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Exploring the role of generative AI in international students' cross-cultural adaptation: A stimulus-organism-response framework approach

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ABSTRACT

As global student mobility continues to rise, facilitating effective cross-cultural adaptation has become crucial for international education. Drawing upon social support theory, cross-cultural adaptation theory, and the Technology Acceptance Model (TAM), this study applies the Stimulus-Organism-Response (S-O-R) framework to investigate how generative AI supports international students' adaptation processes. Using survey responses from 439 international students, the findings demonstrate that generative AI enhances cultural understanding, emotional resilience, and intercultural attitudes by offering informational, emotional, and social support. These enhancements significantly improve students' academic, psychological, and social adaptation. The results also highlight how individual differences, such as gender, educational level, duration of study, and language proficiency, influence adaptation outcomes. The study advocates for AI as a key support tool, proposing an "AI-human collaboration" model for personalized assistance. It highlights the need for balanced cognitive-emotional-behavioral development and phased adaptation strategies, offering theoretical and practical insights for universities to enhance cross-cultural support systems.

Key insights

What is the main issue that the paper addresses?

The paper addresses the challenge of how international students adapt to new cultural, academic, and social environments, and specifically investigates the role that generative AI can play in supporting this cross-cultural adaptation process.

What are the main insights that the paper provides?

Generative AI enhances international students' cross-cultural adaptation by improving cultural cognition, emotional regulation, and attitudes through informational, emotional, and social support. These improvements promote academic, psychological, and social adjustment. The study also highlights the importance of personalized AI support and integrating AI with human-led services for effective adaptation.

1. Introduction

Accelerating globalization has significantly increased international student mobility. UNESCO estimates suggest that by 2025, the global number of international students will surpass 8 million (UNESCO, 2023), positioning this group prominently within global population movements. Although international mobility promotes educational diversity and global integration, it also presents substantial cross-cultural adaptation challenges. Language barriers impede students' active classroom participation (Andrade, 2006), cultural differences often foster social avoidance behaviors (Yeh and Inose, 2003), and educational cognitive dissonance diminishes learning effectiveness (Wu et al., 2024). Collectively, these challenges create a complex phenomenon known as the "adaptation black box" (Wang and Mallinckrodt, 2006), hindering international students' academic and social development. Thus, cross-cultural adaptation emerges as a central concern within international education research.

Cross-cultural adaptation is widely understood as a dynamic and evolving process rather than a static outcome(Kim, 2001). It is commonly conceptualised as a multidimensional phenomenon in which individuals cognitively appraise unfamiliar cultural environments,

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regulate affective responses, and adjust behaviours in order to achieve functional and emotional stability(Berry, 1997; Ward and Kennedy, 1999). For international students in particular, adaptation entails navigating new cultural norms, communicative expectations, and unfamiliar academic contexts while engaging in overseas study. More recent research further highlights that cross-cultural adaptation involves ongoing negotiation, information seeking, and strategic engagement with academic and social systems, rather than a linear or uniform trajectory(Chu and Zhu, 2023; Smith and Khawaja, 2011). Despite this recognition, most existing studies have tended to examined language (Wilczewski and Alon, 2023), culture(Smith and Khawaja, 2011), psychology(Wang et al., 2018), or learning(Bastien et al., 2018) dimensions in relative isolation, and systematic integrative analyses that capture the interactions among these dimensions remain limited.

With the rapid development of artificial intelligence technologies, particularly their wide application in educational contexts, international students' approaches to cross-cultural adaptation are undergoing profound changes(Jin et al., 2025). Artificial intelligence tools that support language translation, academic guidance, and intercultural communication provide international students with more convenient, efficient, and intelligent ways to navigate challenges, and they offer new avenues for research on cross-cultural adaptation. However, existing studies have mainly focused on the functional effects of AI tools in areas such as language learning(Shadiev and Wang, 2022), academic support (VanLehn, 2011), and technology adoption(Zawacki-Richter et al., 2019), while systematic explanations of how generative AI shapes the cognitive, affective, and attitudinal dimensions of cross-cultural adaptation in international higher education remains limited.

To explore how generative AI influences international students' cross-cultural adaptation, this study applies the Stimulus-Organism-Response(S-O-R) framework (Mehrabian and Russell, 1974). Generative AI is conceptualized as the stimulus (S) that provides informational, cognitive, and affective resources, which are expected to influence students' cultural cognition, attitudes, and emotional adjustment (O), ultimately enhancing their cross-cultural adaptation (R). By systematically examining the impact pathways and underlying mechanisms, and further exploring how these mechanisms vary across demographic characteristics (e.g., gender, age, and educational background), this study advances cross-cultural adaptation theory by introducing generative AI as a novel environmental stimulus and expanding the technological dimension of adaptation research. It also underscores the dynamic interplay among cognitive, emotional, and attitudinal adaptation processes, offering deeper theoretical insights into multidimensional adaptation mechanisms. Empirically, the findings demonstrate that generative AI significantly enhances international students' adaptation capacities by providing informational, emotional, and social supports. Moreover, the study reveals that adaptation outcomes vary across individual characteristics such as gender, educational background, duration abroad, and language proficiency. This research offers both theoretical contribution and practical recommendations for educational practitioners, technology developers, and international students navigating cross-cultural adaptation.

2. Literature review

2.1. Cross-cultural adaptation

Previous research on cross-cultural adaptation often adopts static theoretical paradigms.

One dominant perspective is the stage-based adaptation model, notably Lysgaard's (1955) U-curve theory, proposing a linear progression through distinct adaptation phases – honeymoon, crisis, recovery, and adjustment. Gullahorn and Gullahorn (1963) subsequently expanded this framework into a W-curve model to address the complexities of re-adaptation among returnees. However, these stage-based models have faced criticism for oversimplifying adaptation processes, neglecting individual differences (Peltokorpi, 2008; Ward et al., 2001; Zhou and Todman, 2009), and overlooking the complex and dynamic nature of cultural interactions (Berry, 1997).

Alternatively, the compartmentalized approach explores discrete dimensions of adaptation, including linguistic (Zhang and Mi, 2010), cultural (An and Chiang, 2015), psychological (Chu and Zhu, 2023), and academic aspects (Drozdova and Taulean, 2022). Linguistic adaptation research focuses on language barriers' impact on social integration (R and Miller, 2001). Cultural adaptation studies highlight cultural distance as influencing outcomes (Kogut and Singh, 1988). Psychological adaptation research emphasizes emotional regulation strategies addressing anxiety, loneliness, and culture shock (Searle and Ward, 1990), while academic adaptation studies examine the impact of educational system differences on academic performance (Andrade, 2006). Despite valuable insights, these compartmentalized studies often neglect interactions between adaptation dimensions, resulting in fragmented theoretical understanding.

