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Beyond borders and screens in China: L2 motivation, digital literacy, and virtual intercultural experience in GenAI-mediated informal digital learning of English

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Abstract

Against the backdrop of the rapid integration of generative artificial intelligence (GenAI) into informal digital learning settings, this study investigates how Chinese university English as a Foreign Language (EFL) students' L2 motivation interacts with their digital literacy and virtual intercultural experience (VIE) to shape their participation in GenAI-mediated informal digital learning of English (GenAI-IDLE). This study surveyed 568 Chinese undergraduate EFL students and employed a structural equation modeling approach to analyze the data. The findings reveal that students' ideal L2 selves and ought-to L2 selves positively and significantly predict their digital literacy and GenAI-IDLE, respectively. While their ideal L2 selves make a positive and direct impact on their GenAI-IDLE, their ought-to L2 selves do not predict their VIE. The results also demonstrate that students' digital literacy mediates the relationship between L2 motivation and GenAI-IDLE. Their digital literacy and VIE jointly play a chain mediating role in the association between L2 motivation and GenAI-IDLE. However, their VIE fails to mediate the link between the ought-to L2 self and GenAI-IDLE. By elucidating the motivational, digital, and behavioral mechanisms in GenAI-mediated informal learning environments, this study extends the application of Self-Determination Theory within in GenAI-powered educational psychology and provides pedagogical implications.

Keywords: Informal Digital Learning of English (IDLE); generative artificial intelligence (GenAI); L2 motivation; digital literacy; virtual intercultural experience (VIE)

Language(s) Learned in This Study: English

APA Citation: Zou, M. M., Li, M., & He, X. (2026). Beyond borders and screens in China: L2 motivation, digital literacy, and virtual intercultural experience in GenAI-mediated informal digital learning of English. *Language Learning & Technology*, 30(1), 1–29. <https://doi.org/10.64152/10125/73673>

Introduction

The pervasive digital technologies and globalized development presented by intercultural communications have provided plentiful chances for exposure to the target language beyond the classroom. In the area of Computer-Assisted Language Learning (CALL), an increasing body of research has explored how digital-afforded practices enhance the efficacy of language learning for second language (L2) learners, such as Facebook reading and commenting, WhatsApp online video communication, or Twitter web application interaction (Avgousti, 2018; Lee & Markey, 2014; Shadiev et al., 2025). Recently, the concept of Informal Digital Learning of English (IDLE), defined as the “self-directed, informal English learning using a range of different digital devices (e.g., smartphones, desktop computers) and resources (e. g., web apps, social media) independent of formal contexts” (Lee, 2019, p. 768), has gained great momentum. Several studies have shed light on the complex nature of IDLE with linguistic, motivational, affective, and cultural factors, such as enhancing learners' language proficiency

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(Lee & Dressman, 2018; Sundqvist & Uztosun, 2024; Zou et al., 2025e), increasing their L2 motivation (Liu et al., 2024b, 2024c), promoting their L2 enjoyment (Liu et al., 2024a; Zou et al., 2025c), fostering their L2 confidence (Zou et al., 2025e), and facilitating their willingness to communicate (Zou et al., 2025b). These findings collectively present that IDLE enhances not only linguistic development but also the motivational and emotional resources that maintain self-directed language learning (Lai et al., 2022).

Since various and powerful generative AI (GenAI) technologies were launched in late 2022, they have rendered versatile, adaptive, and personalized opportunities for language learners to gain exposure to the target language outside the classroom, which is reshaping a new language learning style (Liu et al., 2025). However, investigating how contemporary L2 learners engage with emergent AI technologies featuring Large Language Models (LLMs) algorithms to invest in IDLE activities is in its infancy, which needs ongoing attention from CALL researchers and practitioners. GenAI-IDLE represents a critical and underexplored area in CALL, as GenAI introduces fundamentally new ways of interacting with language, knowledge, and learning environments. In addition, learning a new foreign language through utilizing digital technologies not only needs the negotiation of emotions (e.g., enjoyment) but also involves the mobilization of one's motivational, technological, and cultural resources (Liu et al., 2024a; Zou et al., 2025d). Building on this premise, this study acknowledges how L2 learners' motivation is a crucial motivator that can shape their investment in language learning endeavors in independent out-of-class settings (Liu et al., 2024a; Zou et al., 2025d, 2025g), how digital literacy serves as a technological factor for language learning within the classroom (Kang & Kim, 2024; Rad et al., 2024), and how virtual intercultural experience (VIE) exerts a significant role in catalyzing learning autonomy (Lee & Lee, 2020; Lee & Markey, 2014).

