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Acculturative stress, loneliness, smartphone addiction, L2 emotions, and creativity among international students in China: a structural equation model

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Introduction: International students in China often face psychological challenges such as acculturative stress, loneliness, and problematic smartphone use, which may affect their second language (L2) learning emotions and creativity. Although these factors have been studied individually, their interrelationships remain unclear.

Methods: Data were collected from 213 international students studying in China using validated instruments: the *Acculturative* Stress Scale for International Students (ASSIS), *UCLA* Loneliness Scale, *Smartphone Addiction Scale Short Version* (SAS-SV), *Foreign Language Enjoyment and Classroom Anxiety Scale* (FLE & FLCA), and the *Inventory of Creative Activities and Achievements* (ICAA). Structural equation modeling (SEM) was employed to assess the hypothesized model and test both direct and indirect relationships among the constructs.

Results: Acculturative stress significantly predicted smartphone addiction directly (β = 0.372, $p < .001$) and indirectly via loneliness (β = 0.169, $p < .005$). It also influenced FLCA through a chain mediation of loneliness and smartphone addiction (β = 0.135, $p < .005$). In terms of creativity, both acculturative stress (β = 0.300, $p < .001$) and FLE (β = 0.310, $p < .001$) positively predicted creative activities, which in turn strongly predicted creative achievement (β = 0.700, $p < .001$). FLCA was also positively related to creative achievement (β = 0.118, $p = .016$).

Discussion: These findings support the Dual Pathway to Creativity Model and suggest that long-term moods (e.g., acculturative stress) and situational emotions (e.g., FLE and FLCA) may differentially affect creativity, aligning with the Hierarchical Model of Affect, Mood, and Emotion, advancing the understanding of international students' cross-cultural adaptation in the digital age.

1 Introduction

The landscape of international education has evolved significantly, with China emerging as a leading destination for global learners (1). Recent data from the State Council Information Office of China indicate that by September 2024, students from 195 countries and regions were pursuing education in China, with the total number of international Chinese language learners exceeding 200 million[1]. This educational internationalization presents unique challenges for students navigating cross-cultural environments, particularly in terms of acculturative stress and loneliness (2–6).

In this digital era, where global smartphone usage has reached 69.4% of the population (7) and Chinese university students average 6.21 hours of daily smartphone use (8), mobile devices serve dual roles as cognitive extensions (9) and potential sources of behavioral addiction (10–12).

Creativity, widely recognized as a cornerstone of contemporary education (13, 14), presents an intriguing paradox in relation to smartphone use and emotional states. While mobile devices can enhance divergent thinking through improved information access (15, 16) and boost critical thinking and creative self-efficacy (17), their excessive use may impair creativity by consuming cognitive resources and disrupting attentional processes (18–20). Similarly, the relationship between emotions and creativity remains complex, with some studies suggesting that negative emotions diminish cognitive flexibility (21, 22), while others argue that negative emotions can enhance persistence and effort, thus fostering creativity (23, 24).

While prior research has explored the individual impacts of acculturative stress, loneliness, smartphone addiction, and L2 emotions on international students (25–28), few studies have examined their combined interplay and collective influence on creativity, particularly in the context of international students in China. Moreover, the application of structural equation modeling (SEM) to investigate the mediating roles of loneliness, smartphone addiction, and L2 emotions in the relationship between acculturative stress and creativity remains underexplored. This study addresses these gaps by proposing and testing an SEM framework that elucidates these complex pathways, offering a novel contribution to understanding cross-cultural adaptation and creativity in a digital and multilingual educational setting.

1.1 Literature review

1.1.1 Acculturative stress and loneliness in international students

International students constitute a distinct population that has attracted increasing scholarly attention in recent years (29). Unlike their domestic counterparts, these students face unique challenges stemming from their immersion in foreign, non-native language environments (30), which make them particularly susceptible to acculturative stress (3, 31). Acculturation is a multidimensional

process in which individuals learn and adapt to a new culture while striving to maintain their original cultural identities. This process typically manifests through four primary strategies: assimilation, separation, marginalization, and integration (2, 3). Acculturative stress specifically refers to the psychological and social pressures individuals experience during the cultural adaptation process, which are often intensified by factors such as perceived discrimination and socioeconomic status (3, 32, 33). These pressures frequently manifest as heightened feelings of homesickness and loneliness among international students (34, 35).

Loneliness, defined as a distressing emotional experience arising from perceived deficiencies in social relationships (36), represents a significant adaptation challenge for this population (4, 37). Empirical studies have consistently documented elevated levels of loneliness among international students, with recent research focusing on the exacerbation of these feelings during the COVID-19 pandemic using both qualitative and quantitative methodologies (26, 38, 39).