In contrast, contemporary scholarship increasingly views cross-cultural adaptation as dynamic and multidimensional, involving cognitive restructuring, emotional regulation, behavioral modification, and attitudinal transformation (Berry, 1997; Kim, 2001). Kim's (2001) Stress-Adaptation-Growth model conceptualizes adaptation as cyclical interactions involving stress, reaction, adjustment, and learning. Similarly, Berry (1997) emphasizes the bidirectional interplay between individual strategies (integration, assimilation, separation, marginalization) and contextual influences. Empirical research further underscores adaptation's systemic, context-dependent, and nonlinear characteristics, highlighting the role of social support, information acquisition, and technological mediation (Lou, 2023; Poyrazli et al., 2004). These theoretical and empirical perspectives converge on the recognition that adaptation develops through interdependent cognitive, affective, and behavioral dimensions. Cognitive adjustment involves acquiring cultural knowledge, expectations, and interpretive schemas; affective adjustment relates to managing emotions such as anxiety, uncertainty, or enjoyment; and behavioural adjustment concerns communicative participation and culturally appropriate action(Ward and Kennedy, 1999). Acculturation and cross-cultural adaptation research consistently demonstrates that these dimensions are interdependent and evolve over time, shaping students' learning experiences, wellbeing, and academic persistence (Holliman et al., 2022; Smith and Khawaja, 2011).

2.2. AI-supported cross-cultural adaptation

With the widespread adoption of generative artificial intelligence in education, a rising number of studies have explored how these tools can support international students' cross-cultural adaptation, providing new perspectives for understanding how technology can facilitate the adaptation process. Linguistically, generative AI improves communicative competence through real-time translation and conversation simulations (Li et al., 2024). Academically, it assists students in navigating complex concepts and managing academic stress (Kim et al., 2025). Socioculturally, AI-driven cultural analytics and tailored interaction recommendations enable students to navigate host cultures effectively (Sarwari et al., 2024). Psychologically, AI provides emotional support to mitigate anxiety and loneliness associated with culture shock(Chin et al., 2023). Consequently, generative AI reshapes traditional adaptation pathways and necessitates updated theoretical frameworks that consider technological mediation. Beyond AI-specific tools, more recent scholarship has examined how digital and institutional resources facilitate these adaptation processes by reducing informational uncertainty, providing emotional support, and scaffolding communication (Chu and Zhu, 2023; Lou, 2023). While prior work has primarily focused on human or institutionally mediated support (e.g., advisors, mentors, peers, and university programmes), little attention has been given to technologically mediated support provided by generative AI systems. As

such tools become embedded in students' academic routines, they may offer new forms of cognitive and affective assistance that support adaptation, particularly in contexts where linguistic, cultural, and social barriers are salient. This gap provides a timely opportunity to examine how generative AI may shape international students' adaptation processes within global higher education.

To analytically structure these processes, this study draws on the Stimulus–Organism–Response (S-O-R) framework, which has been utilised in education and communication studies to explain how environmental inputs elicit cognitive and affective evaluations that shape behavioural outcomes(Mehrabian and Russell, 1974; Peng et al., 2023). Rather than supplanting intercultural adaptation theory, S-O-R offers an analytical lens for structuring the cognitive, emotional, and attitudinal processes through which technologically mediated support may influence adaptation-related outcomes.

3. Theoretical background and hypothesis development

3.1. S-O-R framework

The S-O-R framework originally proposed by Mehrabian and Russell (1974) is a widely adopted theoretical framework in behavioral science for explaining the mechanisms underlying individual behavioral responses. The model posits that individual behavior is not directly determined by external stimuli. Rather, when individuals encounter external information or environmental stimuli, they function as "organisms" that internally process these stimuli through cognitive, emotional, and attitudinal mechanisms, ultimately generating behavioral or adaptive responses. In contrast to the traditional S-R (Stimulus–Response) model (Watson, 1913), the S-O-R model emphasizes the mediating role of subjective cognition and emotional processes in behavioral decision-making, offering greater explanatory power and wider applicability. This framework has been extensively applied across diverse research domains, including environmental psychology (Bitner, 1992), consumer behavior (Prashar et al., 2017; Yu et al., 2024), educational technology (Yao-Ping Peng et al., 2023), and organizational behavior and human resource management (Basalamah et al., 2024).

In the context of cross-cultural adaptation research, international students commonly experience various external challenges during their overseas studies, including language barriers, cultural conflicts, and social isolation(Bethel et al., 2020). In this study generative AI is conceptualized as an external environmental stimulus (S) within the S-O-R framework. Rather than imposing an experimental intervention, we adopt an ecological perspective in which students' naturally occurring use of GenAI for academic, communicative, and emotional tasks, such as completing coursework, using AI for language assistance, receiving emotional support, and accessing social advice. Through these activities, participants interact directly with GenAI, which is assumed to influence their internal psychological states (O), including enhanced cultural cognition, reduced cultural anxiety, and modified cultural attitudes(Xu et al., 2024), and in turn influence students' adaptive behaviors in cross-cultural environments(Chu and Zhu, 2023), leading to measurable improvements in academic adjustment, social engagement, psychological well-being, and cultural integration (R). Prior research employing S-O-R has similarly treated technology use as an external stimulus that activates cognitive and affective states without requiring laboratory-based manipulation (Basalamah et al., 2024; Peng et al., 2023). This approach is particularly appropriate for the context of international student adaptation, where support tools are typically accessed voluntarily and integrated into routine academic and social activities.

3.2. Usefulness of generative AI (S) and organism responses (O)

According to Social Support Theory (House, 1981), individuals experiencing adaptive stress are more likely to regulate their psychological states and adopt positive behavioral responses when they receive effective informational, emotional, and social support (Cohen and Wills, 1985; Weiss, 1983). As an intelligent interactive technology, generative AI provides timely and personalized informational support, facilitates social interactions, and responds to emotional needs, which enable it to significantly influence international students' psychological and behavioral adaptations in cross-cultural contexts, ultimately promoting more effective cross-cultural cognition, attitudes, and behaviors.

First, owing to its robust capabilities in knowledge integration and language generation, generative AI can provide targeted information, such as cultural background, language usage, and academic norms, tailored to users' specific needs (Sajja et al., 2024). This efficient informational support mitigates difficulties arising from information gaps or comprehension barriers (Fitas, 2025), enhances international students' ability to interpret and evaluate foreign cultural elements (Wang et al., 2023), and ultimately strengthens their cultural cognition.

Second, leveraging natural language processing and semantic understanding technologies trained on large-scale corpora, generative AI can accurately identify cultural norms and communicative etiquette across diverse contexts, thereby providing tailored intercultural communication guidance. This personalized social support enhances international students' confidence and willingness to engage with the host culture (Sarwari et al., 2024), facilitating their transition from passive adaptation to active participation and fostering a more open and inclusive cultural mindset. As a result, their overall cross-cultural adaptability is significantly improved.

Third, generative AI further delivers timely emotional support through emotion recognition capabilities, empathetic dialogue systems, and contextually appropriate responses. When international students encounter culture shock or face acculturative challenges, this technology can provide comforting language patterns, affirmative feedback, and constructive guidance to mitigate feelings of anxiety and isolation (Kim et al., 2025). Such emotional support mechanisms not only reduce psychologically distressing effects stemming from cultural disparities but also establish a reliable and consistent emotional outlet, thereby facilitating both psychological adjustment and cultural integration processes.