There are several research gaps that we identified. First, although some previous studies have explored how L2 learners' emotional factors (e.g., foreign language enjoyment), communication readiness (e.g., willingness to communicate), and IDLE/AI-IDLE interplay (e.g., Liu et al., 2025; Zadorozhnyy et al., 2025; Zou et al., 2025c), little is known about how learners' motivational, technological, and cultural factors influence their GenAI-mediated informal language learning behaviors. Especially due to the accelerating frequency of intercultural communication and the growing integration of GenAI technologies into language learning, examining how L2 learners' motivational factors interact with cultural factors and digital literacy to shape their GenAI-IDLE engagement becomes more significant. Second, while there were very limited studies on the predictive role of motivation in (Gen)AI-IDLE (Liu et al., 2024a, 2025; Zou et al., 2025d), to our knowledge, no research has been documented to explore the effects of L2 learners' motivation, digital literacy, and virtual intercultural experience on GenAI-IDLE participation. Third, from a theoretical perspective, while Self-Determination Theory (SDT) has been widely used as a theory in language education, especially in the motivation sub-field, very limited studies have mapped GenAI-IDLE engagement into SDT framework. While there were previous papers on IDLE/AI-IDLE (e.g., Zou et al., 2025f, 2025g), the extension of SDT in GenAI-mediated informal language learning environments was not fully presented. Meanwhile, existing studies have yet to fully elucidate the relationship between GenAI-IDLE engagement and the three basic psychological needs of SDT (i.e., autonomy, competence, and relatedness) well.

Thus, we conducted this study to bridge the research gaps. Addressing these research gaps is theoretically critical, as it could extend the understanding of how motivational, technological, and intercultural factors interact in shaping learners' informal language learning practices in GenAI-mediated contexts, as well as illuminating how GenAI-IDLE engagement can satisfy three core elements of SDT. It is also pedagogically significant, as such a relationship mechanism could help language teachers design effective interventions that foster learners' autonomy, motivation, and facilitate harmonious informal language learning ecologies (Zadorozhnyy et al., 2025). These are the novelties of our study. Therefore, there are two research questions (RQs) that guide the present study:

RQ1: In what ways, if any, does L2 motivation (ideal L2 self and ought-to L2 self) affect Chinese EFL students' digital literacy and virtual intercultural experience?

RQ2: In what ways, if any, do their L2 motivation (ideal L2 self and ought-to L2 self) interact with digital literacy, and virtual intercultural experience to shape their GenAI-IDLE engagement?

Literature Review

Generative AI-mediated informal digital learning of English (GenAI-IDLE)

In recent years, IDLE has increasingly emerged as a sub-field of CALL (Lee & Dressman, 2018; Liu et al., 2024b; Zou et al., 2025e). Drawing upon a growing body of IDLE literature (e.g., Lee, 2019; Lee & Dressman, 2018), GenAI-IDLE refers to “how L2 English learners leverage AI technologies for self-guided and self-directed language learning beyond the classroom” (Liu et al., 2025, p. 2). It is worth noting the crucial role of (Gen)AI-IDLE in L2 learning settings, where learners proactively use (Gen)AI technologies to access and customize digital learning resources, and to obtain instant, personalized, and detailed feedback on their L2 writing (Guan et al., 2024).

While a body of literature has investigated the role of L2 learners’ IDLE engagement outside the classroom (Guan et al., 2024; Lee et al., 2024; Liu et al., 2024b, 2024c; Zou et al., 2025a), research exploring how L2 learners leverage GenAI technologies to engage with IDLE activities beyond the classroom remains insufficient. As intercultural communication continues to intensify and GenAI technologies become increasingly embedded in language learning, it is increasingly important to investigate how L2 learners’ motivational variables interact with cultural influences and digital literacy in shaping their GenAI-IDLE engagement. Although increasing attention has been given to IDLE and L2 motivation or IDLE and emotions, the associations between L2 motivation, digital literacy, virtual intercultural experience, and GenAI-IDLE remain under-explored. Thus, the present study aims to address the research gap.