Although extensive literature exists on the acculturation challenges faced by Chinese international students abroad (5, 6), comparatively fewer studies have focused on international students studying in China. As China has emerged as an increasingly popular destination for higher education, these students encounter unique cultural challenges that are distinct from those in traditional Western host countries. For instance, China's high-context cultural framework - where communication relies heavily on implicit contextual cues, nonverbal signals, and shared cultural knowledge (40) - can amplify L2-related anxiety among students from low-context cultural backgrounds where communication tends to be more explicit and verbally direct (22, 41). A recent comparative study by Ngwira et al. revealed distinct patterns of acculturative stress among Asian and African international students in China, with African students reporting higher stress levels linked to perceived discrimination and Asian students identifying fear and guilt as primary stressors (25).

Moreover, China's distinctive digital ecosystem shapes patterns of smartphone use, potentially creating additional adaptation obstacles (42, 43). Manu et al. found that international students in China strategically increased their social media usage to enhance cultural adaptation and campus engagement (44). Recent studies have also highlighted the challenges of homesickness and loss of social identity faced by international students in China, particularly during pandemic-related border closures (45, 46). These findings underscore the complex interplay among cultural adaptation, technological integration, and psychological well-being among international students in the Chinese educational context.

1.1.2 Smartphone addiction

Unaddressed adaptation challenges may lead to problematic behaviors, such as a heightened risk of smartphone addiction (27, 47–49). Smartphone addiction is broadly defined as excessive and inappropriate reliance on smartphones to the extent that it interferes with daily life, social interactions, mental health, and academic or occupational performance (50, 51). This behavioral addiction manifests through several characteristic features: compulsive usage patterns (50), withdrawal symptoms when

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1 The state council information office of the people's republic of China. Press Con. (2024). https://www.scio.gov.cn/live/2024/34857/index_m.html.

device access is restricted (52), tolerance development requiring increased usage to achieve the same psychological effects (53), and notable functional impairment across various life domains (54). Smartphone addiction shares common psychological and physiological mechanisms with other behavioral addictions, particularly in terms of reward system processing and impulse control (50, 55). Multiple studies have confirmed their adverse effects on student populations, including impaired sleep quality (56, 57), attention deficits (58, 59), deteriorated interpersonal relationships (60, 61), and compromised academic performance (62, 63). These findings were further substantiated by meta-analyses (10, 11, 64, 65).

Research on international students in China suggests that loneliness serves as a significant predictor of smartphone addiction (66, 67), with smartphones offering a 'safer and less demanding' medium for social interaction (68). Other psychological antecedents, including depression (69, 70) and social anxiety, have emerged as key predictors of problematic smartphone use (71–73). Notably, Elhai et al. introduced the concept of "Fear of Missing Out" (FoMO) (74), describing heightened dependence on smartphones as individuals seek to avoid missing critical social interactions or information. This phenomenon may be particularly relevant for international students attempting to maintain connections with their home culture and new social networks in their host countries.

1.1.3 L2 emotions

Emotions constitute a central component of international students' second language (L2) learning experiences (75, 76). Emotions in psychology are broadly defined as transient mental states characterized by physiological responses and observable behaviors (77). However, research in L2 learning contexts has predominantly emphasized negative emotional experiences (75, 78). In particular, anxiety has been identified as one of the most prominent emotional challenges in L2 learning and is conceptualized as a complex interplay of self-perceptions, beliefs, behaviors, and emotional reactions (79). Research has consistently demonstrated its inhibitory effects on L2 acquisition and performance (80).

More recently, however, the academic focus has pivoted toward investigating the role of positive emotions—aligned with the emerging field of positive psychology—in promoting effective L2 learning (81, 82). Among the positive emotions, foreign language enjoyment (FLE) has garnered significant attention. The FLE reflects the state in which psychological needs are met (83) and is considered a core element of positive psychology (84). Studies have consistently revealed that FLE positively correlates with students' willingness to communicate (28), academic achievement (85), and reduced levels of L2 anxiety (86). The research community has developed specialized instruments to measure these L2-specific emotional states, such as the FLE scale and FLCA scale. While these instruments overlap with general emotion scales, they are specifically calibrated to capture the nuanced emotional dynamics of L2 classroom environments (75, 83). These tools provide insight

into how emotions shape international students' experiences and academic trajectories.

It is important to note that previous research may have conflated the concepts of mood and emotion (87). According to the Hierarchical Model of Affect, Mood, and Emotion proposed by Bianchi-Berthouze and Lisetti (88), mood (e.g., cheery and melancholy) typically persists for several days or longer, maintains a global focus and may not be attributed to a specific agency. In contrast, emotions (e.g., surprise, sadness, fear, anger) usually endure for only minutes, are tied to specific events or objects, and are triggered by either internal or external agency, with affect serving as an overarching concept encompassing both. In the context of international students, the stress and loneliness associated with their experiences likely represent long-lasting, persistent states (4, 37, 89), aligning more closely with the mood category. Conversely, short-term emotional experiences such as FLCA and FLE, which arise within specific contexts, align more closely with the definition of emotion (5, 6).