Based on the above literature and theoretical reasoning, we conceptualize generative AI–enabled informational, social, and emotional support as technological stimuli that influence international students' cross-cultural adaptation through cognitive, affective, and attitudinal processes, and propose the following hypotheses.

H1a. Informational support provided by generative AI positively influences international students' cultural cognition.

H1b. Social support provided by generative AI positively influences international students' cultural attitudes.

H1c. Emotional support provided by generative AI effectively alleviates international students' cultural anxiety.

3.3. Organism (O) and cross-cultural adaptation (R)

Drawing upon Berry's cultural adaptation model (Berry, 1997) and the dual-dimensional theory of cross-cultural adaptation developed by Ward et al. (2001), cross-cultural adaptation involves not only social adaptation and behavioral adjustment in a new cultural environment, but also psychological adaptation, which includes emotional regulation and mental well-being. However, for international students, the core tasks of cross-cultural adaptation extend beyond social integration and psychological stability to encompass adaptation to the educational environment. Therefore, this study further refines sociocultural adaptation by proposing a three-dimensional structure that better fits the actual circumstances of international students: learning adaptation, social adaptation, and psychological adaptation. Learning adaptation focuses on individuals' ability to understand and cope with the host

country's educational system, teaching methods, language requirements, and academic culture (Malay et al., 2023); social adaptation emphasizes the capacity to adjust to cross-cultural interpersonal interactions and social behavioral norms (Sadewo et al., 2020); psychological adaptation concerns the ability to regulate emotions and maintain mental health in the new cultural context (Zheng, 2025).

Cultural cognition reflects an individual's comprehension and command of a target culture's knowledge systems, value orientations, and normative social conventions, which exert substantial influence on learning behaviors (Kang and Chang, 2016). Well-developed cultural cognition enables international students to more efficiently assimilate host countries' pedagogical approaches, classroom interaction protocols, and assessment paradigms, consequently minimizing intercultural misunderstandings and reducing adaptation barriers (Spencer-Oatey and Franklin, 2009). Enhanced cultural cognitive capacity facilitates the strategic modification of learning approaches, strengthens self-directed learning competencies, and promotes active classroom engagement, collectively contributing to improved academic adaptation outcomes (Smith and Khawaja, 2011). Consequently, international students demonstrating superior cultural cognition levels typically exhibit greater academic environment adaptability.

Cultural attitude encompass individual's cognitive evaluation, emotional response, and behavioral tendency toward a foreign culture, primarily manifested in openness, tolerance, and acceptance of cultural differences (Deardorff, 2006). According to Berry's (1997) bidimensional model of acculturation, an individual's willingness to accept, understand, and integrate into the host culture is essential for achieving effective social adaptation. The degree of cultural acceptance not only influences the fluidity of cross-cultural communication but also directly affects the depth and quality of social integration (Ward and Kennedy, 1994). A positive cultural attitude encourages individuals to actively participate in local social interactions and establish strong interpersonal networks, thereby enhancing their sense of social belonging and interactive competence in a foreign environment (Ward and Kennedy, 1999). Therefore, international students who possess more open and positive cultural attitudes are more likely to overcome cultural barriers, develop a deeper understanding of the host culture, and adapt effectively to local social norms, thereby exhibiting stronger social adaptation capabilities.

Cultural anxiety involves the feelings of tension, worry, and unease experienced by individuals when encountering an unfamiliar cultural environment, often triggered by uncertainty, cultural differences, and adaptation pressures(Fritz et al., 2008). These emotional responses typically arise from a lack of clear understanding of social norms, language, values, and other cultural elements, constituting a common psychological challenge in the process of cross-cultural adaptation (Zhou et al., 2008). Berry (2006) emphasized that cultural adaptation involves not only behavioral integration into the host society but also emotional regulation and the establishment of psychological equilibrium. If cultural anxiety persists over an extended period, it may lead to psychological issues such as loneliness, depression, and culture shock, thereby disrupting individuals' daily lives and academic performance (Smith and Khawaja, 2011). Conversely, when individuals are able to acknowledge and effectively manage their cultural anxiety, their emotional state tends to stabilize and psychological stress is reduced, promoting more positive cognitive evaluations and emotional responses, which in turn enhance their psychological adaptation (LaFromboise et al., 1993). Therefore, the effective alleviation of cultural anxiety constitutes a critical pathway for safeguarding international students' mental health and improving their cross-cultural adaptation capabilities.

The above literature indicates that cultural cognition, cultural attitudes, and cultural anxiety play important roles in international students' cross-cultural adaptation by shaping their understanding of the academic environment and learning strategy adjustment, their openness to and engagement in intercultural interactions, and their regulation of stress and emotions, thereby influencing learning, social, and psychological adaptation outcomes. Based on this reasoning, we derive the following hypotheses.

H2a. International students' level of cultural cognition positively influences their learning adaptation.

H2b. International students' cultural attitudes positively affect their social adaptation.

H2c. Alleviation of cultural anxiety among international students contributes to the improvement of their psychological adaptation.

3.4. The internal relationship between physiological responses and cross-cultural adaptation

According to the Cognition-Affect Consistency Theory (Rosenberg, 1956), the deeper an individual's understanding of a culture, the more likely they are to develop a positive and rational attitude toward it (Fishbein and Ajzen, 1975). In cross-cultural contexts, international students with higher levels of cultural cognition are better equipped to comprehend the historical background, value systems, and behavioral motivations underlying the host culture, thereby reducing misunderstandings and prejudices while enhancing cultural tolerance (Gudykunst, 2005). This enhanced cognitive foundation not only facilitates the development of a more positive cultural attitude but also strengthens their willingness and ability to engage in cross-cultural communication, which in turn promotes active integration into the host society and contributes to the achievement of social adaptation.

According to the stress-response mechanism (Selye, 1950), once cultural anxiety is alleviated, individuals are more likely to lower their psychological defenses and adopt a more open and tolerant attitude toward the host culture (Ward et al., 2001). Variations in the intensity of cultural anxiety may also influence the extent to which cultural attitudes affect social adaptation (Searle and Ward, 1990). When cultural anxiety is low, positive cultural attitudes are more likely to translate into proactive social behaviors; conversely, under high-anxiety conditions, individuals may suppress their willingness to engage socially due to defensive psychological responses. Therefore, cultural anxiety not only directly impacts the development of cultural attitudes but may also function as a moderating factor in the relationship between cultural attitudes and social adaptation.

As learning adaptation improves, international students become better equipped to understand the host country's educational system, thereby enhancing their academic performance and boosting their self-confidence. This enhanced academic foundation, in turn, fosters more frequent interactions with teachers and peers, strengthens social confidence, and facilitates smoother integration into the new environment (Jieyi et al., 2022). Therefore, learning adaptation positively influences social adaptation by promoting both self-confidence and social competence.