In the subsequent section, we will apply SDT to integrate the variables researched in the present study. And we will review previous literature that corroborated SDT as a well-established theoretical framework in GenAI-mediated language learning contexts.

Self-Determination Theory

Self-Determination Theory (SDT) is a widely recognized theory for understanding the promotion of motivation for autonomous informal digital language learning (Jeon, 2022). It encompasses three components: (1) autonomy (i.e., the necessity for people to experience a sense of agency in their actions and choices), (2) competence (i.e., the aspiration to attain a sense of skilfulness and effectiveness in one’s efforts), and (3) relatedness (i.e., the desire to experience social connectedness and develop meaningful interpersonal bonds in one’s endeavors) (Deci & Ryan, 1985, 2002). When individuals’ psychological needs are satisfied, they are more likely to increase their motivation, engage with self-directed language learning, and strengthen their self-determination (Li et al., 2025; Pan et al., 2025). In the context of GenAI-IDLE, L2 motivation highly pertains to the “autonomy” dimension, as learners are granted flexibility to select learning resources, pursue topics of interest, and determine modes of engagement. This volition and self-direction strengthen their motivation for engaging with language learning activities. Digital literacy corresponds to the “competence” dimension, given that learners need to acquire the skills to effectively navigate online environments, strategically employ AI-powered applications, and critically evaluate the quality of digital resources. Mastery of digital skills reinforces their perception of competence. VIE is linked with the “relatedness” dimension as L2 learners use social media applications or (Gen)AI-mediated digital platforms to interact with others through texts or audios, thereby fostering social bonds. Consequently, GenAI-IDLE integrates these three elements. As such, SDT provides a theoretical framework to connect learners’ L2 motivation with digital literacy and virtual intercultural experience to foster their GenAI-IDLE practices.

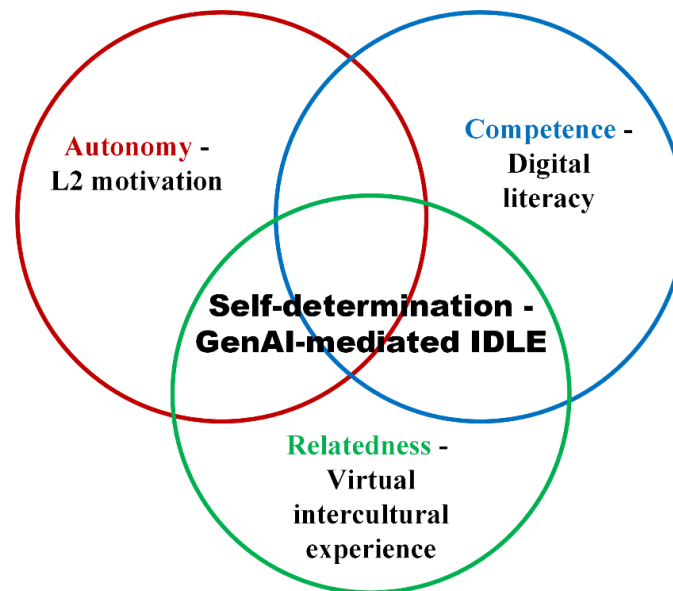
Recent studies have increasingly substantiated that learners’ L2 motivation and digital support enable them to boost their engagement and self-directed learning behaviors outside the classroom (e.g., Chiu et

al., 2022; Jeon, 2022; Pan et al., 2025). For example, Pan et al. (2025) conducted a quasi-experimental study involving 69 Chinese university EFL students, comparing a GenAI-assisted chatbots reading group (GenAI group = 36) with a reading group without GenAI-assisted chatbots (control group = 33). Their findings, framed within SDT, revealed that GenAI chatbots significantly promoted students' autonomous reading motivation and self-directed reading practices outside the classroom. Similarly, further evidence comes from Li et al. (2025), who designed a quasi-experimental study to explore the relationships between autonomous motivation, engagement, and self-directed learning through the lens of SDT. Their insights demonstrated that the experimental group (ChatGPT-empowered instruction) exhibited significantly higher levels of research skills, motivation, engagement, and self-directed learning behaviors. More importantly, students' autonomous motivation and self-directed learning behaviors were enhanced in ChatGPT-mediated learning environments.