The relationship between smartphone use and emotional states demonstrates intricate, context-dependent patterns, as suggested by the Uses and Gratifications Theory (UGT) (90). The UGT posits that individuals turn to particular media forms, including smartphones, to fulfill various personal needs. In international students, feelings of loneliness and anxiety often drive increased smartphone dependence to satisfy the need for social connections and emotional regulation (67, 91). However, excessive smartphone use can paradoxically exacerbate social isolation and reduce engagement in physical activity (92), ultimately intensifying negative emotional states.

Classroom context adds further complexity to this relationship. In L2 learning scenarios, smartphone addiction has been linked to a diminished attention span, impaired language acquisition, and disrupted academic performance (47). Song et al. emphasized that overreliance on smartphones during L2 learning could weaken social support networks with peers and instructors, thereby increasing classroom anxiety in English as a Foreign Language (EFL) (93). Conversely, strategic smartphone use, such as utilizing mobile translation apps or grammar-check tools, has demonstrated the potential to reduce academic procrastination and enhance learners' enjoyment of their L2 learning experiences (94).

Thus, the interplay between smartphone use and emotional state appears to be bidirectional (95). Although short-term adaptive smartphone use can alleviate anxiety and support productive study routines, long-term maladaptive patterns often lead to adverse emotional and academic outcomes. Distinguishing these contrasting effects remains a key challenge in the field, particularly in studies involving international student populations.

1.1.4 Creativity

Creativity is recognized as a critical cognitive ability influencing individuals' personal, academic, and professional development (96). Defined as the capacity to generate ideas, solutions, or products that are both original and useful (97), creativity encompasses diverse manifestations, ranging from everyday expressions (known as

"little-c creativity") to significant professional achievements ("Pro-C creativity"). Assessment approaches target either creative behaviors or creative outcomes. For instance, the Creative Behavior Inventory (CBI) (98) was designed to measure the frequency of creative behaviors, whereas the Creative Achievement Questionnaire (CAQ) (99) focused on assessing creative outcomes and accomplishments. The Inventory of Creative Activities and Achievements (ICAA) (100) successfully integrates both perspectives, measuring not only the frequency of creative activities but also levels of creative achievements. Unlike the CAQ, which emphasizes professional-level achievements (Pro-C, such as creative writing or scientific discoveries), the ICAA also includes creative accomplishments closer to everyday life (Little-C, such as sports or crafting).

In addition to measuring creative behaviors and achievements, divergent thinking tasks serve as widely used proxies for creativity. For instance, the Alternative Uses Task (AUT) (101, 102) asks participants to list alternative uses for a common object, with creativity scored along dimensions such as fluency (total number of responses), flexibility (diversity of categories represented by responses), and originality (uniqueness and quality of ideas). Another widely utilized tool is the Torrance Test of Creative Thinking (TTCT) (103), which assesses creativity through written and visual tasks, has been extensively adapted into multiple languages, and is employed globally (104, 105).

Furthermore, research has explored alternative dimensions of creativity, such as problem-solving creativity (106) and creative personality assessments, as exemplified by tools such as the Creative Personality Scale (CPS) (107) and more contemporary instruments (108). These multifaceted approaches underscore the inherent complexity of creativity and the contextual nuances that influence its manifestations.

These universal frameworks, however, require contextual adaptation when applied to populations navigating cross-cultural transitions. The investigation of creativity among international students offers unique academic value, given their exposure to diverse cultural environments. This multicultural experience fosters the integration of different perspectives (109), promoting cognitive complexity and flexibility in problem-solving (110). Research has consistently demonstrated that multicultural experiences and creative, supportive activities are positively correlated with innovative ideation (111), whereas emotional trust across cultural boundaries facilitates creative collaboration (112). From a language-learning perspective, bilinguals consistently demonstrate higher creativity levels than monolinguals (113, 114). This advantage stems from enhanced executive function developed through the management of multiple languages (115, 116). The use of a second language introduces unique emotional dynamics, with bilinguals often experiencing emotional distancing when using their L2, particularly negative emotional content (117, 118). Notably, recent research suggests that negative emotions have a diminished impact on creative performance in L2 settings compared to L1 environments, potentially enhancing bilinguals' creative expression in their second language (119).

1.1.5 Smartphone addiction and emotion as mediators between acculturative stress and creativity

Building upon these intercultural creative dynamics, the relationship between smartphone use and creativity exhibits complex and multifaceted patterns that warrant careful examination. Several studies have suggested that smartphone addiction impairs creativity by diverting attention, increasing cognitive load, and depleting the cognitive resources available for creative processes (18, 20, 120). By contrast, a substantial body of research has demonstrated that smartphone use may positively influence creativity by providing access to vast informational resources and diverse opportunities for social interaction, thereby fostering inspiration and ideation (15, 16). This positive influence is further supported by Guan et al., who found that smartphone use positively correlates with creative ideation through the mediating effects of critical thinking and creative self-efficacy (17). Additionally, mobile applications and interaction platforms may facilitate creativity by enhancing motivation, engagement, and collaboration (121, 122).

