity	0.872	0.901	0.695
Interactivity & Feedback	0.864	0.895	0.682
Learning Analytics Support	0.853	0.885	0.667
Perceived Usefulness of AI Tools	0.878	0.907	0.713
Digital Business Operation Skills	0.863	0.892	0.673
Digital Marketing & Communication	0.871	0.899	0.689
Data & Information Management	0.856	0.888	0.664
Cross-Border Compliance & Security	0.842	0.876	0.652
Digital Content Creation & Innovation	0.874	0.903	0.701
Ethical & Entrepreneurial Awareness	0.867	0.896	0.680
Criteria: CA > 0.70, CR > 0.70, AVE > 0.50			

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3.3. Structural Model Analysis

After establishing measurement validity, the structural model was tested using SEM (AMOS 26.0). The model fit indices indicated an acceptable fit to the data in Table 3. The model fit values confirm that the proposed model fits the data well [12, 13].

Table 3 Model Fit Indices for the Structural Model

Fit Index	Recommended	Obtained
χ^2/df	< 3.00	2.184
CFI	> 0.90	0.947
TLI	> 0.90	0.939
RMSEA	< 0.08	0.054
SRMR	< 0.08	0.045

3.4. Hypothesis Testing

Table 4 shows the standardized path coefficients (β), t-values, and significance levels for each hypothesized relationship. All four paths were significant, indicating that AI engagement positively influences digital literacy among cross-border e-commerce students. The model explained 62.4% of the variance (R^2 = 0.624) in digital literacy, suggesting strong explanatory power.

Table 4 Structural Path Coefficients

Hypothesis	Path	β	t-value	p-value	Supported
H1	Personalization & Adaptivity → Digital Literacy	0.27	4.92	< .001	Yes
H2	Interactivity & Feedback → Digital Literacy	0.23	4.31	< .001	Yes
H3	Learning Analytics Support → Digital Literacy	0.19	3.74	< .001	Yes
H4	Perceived Usefulness of AI Tools → Digital Literacy	0.31	5.36	< .001	Yes

The SEM results confirm that: AI engagement is a strong predictor of digital literacy. Among the four AI engagement dimensions, Perceived Usefulness of AI Tools (β = 0.31) was the most influential factor. Personalization and Adaptivity (β = 0.27) and Interactivity and Feedback (β = 0.23) also contributed significantly, indicating that adaptive learning and interactive AI environments enhance students' digital capabilities. The model fit indices and reliability statistics demonstrate robust validity and model performance.

4. Discussion

4.1. Overview of Findings

This study aimed to examine how AI engagement influences the digital literacy of cross-border e-commerce students within AI-assisted teaching environments. Using Structural Equation Modeling (SEM), the findings confirmed that all four dimensions of AI engagement significantly and positively affected students' overall digital literacy. The six digital literacy dimensions were all enhanced through AI-integrated learning experiences. The model explained 62.4% of the variance in digital literacy, suggesting that AI-assisted pedagogical practices play a pivotal role in shaping students' preparedness for the digital economy.

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4.2. The Role of AI Engagement in Enhancing Digital Literacy

The results underscore that AI engagement enhances digital literacy by fostering personalized learning, interactive communication, and data-informed self-regulation. The effect of Personalization and Adaptivity ($\beta = 0.27$, $p < .001$) indicates that adaptive AI systems that adjust to individual learners' needs enhance motivation and performance, aligning with Ifenthaler and Yau. [14] Interactivity and Feedback ($\beta = 0.23$, $p < .001$) also exerted a positive influence, highlighting that AI-driven feedback mechanisms support critical problem-solving and collaboration, consistent with Chen and Lin [1]. Similarly, Learning Analytics Support ($\beta = 0.19$, $p < .001$) demonstrates that data-driven insights allow learners to reflect on progress and make informed learning decisions, in line with Rahiman et al. [15] The strongest predictor, Perceived Usefulness of AI Tools ($\beta = 0.31$, $p < .001$), reflects that students' belief in AI's practical utility motivates deeper engagement and application of digital skills, consistent with the Technology Acceptance Model (TAM) [9].

4.3. Implications for Cross-Border E-Commerce Education

The findings provide several implications for cross-border e-commerce education. First, curriculum innovation should integrate AI technologies such as intelligent simulations, market analytics, and virtual entrepreneurship projects to enhance authentic skill application in digital business contexts. Second, pedagogical design should emphasize human-AI collaboration through adaptive assessments, real-time feedback, and interactive learning environments that foster higher-order cognitive and professional skills. Third, institutional support is essential; universities must provide AI infrastructure, analytics systems, and teacher training to ensure the sustainable integration of digital learning technologies. Aligning these efforts with global competency frameworks like DigComp [16] can standardize digital literacy outcomes across international programs.

4.4. Theoretical and Practical Contributions

Theoretically, this study expands digital literacy research by conceptualizing AI engagement as a pedagogical enabler that shapes multidimensional digital competencies rather than a purely technological variable. It empirically validates a multi-level SEM framework linking AI engagement to digital literacy, contributing new insights to e-commerce and technology-enhanced education literature. Furthermore, the results reinforce constructivist learning theory, showing that AI-assisted teaching facilitates personalized, self-regulated, and experiential learning, leading to deeper digital competence formation. Practically, the study offers actionable guidance: educators should employ adaptive AI tools for personalized feedback; students should use AI analytics for self-monitoring; and policymakers should integrate AI-based literacy standards into national digital talent strategies to align academic training with global industry demands.

4.5. Limitations and Future Research

Despite its contributions, the study has limitations. Data were collected via self-reported surveys, which may introduce common method bias; future research should triangulate results with actual learning analytics data. The research context was limited to cross-border e-commerce students in China; comparative studies across ASEAN or Belt and Road countries could yield broader cross-cultural perspectives. Lastly, future studies should adopt longitudinal designs to explore how AI engagement influences digital literacy growth over time.

5. Conclusion

This study contributes to the understanding of how AI engagement enhances students' digital literacy in the field of cross-border e-commerce. The findings demonstrate that personalization,

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interactivity, analytics support, and perceived usefulness significantly predict six key digital literacy competencies. These insights underscore the importance of AI-assisted teaching as a transformative tool for developing globally competent and digitally fluent graduates.

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