Building on the above discussion, the present study is grounded in SDT, which suggests that the cultivation of digital literacy (covering AI literacy) can facilitate L2 learners' autonomous learning beyond the classroom. Meanwhile, learners with higher levels of L2 motivation more frequently access virtual digital spaces to interact with others beyond borders and screens. Thus, this framework provides a lens to explore how EFL students' L2 motivation (ideal L2 self and ought-to L2 self) interacts with digital literacy and VIE to invest in GenAI-IDLE practices in China. Drawing upon the above discussion, we designed a model based on SDT incorporating L2 motivation, digital literacy, VIE, and GenAI-IDLE to delineate the constructs of autonomy, competence, and relatedness (see Figure 1).

Figure 1

A Model of Self-Determination Theory in GenAI-Mediated Informal Learning Contexts



In the following sections, we will introduce the conceptualizations of L2 motivation, digital literacy, and VIE. We will also review prior empirical studies that help formulate the research hypotheses.

L2 Motivation

Drawing upon the L2 Motivational Self System (L2MSS) by Dörnyei (2009), ideal L2 self and ought-to L2 self, as two subdimensions of L2MSS, have been extensively researched in EFL contexts (Liu et al., 2024b, 2024c; Zou et al., 2025a, 2025g). Dörnyei (2009) claimed that the ideal L2 self can drive learners “to learn the L2 because of the desire to reduce the discrepancy between [their] actual and desired future L2 selves” (p. 29). This construct serves as an influential motivator by driving learners to reduce the

discrepancy between their present and desired future self-image. By contrast, the ought-to L2 self could compel learners to learn L2 to fulfil peripheral expectations (e.g., parents or teachers) and avoid detrimental outcomes (e.g., high-stake examination failure). This dimension, which includes extrinsic motivation, functions as a salient motivator to drive L2 learners to study due to the fear of disappointing others and confronting adverse outcomes.

More significantly, it should be acknowledged that L2MSS is encountering evolving scholarly debates in terms of its conceptual soundness and discriminant validity of its scales (e.g., Al-Hoorie et al., 2024; Papi & Teimouri, 2024). Al-Hoorie et al. (2024) conducted correlational and factor-analytic quantitative analyses among 384 South Korean secondary school students. They claimed the framework suffers from discriminant validity issues and suggested its reconsideration for future L2 motivation research. Subsequently, Papi and Teimouri (2024) refuted their claims by pointing out methodological and implementation flaws in Al-Hoorie et al.'s (2024) study. Specifically, Papi and Teimouri (2024) contended that Al-Hoorie et al. (2024) analyzed the data inappropriately and utilized a 7-point Likert scale, raising concerns about the ambiguity of its neutral midpoint. Moreover, Papi and Teimouri (2024) underscored the significance of establishing definitional validity across different dimensions, ensuring that operationalization aligns with agreed-upon definitions and the contextual framework of each study. By following these guidelines, the current study carefully conceptualized the definitions of the ideal L2 self and the ought-to L2 self and fully considered the congruence between items of scales and contexts of measurement, ensuring definitional validity.

Concerning the relationship between L2 motivation and GenAI-IDLE, some empirical studies have substantiated that the ideal L2 self and the ought-to L2 self play crucial roles in (Gen)AI-IDLE (e.g., Liu et al., 2024a, 2024b; Zou et al., 2025a, 2025g). For instance, Liu et al. (2024c) found that Chinese EFL students' ideal L2 selves positively predict their IDLE, while their ought-to L2 selves fail to predict their IDLE ($N = 391$). Similarly, another study by Liu et al. (2024a) unveiled that Chinese EFL students' ideal L2 selves positively predicted AI-IDLE, while their ought-to L2 selves failed to predict AI-IDLE. Likewise, Zou and colleagues (2025a) found that students' ideal and ought-to L2 selves both positively shape IDLE engagement ($N = 1388$). Given that L2 motivation has been regarded as a pivotal catalyst of autonomous and self-directed language learning beyond the classroom (Zou et al., 2025a, 2025g), we propose the following two hypotheses (H):

H1: Ideal L2 self positively predicts GenAI-IDLE engagement.