Recent meta-analytic findings by Olson et al. provided important nuance to this relationship, revealing that correlations between smartphone use and divergent thinking are generally small and inconsistent (rs = −0.09 to 0.09) (123). These inconsistencies suggest that contextual factors, particularly user personality traits, may moderate the relationship between smartphone use and creativity (124). Within this complex dynamic, emotion emerges as a critical mediator that influences the relationship between smartphone addiction and creativity (20, 125).

The emotional dimension becomes particularly salient when considering that smartphone addiction correlates with long-term emotional states, such as acculturative stress and loneliness, while short-term and situational emotional states play crucial roles in shaping creative potential (126). Positive emotions consistently enhance creativity by promoting cognitive flexibility and ideational originality (127–129). These positive emotional states activate memory retrieval (130) and broaden attentional scope (131), enabling individuals to approach problems more creatively (132).

The effects of negative emotions on creativity present a more nuanced perspective. Early research suggested that negative emotions could hinder creativity by reducing cognitive flexibility through approach-avoidance behaviors aimed at minimizing risks and errors (Regulatory Focus Theory) (21). Such avoidance tendencies may particularly impair willingness to engage in creative tasks (133–135). This perspective is supported by Baas et al.'s meta-analysis, spanning 25 years of research, which found that activating positive emotions correlated positively with creativity, whereas activating negative emotions showed negative correlations (128). In educational contexts, anxiety often leads students to adopt risk-avoidant behaviors and avoid challenging tasks that typically foster creative performance (136). Moreover, individual differences significantly influence this emotional-creativity relationship, with those possessing lower dispositional

autonomy showing more pronounced effects of both positive and negative emotions on creativity (137).

However, emerging evidence suggests that negative emotions may enhance creativity under certain conditions. George and Zhou demonstrated that negative emotions can motivate individuals to exert additional effort and engage in more thorough problem-solving behaviors (23). Similarly, Roskes et al. found that negative emotions promote cognitive persistence and augment creative performance in tasks requiring sustained focus (138). This perspective is supported by Akinola and Mendes, who found that individuals with heightened biological vulnerability to stress exhibited enhanced artistic creativity in negative emotional states (139).

The Dual Pathway to Creativity Model (DPCM) proposed by Nijstad et al. offers a comprehensive framework for understanding these seemingly contradictory findings (24). This model posits that both positive and negative emotions can enhance creativity through distinct pathways; positive emotions predominantly foster cognitive flexibility, enabling divergent thinking, whereas negative emotions primarily promote cognitive persistence, facilitating a sustained focus on problem-solving tasks. Baas et al. extended this framework by examining personality traits and found that openness and other positive traits typically influence flexibility, whereas neuroticism and negative trait emotions drive persistence (140). Recent applications of DPCM across various contexts have provided robust empirical validation (141, 142).

Existing research has extensively examined acculturative stress, loneliness, smartphone addiction, L2 emotions, and creativity in isolation. However, few studies have investigated their combined dynamics, especially among international students in China. This study seeks to fill these gaps by exploring how these factors interact to influence creativity in this population.

1.2 The present study

This study investigates the complex interplay between acculturative stress and creativity among international students in China, employing a structural equation model (SEM) to test hypothesized relationships. Our approach is grounded in the Hierarchical Model of Affect, Mood, and Emotion (88), which provides a framework for distinguishing between long-term mood states and short-term emotions. Specifically, we classify acculturative stress and loneliness as enduring mood states that shape broader psychological tendencies over time. In contrast, L2 emotions—such as foreign language classroom anxiety (FLCA) and foreign language enjoyment (FLE)—are treated as transient, context-specific emotional responses tied to language learning experiences. Previous research on the connection between emotion and creativity has often induced short-term emotional states using videos or music (119), aligning with the definition of emotion rather than mood. This distinction is critical because enduring mood states like loneliness may establish a baseline influence on cognitive and behavioral tendencies (143), such as sustained engagement in creative activities, whereas transient

emotions like FLCA and FLE may trigger immediate, context-specific responses that differentially shape creativity. International students in China are particularly susceptible to these dynamics due to cultural and language barriers (40, 41), restricted access to familiar digital platforms (42, 43), and academic pressures in a foreign educational environment (93, 94), amplifying the relevance of this model to their experiences.

Therefore, we propose a structural equation model that hypothesizes that acculturative stress and loneliness serve as contextual antecedents in a broader environment and influence creativity through the mediating effects of smartphone addiction and L2 learning emotions. Based on this framework, we tested the following hypotheses.

> H1: Among international students in China, acculturative stress leads to smartphone addiction, with loneliness serving as a mediator.
>
> H2: Acculturative stress affects L2 learning emotions (foreign language enjoyment and classroom anxiety), with loneliness and smartphone addiction serving as mediators.
>
> H3: Acculturative stress influences creativity (creative activities and achievements) by mediating the effects of loneliness, smartphone addiction, and L2 learning emotions.

2 Research methods

2.1 Participants

Data were collected from October to November 2024 through an offline survey conducted at a university in China. The survey was administered via "WenJuanXing," a professional Chinese survey platform. The questionnaire consisted of sections on informed consent, demographic information, and validated scales measuring acculturative stress, smartphone addiction, loneliness, and L2 learning emotions, as described in the next section.