As psychological adaptation improves, international students become more capable of coping with culture shock and emotional stress, enhancing their self-regulation abilities and emotional stability, and increasing their confidence in establishing interpersonal connections. This, in turn, encourages more active participation in social situations and facilitates smoother integration into the new environment (Holliman et al., 2022). Therefore, psychological adaptation positively influences social adaptation by strengthening emotional stability and social confidence.

Building on the above discussion, cultural cognition, cultural attitudes, and cultural anxiety not only directly influence learning, social, and psychological adaptation, but also interact with one another in shaping cross-cultural adjustment outcomes. Specifically, higher cultural cognition and lower cultural anxiety are expected to foster more positive cultural attitudes, which in turn facilitate social engagement and integration. Moreover, learning and psychological adaptation processes may reinforce one another, collectively supporting better social

adaptation. Based on these theoretical considerations, the following hypotheses are proposed:

H3a. The level of cultural cognition positively influences cultural attitudes.

H3b. The alleviation of cultural anxiety positively influences cultural attitudes.

H3c. Learning adaptation positively influences social adaptation.

H3d. Psychological adaptation positively influences social adaptation.

3.5. The moderating role of perceived ease of use of generative AI

The Technology Acceptance Model (Davis, 1989) identifies perceived ease of use as a critical factor influencing users' acceptance and utilization of technology. When users perceive a system or technology as easy to learn and operate, their willingness to adopt it and overall satisfaction typically increase significantly (Akour et al., 2006). In the context of cross-cultural research, perceived ease of use is further refined into three dimensions: ease of operation, ease of learning, and ease of interaction. Ease of operation refers to the convenience with which international students can use the system, reducing usage barriers and facilitating information acquisition(Raza et al., 2011), thereby supporting the understanding and internalization of cultural knowledge. Ease of learning emphasizes students' ability to quickly master system functions, lowering learning thresholds and promoting continued engagement(Roldán-Álvarez et al., 2016), enabling more efficient acquisition and practice of social strategies and gradually fostering open and inclusive cultural attitudes. Ease of interaction focuses on the quality of students' engagement with the system, including naturalness, coherence, and timely feedback, which may improve interaction experiences(Görnemann and Spiekermann, 2024), alleviate cultural anxiety, and support emotional regulation. Therefore, high perceived ease of use may amplify the positive effects of generative AI in enhancing international students' cultural cognition, attitude adjustment, and emotional regulation.

In the process of cross-cultural adaptation, the ease and smoothness of operating generative AI directly influence its effectiveness in providing information support. Perceived ease of use can enhance international students' focused engagement (Venkatesh and Davis, 2000), lower cognitive and operational barriers, and increase both their willingness to use the system and the perceived usefulness of the technology (Davis, 1989). Consequently, it improves the efficiency of information acquisition and facilitates the absorption and internalization of cultural knowledge (Zhou, 2012). Therefore, when generative AI exhibits a high degree of ease of use, its role in promoting international students' cultural cognition through information support becomes significantly more pronounced.

Whether international students can quickly master the operation of generative AI for social simulation, language practice, and contextual strategy acquisition directly influences the effectiveness of its social support function in shaping cultural attitudes. Ease of learning reduces cognitive barriers, thereby increasing international students' willingness to adopt the technology (El-kasim and Idid, 2016) and fostering the development of sustained usage habits (Venkatesh et al., 2016). Consequently, this facilitates international students' deeper understanding of social norms and promotes the cultivation of a more open and inclusive cultural attitude. Therefore, a high ease of learning for generative AI enhances the impact of social support on cultural attitudes.

The naturalness, coherence, and consistency of generative AI's language interaction directly influence its emotional support function. Smooth and fluent interactions can simulate empathetic conversations and provide comforting suggestions, thereby facilitating international students' reception of emotional feedback, alleviating cultural anxiety, and enhancing effective emotion regulation, which in turn boosts self-confidence (Morris et al., 2018). Therefore, a high level of interaction fluency in generative AI strengthens the role of emotional support in mitigating cultural anxiety.

The above literature suggests that, as a form of technological support in cross-cultural contexts, generative AI differs in its usability features, which influence the extent to which international students can effectively utilize informational, social, and emotional support. When such technologies are easier to use, learn, and interact with, the supportive functions they provide are more likely to be fully utilized, thereby strengthening their effects on cultural cognition, cultural attitudes, and the alleviation of cultural anxiety. Based on these theoretical considerations, the following hypotheses are proposed:

H4a. The ease of use of generative AI positively moderates the effect of information support on cultural cognition.

H4b. The ease of learning of generative AI positively moderates the effect of social support on cultural attitudes.

H4c. The ease of interaction of generative AI positively moderates the effect of emotional support on the alleviation of cultural anxiety.

Based on the above theoretical framework and hypotheses, and following the stimulus–organism–response (S–O–R) framework, this study conceptualizes generative AI–enabled informational, social, and emotional support as stimuli; cultural cognition, cultural attitudes, and cultural anxiety as organismic responses; and learning, social, and psychological adaptation as adaptation outcomes, which together organize these constructs and their hypothesized relationships into an integrated analytical structure. The proposed research model is presented in Fig. 1.

4. Methodology

4.1. Measurement

To ensure the quality of the measurement scales, all measurement items for the variables in this study were adapted from existing literature and appropriately modified to fit the research context of cross-cultural adaptation (see Table 1). Specifically, the measurement items for information support were adapted from Liang et al. (2011); social support from Cutrona and Russell (1990); emotional support from Zimet et al. (1988); cultural cognition from Ang et al. (2007); cultural attitudes from Berry et al. (1989); cultural anxiety from Gudykunst et al. (1988); learning adaptation from Baker and Siryk (1984); social adaptation from Ward and Kennedy (1999); psychological adaptation from Biesecker et al. (2013); and perceived ease of use from Davis (1989) and operationalized into three dimensions: ease of operation, ease of learning, ease of interaction. All questionnaire items employed a 7-point Likert scale, with "1" representing "strongly disagree" and "7" representing "strongly agree."

Gender, age, educational level, and duration of overseas study were included as controls because prior research has found associations between these variables and cross-cultural adaptation outcomes(Holliman et al., 2022; Poyrazli et al., 2004). Duration of study abroad has been shown to influence psychosocial adaptation trajectories (Pedersen, 1995), while educational level and age often correlate with coping resources and strategy use during cultural transition(Smith and Khawaja, 2011). Controlling for these variables improves the precision of estimated relationships between generative AI use and adaptation outcomes. Therefore, beyond testing the main hypotheses, exploratory subgroup analyses were conducted to examine demographic heterogeneity in the model pathways.