H2: Ought-to L2 self positively predicts GenAI-IDLE engagement.

Digital Literacy

Digital literacy refers to the ability to access, understand, curate, and utilize digital resources derived from digital applications or platforms, while also managing knowledge in a proficient way (Gilster, 1997). Digital literacy not only associates with reading and writing practices via digital media, but also involves new ways of engaging, relating, thinking, being, and meaning (Jones & Hafner, 2021; Liu, 2025). Amid the multifaceted challenges of the digital era—spanning technological, social, and emotional dimensions—digital literacy is increasingly recognized as a vital competence for navigating today's complex information landscape. A body of literature has documented the capability of digital literacy in strengthening academic motivation, enhancing language proficiency/skills, and increasing language learning behaviors (Barkati et al., 2025; Li & Thien, 2025; Kang & Kim, 2024; Rad et al., 2024).

Situated at the crossroad between the flourishing of digital devices and technology integration, there were very limited empirical studies regarding the interaction between L2 motivation and digital literacy in L2 settings (e.g., Kang & Kim, 2024; Rad et al., 2024). Specifically, Rad et al. (2024) conducted a quasi-experimental design that included two experimental groups (EGs) - adaptive learning (AL) as EG1 and AL-enhanced group supported by digital literacy instruction as EG2 and a control group (a technology-enhanced non-AL group) to investigate the role of digital adaptivity in Iranian students' motivation and

writing competence ($N = 93$). Their findings revealed that the use of digital literacy instruction can improve students' writing proficiency and motivation, which was further substantiated by interviews insights. Notably, students with higher levels of digital literacy are more likely to autonomously engage with learning activities and strengthen learning motivation, thereby improving their language competence (Kang & Kim, 2024). Similarly, an observation by Wang et al. (2025) displayed that 706 Chinese EFL students with a strong sense of motivation had a greater likelihood to produce behavioral intention to use GenAI in language learning, thereby fostering their digital literacy and AI literacy. Given the close relationship between digital literacy and L2 motivation in the existing research, we pose the following two hypotheses in our present study:

H3: Ideal L2 self positively predicts digital literacy.

H4: Ought-to L2 self positively predicts digital literacy.

Furthermore, concerning the association between digital literacy and GenAI-IDLE, several studies have evidenced that L2 learners who have higher levels of digital literacy tend to more frequently engage with (GenAI-)IDLE activities beyond the classroom (e.g., Barkati et al., 2025; Cui et al., 2025; Li & Thien, 2025). For instance, Cui et al. (2025) found that students' digital literacy directly and positively influences the motivated learning behavior ($N = 944$). Likewise, drawing upon the technology acceptance model (TAM), Li and Thien (2025) revealed that students' ChatGPT literacy makes a positive and significant impact on actual use of technology in language learning ($N = 543$). In the same vein, Barkati et al. (2025) employed SEM to explore the contributing roles of self-efficacy, L2 grit, and digital literacy in IDLE ($N = 313$). Their findings uncovered that digital literacy, as the strongest predictor, has a positive and significant impact on IDLE engagement. Given that previous studies reached a consistent conclusion on the predictive effect of digital literacy on (GenAI-)IDLE (Barkati et al., 2025; Sun & Shi, 2024), we put forward a hypothesis below:

H5: Digital literacy positively predicts GenAI-IDLE engagement.

Virtual Intercultural Experience

Because of the challenges and constraints of conducting physical intercultural exchanges, digital applications have increasingly become crucial tools for promoting intercultural communication and enhancing L2 learners' intercultural understanding and competence (Shadiev et al., 2025). With a multilingual and multicultural digital environment, contemporary L2 students are increasingly re-identifying their positions and roles. Becoming legitimate L2 users not only requires them to master linguistic knowledge but also necessitates them to understand diverse cultures and achieve intercultural communication across borders (Lee & Lee, 2020). Some researchers found that EFL learners are increasingly leveraging digital social media platforms (e.g., Facebook or WhatsApp) to interact with various English accents and users to communicate (Barrot, 2022; Lee & Markey, 2014; Shadiev et al., 2025), which was attributed to the accessibility of digital resources and the affordances of technology (Lai et al., 2022). To provide a clear operationalization of VIE in the present study, we define Virtual Intercultural Experience (VIE) as L2 learners's participation in intercultural interactions and communication practices via virtual digital technologies (e.g., social media applications or AI chatbots).