Given the linguistic diversity of the international student population at this university, the questionnaire was provided in a primary English version as well as in three bilingual versions (English paired with Turkmen, Thai, or Russian). Since some scales did not have empirically validated versions in these languages and because the feasibility of machine translation has been verified (144)—we used ChatGPT to generate draft translations. Two native-speaking researchers specializing in linguistics and applied linguistics to each language cross-verified the drafts to ensure their reliability.

The survey distribution was facilitated through WeChat, China's predominant social media platform, with instructors sharing survey invitations and links in international student classes. The inclusion criteria were as follows: (1) non-Chinese nationality; (2) current study experience in China; (3) age 18 years or older; (4) ownership and ability to use a personal smartphone; and (5) proficiency in reading English, Thai, Turkmen, or Russian. The survey took approximately 20 minutes to complete, and

participants retained the right to withdraw or retract their data at any time during the process.

From the 222 completed questionnaires, we excluded six responses showing highly patterned answers and three containing logical inconsistencies (such as reporting extremely high creative achievement scores alongside minimal creative activity participation). The final analysis included data from 213 participants (107 males and 106 females), yielding an effective response rate of 95.95%. The sample comprised students from diverse native language backgrounds: Turkmen (n=102), Thai (n=34), Russian (n=45), and English (n=32). Participants represented various academic disciplines within the university. Due to the imbalance in group sizes across language backgrounds, the participants were analyzed as a collective group of international students rather than by individual language groups.

2.2 Measures

The survey collected demographic data, including age, sex, nationality, first language, study duration in China, and Chinese language proficiency. All measurement scales demonstrated robust reliability in our sample. Specific details are provided below.

Acculturative Stress Scale for International Students (ASSIS)

We used the ASSIS developed by Sandhu and Asrabadi to measure acculturative stress (145). This 36-item instrument encompasses seven dimensions: perceived discrimination, homesickness, perceived hate, fear, stress due to change, guilt, and non-specific miscellaneous concerns. Participants responded on a five-point Likert scale, with higher scores indicating greater perceived acculturative stress. The ASSIS has been validated extensively in studies on international students in China (146–148). The scale demonstrates excellent internal consistency (Cronbach's alpha = 0.966).

UCLA Loneliness Scale (Version 3)

Loneliness was assessed using Version 3 of the UCLA Loneliness Scale, which comprises 20 items (149). Participants indicated the frequency of their experiences of loneliness on a four-point Likert scale. Total scores were calculated by adding the individual item responses, with higher scores reflecting increased loneliness levels. This scale has shown strong validity in previous studies on international students in China (66, 150). Our sample yielded high reliability (Cronbach's α = 0.893).

Smartphone Addiction Scale-Short Version (SAS-SV)

Smartphone addiction was assessed using the short version of the Smartphone Addiction Scale (SAS-SV) (151), which has been validated in multiple empirical studies involving university students (152, 153) and in participants from different linguistic and cultural backgrounds (154–157). The SAS-SV consists of 10 items, with each item scored on a six-point Likert scale (1 = "strongly disagree" and 6: "strongly agree"). The final score was calculated by summing the scores of the ten selected items. Higher scores indicate a greater tendency toward smartphone addiction. In this study, Cronbach's alpha for reliability was 0.842.

L2 Learning Emotions Scales

L2 learning emotions were measured using the Foreign Language Enjoyment Scale (FLE, 21 items) and the Foreign Language Classroom Anxiety Scale (FLCA, 8 items) developed by Dewaele and MacIntyre (83). Both scales employ five-point Likert responses, with mean scores calculated to reflect the levels of enjoyment and anxiety in L2 learning. These instruments have been widely validated among international students (158, 159). In our sample, both scales showed high reliability (FLE: Cronbach's α = 0.815; FLCA: Cronbach's α = 0.854).

Inventory of Creative Activities and Achievements (ICAA)

Creativity was assessed using the ICAA (100), which evaluates eight domains: Literature, Music, Arts and Crafts, Creative Cooking, Sports, Visual Arts (graphics, painting, cultivating, and architecture), Performing Arts (Theatre, dance, and film), and Science and Engineering. Each dimension was assessed for creative behavior and achievement. The Creative Activity (CAct) scale asks how frequently a participant has engaged in a particular activity in the past 10 years (from "never" to "more than 10 times"). The Creative Achievement (CAch) scale assesses creative achievement across 11 levels per domain (from "I have never been engaged in this domain" to "I have already sold some of my work in this domain").

2.3 Analyses

Our analytical approach combined multiple statistical methods to examine the relationships among the study variables comprehensively. Initial analyses were conducted using SPSS 27 for descriptive statistics and Spearman's correlation analyses. Subsequently, we employed structural equation modeling (SEM) using the lavaan package in R, with the maximum likelihood (ML) estimator, to test our hypothesized relationships. The ML estimator was selected given the robustness of our sample size and the continuous nature of the latent variables, though robust methods could be considered for Likert-scale data in future analyses.