4.2. Sample and data collection

The sample for this study was collected using a combination of online and offline methods. For the online portion, the research team distributed the questionnaire through mainstream social media platforms (e.g.,

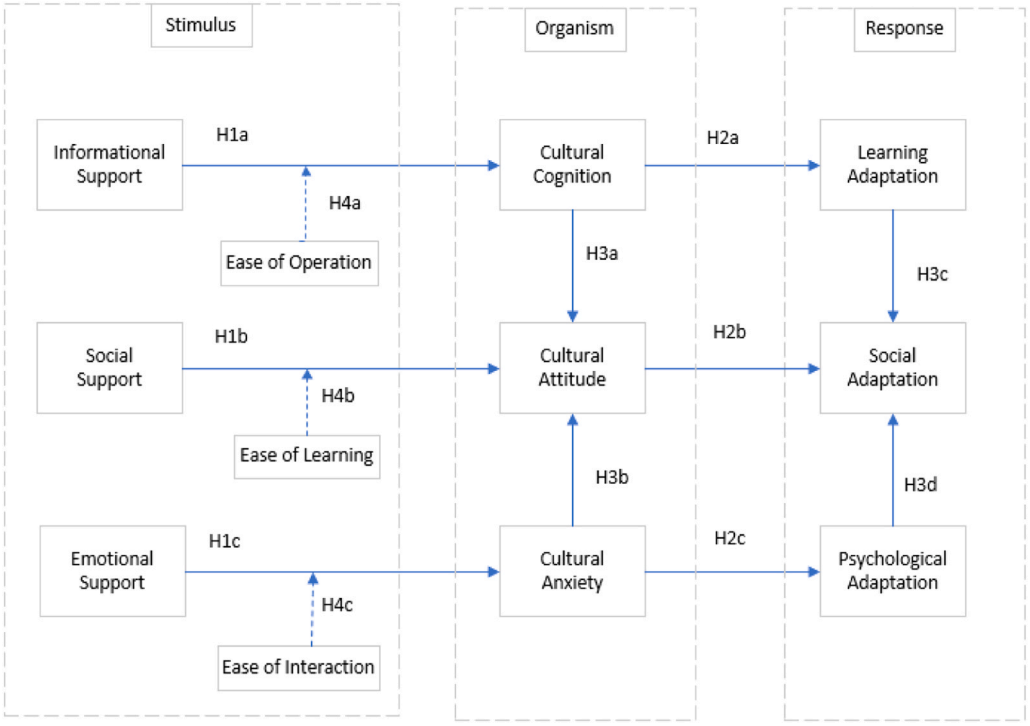

Fig. 1. Research model.

WeChat, Xiaohongshu, and WhatsApp) employing both direct distribution and reciprocal sharing approaches. For the offline portion, international students in the UK were invited to complete the questionnaire on-site via an online link provided in libraries and study rooms at several British universities. The data collection period spanned from March 7 to April 12, 2025, lasting a total of 37 days. The average completion time for the questionnaire was 5 min and 6 s. In total, 455 valid responses were collected.

To minimize the impact of low-quality responses—such as rapid completion, excessive selection of neutral options (Baumgartner and Jan-Benedict, 2001), or repetitive use of the same response option (Huang et al., 2012)—the following screening criteria were applied to ensure response validity:

(1) Responses completed in less than 2 min were excluded(Given that non-native speakers read at an average speed of 100–200 words per minute, it takes at least 2 min to complete this survey questionnaire.
(2) Responses with more than 90% of answers marked as "neutral" or with over 90% identical responses were also excluded.

After screening, a total of 439 valid responses were retained, resulting in a valid response rate of 96.48%. The demographic characteristics of the sample are presented in Table 2.

5. Data analysis and findings

5.1. Sample profile

The demographic profile of the respondents was analyzed in terms of gender, age, educational level, duration of overseas study, English proficiency, and AI usage duration (see Table 2 for details).

5.2. Reliability and validity testing

To assess the reliability and validity of the measurement scales, a series of systematic tests were performed. The detailed results are presented in Table 3 and Table 4.

As shown in Table 3, all factor loadings exceed 0.7, indicating that each item exhibits strong explanatory power for its corresponding latent construct. The Cronbach's α values for all latent variables range from 0.728 to 0.967, all above the threshold of 0.6 (Nunnally, 1978), and the composite reliability (CR) values range from 0.847 to 0.960, all surpassing the recommended cutoff of 0.7, suggesting good scale reliability. Furthermore, the average variance extracted (AVE) values reported in Table 3 range from 0.649 to 0.968, all exceeding the 0.5 benchmark, indicating strong convergent validity. Table 4 demonstrates that the square root of the AVE for each construct (bolded values on the diagonal) is greater than its correlations with other constructs, thereby confirming good discriminant validity of the measurement scales. Collectively, these results confirm that the scales employed in this study exhibit satisfactory reliability, convergent validity, and discriminant validity, following the criteria proposed by Fornell and Larcker (1981).

5.3. Common method bias test

During data collection, similarities in question context (Podsakoff et al., 2003), measurement environment (Spector, 2006), and data sources (Chang et al., 2010) may introduce bias, resulting in common method bias (CMB) that compromises the validity of the model. To assess the presence of CMB, this study follows the criterion proposed by Kock et al. (2012), which posits that if the variance inflation factor (VIF) for all latent variables is less than or equal to 3.3, common method bias can be considered absent. As shown by the VIF values reported in Table 5, all latent variables in this study have VIFs ranging from 1.000 to 2.940, all below the threshold of 3.3, indicating that common method bias is unlikely to be a concern in this research.

5.4. Hypothesis testing

The four groups of research hypotheses proposed earlier were empirically tested using SmartPLS 4.1, with the results presented in Table 6 and Fig. 2. In Fig. 2, the numbers on the arrows indicate path coefficients, with their significance levels indicated. According to the p-

Table 1
Questionnaire items used in this study.

Variables	Items	Source
Information support (IS)	Helps deepen my understanding of the local culture Helps me understand the education system and learning methods of the study-abroad country	Liang et al. (2011)
Social support (SS)	Helps me interact more smoothly with locals and understand behaviors and ideas from different cultural backgrounds Helps me become more accepting of different cultures and more willing to actively engage with locals	Cutrona and Russell (1990)
Emotional support (ES)	Helps alleviate anxiety caused by cultural differences Makes my emotions more stable and makes it easier to adapt to the local culture	Zimet et al. (1988)
Cultural cognition (CC)	improve my understanding of the educational system and learning behavior norms in the host country enhanced my awareness of the cultural values	Ang et al. (2007)
Cultural attitude (CAT)	Encourages me to participate more actively in local cultural activities and social events. Makes me more proactive in establishing connections in unfamiliar social settings Helps me adapt to new social environments	Berry et al. (1989)
Cultural anxiety (CAN)	Helps me relieve nervousness and reduces my anxiety Enhances my psychological adaptation ability	Gudykunst et al. (1988)
Learning adaptation (LA)	I can adapt to the teaching methods (classroom interaction, assignments, assessments) and understand the course content in the study-abroad country I can use the study-abroad country's learning resources (e.g., libraries, online platforms) to support my studies I can express academic opinions clearly, communicate effectively with teachers and classmates, and actively participate in class discussions	Baker and Siryk (1984)
Social adaptation (SA)	I can build friendly relationships with locals, adapt to local social culture, and interact smoothly. I can handle daily tasks (e.g., shopping, dining, using public transportation) in the study-abroad country. I can build a social network in the study-abroad country and gain necessary support.	Ward and Kennedy (1999)
Psychological adaptation (PA)	I feel comfortable living in the study-abroad country and enjoy new cultural experiences. I can effectively manage stress caused by cultural differences and avoid feeling anxious or lonely. I feel confident and at ease when communicating with people from different cultural backgrounds, without feeling nervous or uneasy.	Biesecker et al. (2013)
Ease of operation (EO)	I find it easy to get AI to do what I want it to do Ease of operation allows me to quickly find the information I need Ease of operation enhances my efficiency in using AI	Davis (1989)
Ease of learning (EL)	Learning to operate AI is easy for me I can quickly learn how to use AI effectively It is easy for me to become skillful at using AI	Davis (1989)
Ease of interaction (EI)	AI responds quickly to my inputs AI responds smoothly and accurately to my inputs My interaction with AI is clear and understandable	Davis (1989)