The SEM framework incorporated acculturative stress as a predictor variable, with loneliness, smartphone addiction, and second language learning emotions (FLCA and FLE) serving as mediators that influenced creative activities and achievements. Gender was included as a control variable to account for potential demographic effects. To enhance model parsimony and robustness, we excluded non-significant paths with p > 0.20 from the final model. This threshold was chosen to retain paths with marginal significance (p < 0.20) that may hold theoretical relevance in this exploratory context, following recommendations for SEM in behavioral research (160). While this approach is more lenient than the conventional p > 0.05 cutoff, it ensures that potentially meaningful relationships are not prematurely discarded, though it may increase the risk of retaining weaker effects.

We employed two complementary approaches to ensure adequate statistical power and reliability. First, we conducted a *post hoc* power analysis using G*Power (version 3.1.9.4) based on the chi-squared value, sample size (N = 213), and effect size (w = 0.279). The analysis yielded a power level of 0.81 (1 - β error

probability), exceeding the conventional threshold of 0.80. Additionally, we performed bootstrap analysis with 5,000 resamples to validate the stability of our parameter estimates. All key paths demonstrated 95% bias-corrected confidence intervals (excluding zero), confirming the reliability of our findings.

3 Results

Initial analyses included Spearman's correlation to examine relationships among key variables, chosen over Pearson's correlation due to its robustness to non-normal distributions and suitability for ordinal or non-linear data. The results revealed significant relationships among the study's key variables, including Acculturative Stress (AS), loneliness (LON), Smartphone Addiction (SA), Foreign Language Enjoyment (FLE), Foreign Language Classroom Anxiety (FLCA), Creative Activity (CAct), and Creative Achievement (CAch). Table 1 presents the correlations in detail.

Acculturative stress demonstrated a strong positive correlation with loneliness (r = .589, p <.001) and FLCA (r = .594, p <.001), along with a significant but weaker positive correlation with creative achievement (r = .223, p = .001). Notably, acculturative stress was negatively correlated with FLE (r = −.240, p <.001). These initial findings aligned with theoretical predictions and provided a foundation for more sophisticated structural equation modeling analyses. Descriptive statistics for the key variables are reported in Appendix S1, Table S1.

The structural equation model examining relationships among cultural adaptation stress, loneliness, smartphone use, emotional responses, and creativity demonstrated a good fit to the data: $\chi^2(10)$ = 16.59, p = .084; CFI = 0.986, TLI = 0.962, RMSEA = 0.056 (90% CI: 0.000–0.101), SRMR = 0.035. The non-significant chi-square (p >.05) and excellent incremental fit indices (CFI/TLI > 0.95) supported the plausibility of the hypothesized structure.

The standardized path coefficients revealed significant relationships (p <.05). Acculturative stress positively predicted loneliness (β = 0.543, 95% CI [4.713, 7.199], p <.001) and SA (β = 0.372, 95% CI [0.214, 0.529], p <.001). Loneliness, in turn, was associated with increased FLCA (β = 0.249, 95% CI [0.011, 0.035], p <.001) and reduced FLE (β = −0.293, 95% CI [−0.035, −0.004], p <.001). Acculturative stress showed a direct positive effect on FLCA (β = 0.135, 95% CI [0.008, 0.256], p = .026). Creative activity was

significantly predicted by FLE (β = 0.31, 95% CI [0.195, 0.443], p <.001) and acculturative stress (β = 0.3, 95% CI [0.153, 0.456], p <.001), whereas creative achievement was influenced by creative activity (β = 0.7, 95% CI [0.586, 0.823], p <.001) and FLCA (β = 0.118, 95% CI [0.033, 0.210], p = .016). Sex exerted a significant negative effect on AS (β = −0.24, 95% CI [−0.738, −0.214], p <.001) and FLCA (β = −0.14, 95% CI [−0.320, −0.039], p = .008), but non-significant effects on other paths (p >.05). The model explained substantial variance in the key outcomes: 53.9% of creative achievement (R^2 = 0.539), 41.9% of FLCA (R^2 = 0.419), and 31.8% of loneliness (R^2 = 0.318). A path diagram is shown in Figure 1. The fully standardized path coefficients are detailed in Supplementary Table S2.

4 Discussion

This study employed structural equation modeling to elucidate the complex relationships between acculturative stress, loneliness, smartphone addiction, L2 learning emotions, and creativity among international students in China. Our findings validate and extend existing theoretical frameworks while offering novel insights into the interplay of these factors in the context of cross-cultural adaptation.

The results support Hypothesis 1 by demonstrating that international students experiencing acculturative stress are more susceptible to developing smartphone addiction, with loneliness serving as a mediating factor. Previous research in domestic contexts has identified loneliness as a key predictor of smartphone addiction (47, 49). The current study extends these findings to international students, revealing that acculturative stress exhibits a direct effect on smartphone addiction (β = 0.372, p <.001), accounting for 68.7% of its total predictive influence. Although the indirect pathway through loneliness remains statistically significant (β = 0.169, p <.005), the magnitude of the direct effect exceeds that of the indirect effect. This empirical pattern aligns with Ngwira et al.'s identification of cultural stressors as dominant predictors of behavioral maladaptation among international students (25, 161), highlighting the unique challenges faced by this population may fundamentally stems from cross-cultural adaptation challenges rather than generalized emotional distress.

These findings suggest that Berry's traditional acculturation model may require refinement in the digital era (2, 3). Conventional models that heavily emphasize physical interactions, such as face-

TABLE 1 Spearman correlation coefficients between key variables.

Variable	LON	SA	FLE	FLCA	CAct	CAch
AS	.589** (<0.001)	.518** (<0.001)	-.240** (<0.001)	.594** (<0.001)	.206** (0.002)	.223** (0.001)
LON		.422** (<0.001)	-.276** (<0.001)	.503** (<0.001)	.196** (0.004)	.145* (0.035)
SA			-.116 (0.090)	.404** (<0.001)	.142* (0.038)	.094 (0.170)
FLE				-.192** (0.005)	.286** (<0.001)	.207** (0.002)
FLCA					.069 (0.315)	.192** (0.005)
CAct						.743** (<0.001)
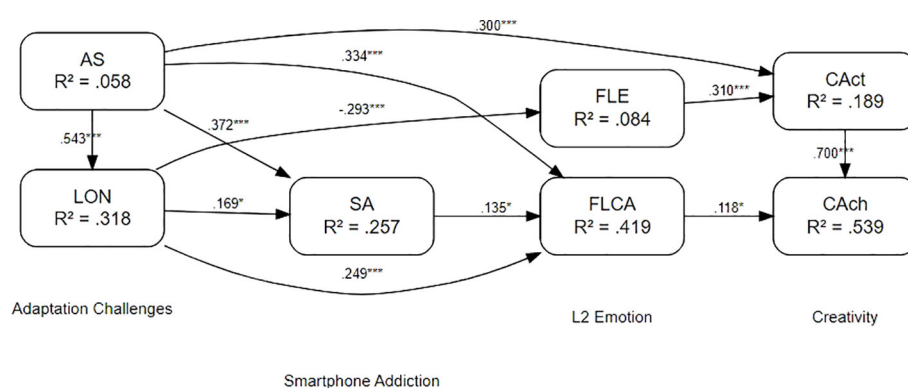
FIGURE 1
Path diagram of the structural equation model.

to-face socializing and community engagement (162), are being transformed by digital media. For instance, algorithm-driven "filter bubbles" (163) can confine users to familiar digital spaces, potentially hindering integration into local cultures. This dynamic may promote separation strategies and increase the reliance on smartphones to meet social needs (67, 91). These effects may be particularly pronounced in China's rapidly evolving digital society (42, 43). Thus, our study highlights the importance of incorporating the influence of digital media into traditional adaptation frameworks and sets the stage for examining our second hypothesis regarding second language learning emotions.

Regarding Hypothesis 2, our results confirmed that acculturative stress influenced FLCA both directly (β = 0.334, p <.001) and indirectly through the mediating effects of loneliness and smartphone addiction (β = 0.135, p <.005). This finding aligns with the Hierarchical Model of Affect, Mood, and Emotion (87), suggesting that long-term emotional states (mood) such as acculturative stress and loneliness can affect short-term situational emotions through intermediary mechanisms such as smartphone addiction. According to Compensatory Internet Use Theory, individuals facing psychosocial difficulties—such as challenges in cultural adaptation—turn to digital media to address unmet emotional or social needs (164). For example, a student struggling with cultural isolation might use their smartphone to connect with friends or family in their home country through social media or messaging apps, seeking comfort and a sense of belonging. While this behavior may temporarily alleviate loneliness, it can paradoxically worsen FLCA by reducing opportunities for real-world interaction with the host culture and limiting L2 practice. Consequently, the student may feel less engaged in L2 settings, such as language classrooms, where proficiency is directly tested, thus heightening anxiety.

Cultural models of emotion further suggest that individualistic versus collectivistic backgrounds shape how emotions are conceptualized and experienced (165). Prolonged stress may alter the thalamocortical networks involved in emotion processing (166),

potentially increasing the sensitivity to anxiety-inducing stimuli. In the context of language learning, acculturative stress can undermine self-confidence and self-efficacy (167), which, when combined with limited language proficiency, may create an inherent threat (79), further amplifying anxiety. These insights offer a new perspective that could help reconcile previous contradictory findings regarding the predictive roles of smartphone addiction and emotions (67, 91, 92). Future research should consider further differentiations between long-term mood states and short-term emotions.

Notably, our study found no significant direct correlation between acculturative stress and Foreign Language scores. While loneliness appeared to negatively affect FLE, its explanatory power remained limited (R^2 = 0.084), suggesting that neither acculturative stress nor loneliness were major predictors of FLE. This finding is consistent with Dewaele et al.'s framework, which posits that FLCA and FLE are distinct dimensions; students can experience both simultaneously rather than experiencing a simple seesaw relationship (75, 83, 168). Our research extends this framework by suggesting that long-term, diffuse negative moods, such as acculturative stress, may not directly impact FLE (169). Instead, FLE appears to be more strongly influenced by immediate factors, such as classroom activities and teacher support (84, 86).