Table 2
Demographic profile of the respondents.

Demographic factor		Frequencies	Percentages (%)
Gender	Male	138	31.4
	Female	301	68.6
Age	18–21	116	26.4
	22–25	255	58.1
	26–30	43	9.8
	30 and above	25	5.7
Educational Level	Undergraduate	297	67.7
	Master	100	22.8
	PhD	33	7.5
	Postdoctoral researcher	9	2.0
Duration of overseas study	Less than 1 year	134	30.5
	1–2year	102	23.2
	2–3year	85	19.4
	3–4year	55	12.5
	More than 4 years	63	14.3
English proficiency[a]	Basic	30	6.8
	Beginner	39	8.9
	Intermediate	225	51.3
	Fluent	110	25.1
	Very fluent	35	8.0
AI usage duration (hours per day)	Less than 1 h	128	29.2
	1–3 h	191	43.5
	3–5 h	89	20.3
	5–8 h	22	5.0
	More than 8 h	9	2.1

[a] Self-reported perceived English communication ability in academic and daily-life contexts

values shown in Table 6, all hypotheses were supported except for H4b and H4c. Most path coefficients were significant at the 1% level, hypothesis H4a was significant at the 5% level, and hypothesis H3a was significant at the 10% level.

5.5. Findings

Our findings show that generative AI plays a constructive role in facilitating international students' cross-cultural adaptation by offering multidimensional support, namely informational, social, and emotional. Informational support significantly enhances students' cultural cognition, allowing them to develop a deeper understanding of and adapt more effectively to foreign cultural contexts. Social support, meanwhile, positively influences their cultural attitudes by encouraging openness to and engagement with cultural diversity. Emotional support proves crucial in alleviating cultural anxiety, helping students to better manage emotional stressors encountered in unfamiliar environments. These results confirm hypotheses H1a, H1b, and H1c, illustrating that generative AI meaningfully contributes to improvements in cultural cognition, emotional regulation, and intercultural attitudes.

Furthermore, the study finds that cultural cognition, cultural attitudes, and cultural anxiety are critical internal mechanisms influencing international students' adaptive outcomes. Enhanced cultural cognition enables students to navigate foreign academic systems more effectively, thereby improving their learning adaptation. Likewise, the development of positive cultural attitudes supports deeper social engagement and integration, leading to stronger social adaptation. Reduced cultural

Table 3
Loadings, composite reliability and average variance extracted.

Constructs	Loadings	Cronbach's alpha	Composite reliability (rho_c)	Average variance extracted (AVE)
Information support (IS)	0.916 0.921	0.815	0.915	0.844
Social support (SS)	0.939 0.935	0.862	0.935	0.879
Emotional support (ES)	0.959 0.959	0.913	0.958	0.920
Cultural cognition (CC)	0.949 0.972	0.918	0.960	0.923
Cultural attitude (CAT)	0.900 0.871	0.864	0.917	0.786
Cultural anxiety (CAN)	0.983 0.985	0.967	0.984	0.968
Learning adaptation (LA)	0.849 0.837 0.804	0.774	0.869	0.689
Social adaptation (SA)	0.807 0.746 0.860	0.728	0.847	0.649
Psychological adaptation (PA)	0.818 0.864 0.830	0.786	0.875	0.701
Ease of operation (EO)	0.848 0.814 0.824	0.774	0.868	0.687
Ease of learning (EL)	0.821 0.854 0.858	0.799	0.882	0.713
Ease of interaction (EI)	0.804 0.873 0.841	0.791	0.878	0.705

anxiety mitigates psychological stress, equipping students to handle emotional fluctuations more calmly and enhancing their psychological adaptation. These findings support hypotheses H2a, H2b, and H2c, underscoring the importance of these cognitive, attitudinal, and emotional pathways in the cross-cultural adaptation process.

In addition, the results reveal tightly interwoven relationships among cognition, emotion, and attitude—as well as among the different dimensions of adaptation. An increase in cultural cognition not only deepens students' understanding of the host culture but also nurtures more inclusive and accepting cultural attitudes. Reduced cultural anxiety alleviates negative emotional experiences and simultaneously strengthens students' openness to unfamiliar cultural norms, supporting hypotheses H3a and H3b. Effective learning adaptation boosts confidence and promotes greater engagement in academic settings, which in turn facilitates social participation. Similarly, psychological adaptation enhances students' ability to manage emotional stressors during social interactions, smoothing their integration into the host society. These findings confirm hypotheses H3c and H3d, and demonstrate the systemic, mutually reinforcing nature of the adaptation process.

Finally, While the perceived ease of use of generative AI, encompassing ease of operation, ease of learning and ease of interaction, shows some moderating effects, its overall influence on cross-cultural adaptation remains limited. The analysis indicates that ease of operation enhances the impact of informational support on cultural cognition—suggesting that user-friendly AI platforms can lower barriers to access and improve students' ability to find and utilize relevant resources. However, the ease of learning does not significantly moderate the relationship between social support and cultural attitudes. This suggests that the development of cultural attitudes may be more influenced by deeper socio-emotional factors, such as prior cultural experiences and personal dispositions, than by the simplicity of AI tools. Similarly, ease of interaction shows only a minimal effect on the

Table 4
Assessment of discriminant validity (Fornell–Larcker criterion).

Constructs	**IS**	**SS**	**ES**	**CC**	**CAT**	**CAN**	**LA**	**SA**	**PA**	**EO**	**EL**	**EI**
IS	**0.918**											
SS	0.699	**0.937**										
ES	0.654	0.690	**0.959**									
CC	0.866	0.607	0.567	**0.961**								
CAT	0.689	0.791	0.688	0.614	**0.887**							
CAN	0.636	0.701	0.936	0.568	0.691	**0.984**						
LA	0.283	0.233	0.201	0.345	0.243	0.226	**0.830**					
SA	0.350	0.328	0.330	0.368	0.341	0.321	0.618	**0.806**				
PA	0.338	0.354	0.373	0.303	0.381	0.382	0.498	0.590	**0.837**			
EO	0.702	0.709	0.666	0.671	0.742	0.677	0.351	0.372	0.325	**0.829**		
EL	0.692	0.712	0.683	0.661	0.744	0.688	0.341	0.407	0.362	0.865	**0.844**	
EI	0.696	0.724	0.717	0.635	0.769	0.727	0.326	0.344	0.382	0.858	0.867	**0.840**

Table 5
Results of Common Method Bias Test.

	IS	SS	ES	CC	CAT	CAN	LA	SA	PA
IS				2.175					
SS					2.604				
ES						2.072			
CC					1.951		1.000		
CAT								1.175	
CAN					2.338				1.000
LA								1.335	
SA									
PA								1.469	
EO				2.060					
EL					2.940				
EI						2.331			
EO*IS				1.479					
EL*SS					1.498				
EI*ES						1.381			

Table 6
Results of hypothesis testing.

Hypotheses	Original sample (O)	Sample mean (M)	Standard deviation	T statistics	P values	Results
H1a : IS ->CC	0.750	0.750	0.049	15.339	0.000	Support
H1b : SS -> CAT	0.455	0.459	0.056	8.176	0.000	Support
H1c : ES -> CAN	0.851	0.850	0.025	34.212	0.000	Support
H2a : CC -> LA	0.345	0.345	0.070	4.944	0.000	Support
H2b : CAT-> SA	0.109	0.108	0.038	2.846	0.004	Support
H2c : CAN -> PA	0.382	0.382	0.053	7.268	0.000	Support
H3a : CC ->CAT	0.085	0.083	0.050	1.686	**0.092**	Support
H3b : CAN-> CAT	0.140	0.141	0.053	2.620	0.009	Support
H3c : LA -> SA	0.424	0.425	0.057	7.446	0.000	Support
H3d : PA ->SA	0.338	0.337	0.057	5.886	0.000	Support
H4a : EO * IS -> CC	0.042	0.042	0.021	2.008	**0.045**	Support
H4b : EL * SS ->CAT	0.026	0.027	0.017	1.557	**0.120**	Reject
H4c : EI * ES ->CAN	0.009	0.010	0.010	0.924	**0.356**	Reject

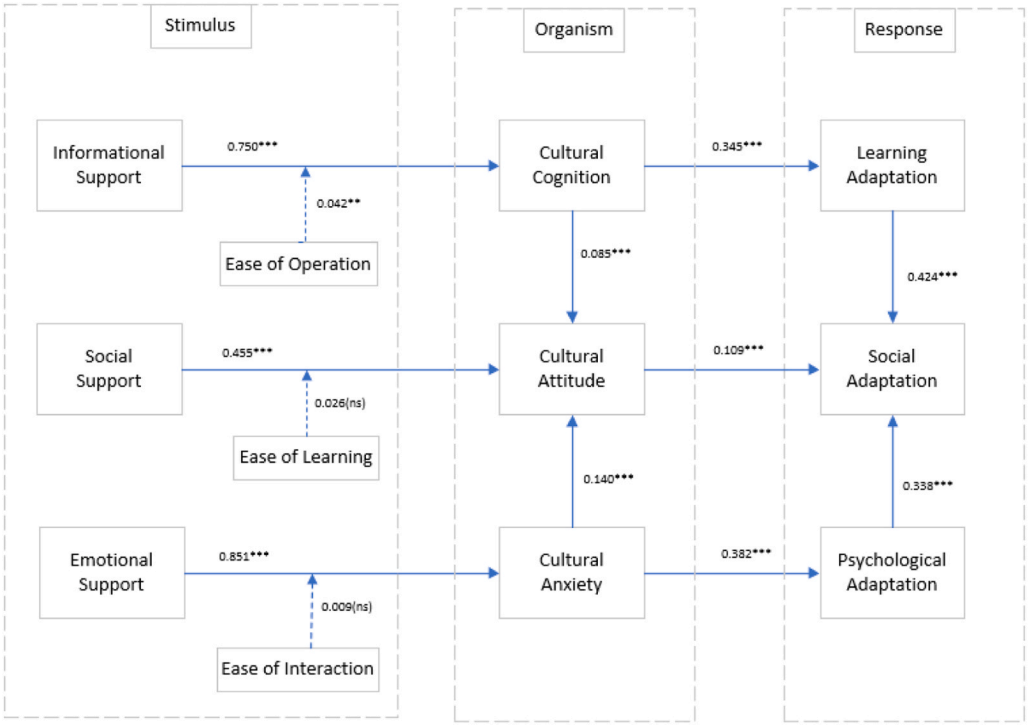

Fig. 2. Research model results. Note(s): ***: $p < 0.01$; **: $p < 0.05$; *: $p < 0.10$; ns: not significant.

relationship between emotional support and cultural anxiety. Although smooth technical interaction may aid communication, the effectiveness of emotional support appears to rely more on empathy and relational depth than on interface design. Therefore, while perceived ease of use plays a facilitating role—particularly in accessing informational support—its broader moderating influence across the cross-cultural adaptation framework is relatively modest. It should be noted that individual differences, language proficiency, and prior cross-cultural experience may influence the moderating effect of perceived ease of use, suggesting that its effect may vary depending on users' characteristics.

6. Exploratory subgroup analysis

To examine whether demographic and usage differences significantly influence the hypothesized pathways, an exploratory subgroup analysis was conducted using the following grouping variables: gender (male vs. female), educational level (undergraduate vs. master's and above), duration of study abroad (1 year or less vs. more than 1 year), based on Pedersen (1995) finding that new immigrants or international students typically undergo an adjustment period of six months to one year, especially in terms of psychosocial adaptation, English proficiency (intermediate and below vs. above intermediate), and daily AI usage time (less than 3 h vs. more than 3 h per day). The latter criterion is informed by Kuss et al. (2014), who suggest that internet use exceeding three hours per day may be associated with a heightened risk of internet addiction. The results of the path comparisons across these subgroups are presented in Table 7, with the reported values indicating the p-values for the differences between groups.

According to the results presented in Table 7, aside from AI usage duration, differences in gender, educational level, duration of overseas study, and English proficiency all exhibit significant variation in certain impact paths.

Cultural attitude exerts a significant positive effect on social adaptation for both male and female students; however, the underlying mechanisms of this influence differ by gender. Female students may be more inclined to translate positive cultural attitudes into socially integrative behaviors, such as active participation in group activities and a stronger sense of belonging, through emotional identification and

Table 7
Results of exploratory subgroup analysis.