These findings corroborate the Dual Pathway Model of Creativity (24). Both acculturative stress (β = 0.3, 95% CI [0.153, 0.456], p <.001) and FLE (β = 0.31, 95% CI [0.195, 0.443], p <.001) positively and significantly predicted a higher frequency of creative activity with moderate effect sizes. In turn, creative activity mediates the influence on creative achievement (β = 0.7, 95% CI [0.586, 0.823], p <.001), echoing previous literature that highlights the positive role of positive emotions on creativity (127, 128, 132).

A particularly noteworthy finding is that FLCA showed no direct association with creative activity but positively predicted creative achievement (β = 0.118, 95% CI [0.033, 0.210], p = .016). This finding underscores the need to distinguish between long- and short-term emotions in the creative process. Although both

acculturative stress and FLCA are viewed as negative affective states, their mechanisms of influence on creativity appear to differ, which might explain the inconsistent findings regarding the impact of negative emotions on creativity (128).

In cross-cultural settings, prolonged negative mood may prompt students to engage more deeply with the local culture (44), including increased participation in creative activities. This engagement often activates alternative creative strategies, particularly evident in cross-cultural language practices such as sign language communication (170, 171). Furthermore, acculturative stress appears to be linked to intercultural sensitivity, with highly sensitive individuals demonstrating an enhanced ability to integrate cultural differences and mitigate the negative impact of stress on creativity through effective emotional regulation (172, 173).

Conversely, anxiety, as a situational emotion, appears to operate through different mechanisms, potentially leading individuals to enhance the quality of their creative output through iterative refinements (24, 138) rather than simply increasing the frequency of creative activities. This distinction in creative outcomes may also reflect the differences in measurement approaches. While previous research has often focused on divergent thinking (e.g., using an alternative use task) or overall creativity assessments (e.g., the Torrance Tests of Creative Thinking) (104, 105, 174), our study specifically measured both creative activities and achievements, providing a more comprehensive view of how different emotional states influence various aspects of creative performance.

5 Conclusion and future research

This study advances our understanding of how cross-cultural acculturative stress, loneliness, smartphone addiction, second language learning emotions, and creativity interrelate among international students in the digital age. Our findings confirmed that acculturative stress exerts indirect effects through the mediating roles of loneliness and smartphone addiction, highlighting its distinctive impact on the behavioral and emotional states of international students. The results provide strong support for the Dual Pathway to Creativity Model, demonstrating that both acculturative stress and foreign language enjoyment can positively contribute to creative activities. Furthermore, our findings validate the Hierarchical Model of Affect, Mood, and Emotion in explaining the complex interplay between negative emotions and creativity. Particularly in cross-cultural environments, enduring emotional states such as acculturative stress may propel students to engage more proactively in creative endeavors, whereas anxiety can enhance creative output quality through iterative refinement processes.

This study has several limitations that warrant consideration and suggest directions for future research. First, the reliance on self-report measures may introduce a subjective bias. Future investigations should incorporate diverse data collection methods, including physiological assessments and behavioral observations, to achieve methodological triangulation and strengthen the reliability of the findings. Second, because our sample was limited to international students in China, the generalizability of our

findings to different cultural contexts remains uncertain. Students from individualistic versus collectivist backgrounds may exhibit distinct adaptation patterns, necessitating future research that broadens the sample diversity and facilitates multidimensional comparisons of cross-cultural adaptation processes.

Additionally, while our study delineated the relationships between acculturative stress, second language learning emotions, and creativity, it did not fully address the temporal dynamics of these associations. Given that international students' adaptation states likely evolve over time, longitudinal research designs would be valuable in examining trends in acculturative stress, loneliness, and smartphone addiction, as well as their long-term effects on learning emotions and creative performance.

Finally, while this study emphasized the application of the Hierarchical Model of Affect, Mood, and Emotion, its efficacy in cross-cultural settings requires further empirical validation. Future research should explore the interactions among various emotional types during acculturation adaptation and assess how these distinct emotions specifically influence academic and creative development. The potential moderating role of cross-cultural sensitivity on the relationship between acculturative stress and creativity merits further investigation. Subsequent studies could focus on elucidating the underlying mechanisms through which cultural differences mediated by emotion regulation affect students' creative output.

Future research should strive to refine and deepen our understanding of the interconnections between cross-cultural acculturative stress, emotional experiences, and creativity in international students by employing diverse data sources, enhancing sample heterogeneity, adopting longitudinal approaches, and extending the current theoretical frameworks. These efforts will contribute to more effective support systems for international students and enhance our understanding of creative development in cross-cultural educational contexts.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author/s.

Ethics statement

The studies involving humans were approved by the Ethics Committee of School of International Education in Shantou University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JG: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2025.1585302/full#supplementary-material

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