Hypotheses	Gender	Academic level	Duration of overseas study	English proficiency	AI usage duration
H1a : IS -> CC	0.971	0.393	0.847	0.080	0.069
H1b : SS -> CAT	0.346	0.585	0.390	**0.048**	0.751
H1c : ES -> CAN	0.420	0.982	0.160	0.879	0.358
H2a : CC -> LA	0.403	0.749	0.718	0.158	0.886
H2b : CAT ->SA	**0.000**	0.140	0.731	0.852	0.081
H2c : CAN ->PA	0.722	**0.032**	0.807	0.206	0.208
H3a : CC -> CAT	0.782	0.533	0.862	0.542	0.642
H3b : CAN -> CAT	0.640	0.512	0.366	0.077	0.552
H3c : LA ->SA	0.464	**0.048**	**0.048**	0.014	0.724
H3d : PA ->SA	0.073	0.111	0.282	0.126	0.297
H4a : EO * IS ->CC	0.198	0.873	0.568	**0.031**	0.875
H4b : EL * SS ->CAT	0.201	0.060	0.824	0.706	0.323
H4c : EI * ES ->CAN	0.221	0.091	**0.012**	0.731	0.143

interpersonal engagement, thereby enhancing their social adaptation. In contrast, male students tend to focus more on understanding and adhering to local cultural norms, channeling their cultural attitudes into effective adaptation across academic, professional, and everyday social domains, which in turn facilitates improved social integration.

Differences were also observed in the paths from cultural anxiety to psychological adaptation and from learning adaptation to social adaptation across educational levels. These variations may stem from the fact that individuals with higher educational attainment generally possess stronger cognitive and problem-solving skills, enabling them to more effectively manage cultural anxiety and achieve better psychological adaptation. Moreover, they are likely to have broader academic experience and stronger self-regulation abilities, which help them adjust learning strategies more efficiently, thus improving both learning and social adaptation. In contrast, those with lower levels of education may have more limited cognitive resources and adaptive strategies, making them more susceptible to challenges in psychological and social adjustment.

Variation in path relationships also emerged across groups with different durations of overseas study. Notably, differences were identified in the paths from learning adaptation to social adaptation and from the interaction of perceived ease of use and emotional support to cultural anxiety. Students who have spent more time studying abroad tend to accumulate richer academic and cultural experiences, allowing them to adjust learning strategies more effectively and thereby enhance their social adaptation. They are also more familiar with and reliant on AI-based support tools, which enables them to better leverage emotional support from AI to reduce cultural anxiety. In contrast, students with shorter overseas experiences may have limited exposure to local contexts and fewer opportunities to utilize support resources effectively, leading to less pronounced benefits along these paths.

Finally, significant differences were found across English proficiency groups in the paths from social support to cultural attitude, from learning adaptation to social adaptation, and from the interaction of perceived ease of use and information support to cultural cognition. These results likely reflect the fact that English proficiency directly affects students' ability to access, interpret, and apply cultural and social information. Students with higher proficiency typically exhibit stronger information-processing capabilities, enabling them to make more effective use of AI-provided social support, which fosters more positive cultural attitudes. Their stronger language skills also facilitate a deeper understanding of cultural content during the learning process, thus enhancing social adaptation. In addition, greater ease with English improves the operability of AI and related information technologies, reinforcing the impact of information support on cultural cognition. These combined factors help explain the significant differences observed in these pathways.

7. Discussion and conclusions

7.1. Discussion

The findings of this study extend existing research on cross-cultural adaptation in three ways. First, consistent with adaptation models emphasizing the role of contextual support (Berry, 1997; Kim, 2001), we show that generative AI can facilitate cultural cognition, emotional regulation, and attitudinal openness by providing informational, social, and emotional support. This extends prior work by identifying generative AI as a novel form of technologically mediated support within international higher education. Second, this study further discusses the interrelationships among cultural cognition, cultural attitudes, and cultural anxiety within the S-O-R framework. The results demonstrate that the cognitive, emotional, and attitudinal components of adaptation interact to shape downstream academic, psychological, and social outcomes, aligning with systemic and multidimensional conceptualizations of cultural adjustment(Smith and Khawaja, 2011; Ward and Kennedy, 1999). This contributes to ongoing efforts within international education to move beyond linear or stage-based models of adaptation. Third, subgroup analyses indicate that individual characteristics such as language proficiency and educational level influence how students benefit from generative AI. This finding highlights the importance of differentiated and inclusive support structures within universities, particularly for students with lower proficiency or more limited prior exposure to international environments."

7.2. Conclusions

Grounded in the S-O-R framework, this study examines how generative AI influences international students' cross-cultural adaptation. The findings show that generative AI provides informational, emotional, and social support, which in turn enhances students' cultural cognition, emotional regulation, and cultural attitudes. These internal changes significantly contribute to academic, psychological, and social adaptation. The results also highlight strong interconnections between cognitive, emotional, and attitudinal factors, as well as meaningful variation based on individual characteristics such as gender, educational level, duration of study abroad, and English proficiency.

This research contributes to cross-cultural adaptation theory by integrating generative AI as an environmental stimulus and advancing a multidimensional understanding of adaptation as an interactive and dynamic process. It challenges linear and compartmentalised approaches by emphasising the co-evolution of adaptation domains and offers a systems-based perspective that more accurately reflects the lived experiences of international students.

Practically, the findings suggest that generative AI can serve as a valuable tool in institutional support strategies. Universities may consider incorporating AI into student services to deliver personalised guidance across cultural, academic, and emotional domains. A phased model of adaptation, beginning with academic adjustment, followed by emotional regulation and social integration, can be supported through AI-driven platforms that evolve alongside students' changing needs. At the same time, the limited moderating effect of ease of use points to the need for a balanced "AI + human" approach. While AI can offer

immediate and scalable support, human-led services such as counselling, peer mentorship, and intercultural training remain essential for emotional resonance and context-sensitive support.

Given the significant role of individual background factors in shaping adaptation pathways, the study also advocates for more personalised and adaptive AI design. Systems should respond flexibly to users' linguistic, educational, and cultural profiles, allowing for differentiated interaction and tailored content delivery. Moving beyond a one-size-fits-all model, a student-centred, responsive AI framework can better support diverse adaptation needs and facilitate more effective and inclusive international education environments.

7.3. Limitation and future research

This study has several limitations that suggest avenues for future research. First, the study treated generative AI as a unified category without distinguishing between specific tools or functions. Second, Participants were primarily recruited through social media platforms (WeChat and Xiaohongshu), and the voluntary, network-based nature of participation made stratified sampling challenging. Given the user base of these platforms and the focus on English-medium universities in the United Kingdom, the sample likely consisted predominantly of students of Asian descent, which may limit the generalizability of the findings to multilingual or non-English contexts. Third, proficiency and individual characteristics were self-reported, which may introduce perceptual variance. Future research could extend these findings through longitudinal designs, cross-context comparisons, or by examining specific AI tools in detail.

CRediT authorship contribution statement

Xinling Zhu: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Jessica Hong Yang:** Writing – review & editing, Validation, Supervision, Project administration, Conceptualization.

Declaration of Competing Interest

The authors declare that there is no conflict of interest regarding this research.

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Ethics statement

Ethical approval was obtained from the University of Reading (Reference: SREC-HBS-20250522-XIZH0836), and informed consent was obtained from all participants.

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