VIE is not only influenced by motivational, emotional, and cognitive factors (Ismailov, 2021; Lee & Lee, 2020; Mirzaei & Forouzandeh, 2013), but also plays a significant role in promoting communication willingness or learning behaviors (Lee & Lee, 2020). While research on investigating the relationship between L2 motivation and VIE is very limited, only one study has documented that L2 learners with a stronger L2 motivation tend to immerse in intercultural environments more frequently (Mirzaei & Forouzandeh, 2013). To be specific, Mirzaei and Forouzandeh (2013) collected 180 data from Iranian EFL undergraduate students and found that there was a strong and positive association between students' intercultural communicative competence and L2 motivation. Given the tight relationship between L2 motivation and VIE, we propose the following hypotheses:

H6: Ideal L2 self positively predicts VIE.

H7: Ought-to L2 self positively predicts VIE.

In addition, while prior research did not validate the predictive role of digital literacy in VIE, the study of Lee and Lee (2020) found that L2 learners who engage in digital settings tend to engage with virtual intercultural activities more frequently. Their digital competence helps them navigate virtual intercultural practices proficiently. Additionally, Lee and Markey (2014) surveyed 28 students from two cross-cultural universities (including American and Spanish learners) to explore how Twitter Web 2.0 applications affect learners' cross-cultural communication. Their findings revealed that online virtual exchanges are viewed as superb venues for intercultural communication, which help them raise awareness of cultural norms. Based on the extant research, we formulate the following hypothesis:

H8: Digital literacy positively predicts VIE.

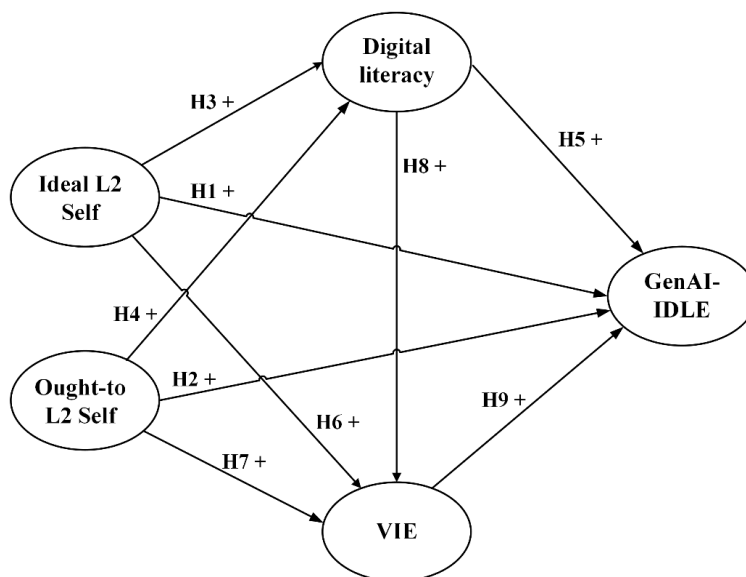
Furthermore, while little research has directly explored the association between VIE and GenAI-IDLE, some studies have evidenced the close positive relationship between intercultural communicative competence and virtual exchanges (Avgousti, 2018; Ismailov, 2021; Lee & Lee, 2020). For example, Avgousti (2018) found that multimodality functions of digital tools influence learners' intercultural communication, thereby facilitating their engagement with online exchanges activities. Another study by Lee and Markey (2014) also validated the relationship and highlighted that students who perceived the effectiveness of using digital technologies for interacting with native speakers were more likely to allocate sufficient time and make a commitment to engaging with online exchanges. Building on the previous insights, we pose the final hypothesis:

H9: VIE positively predicts GenAI-IDLE engagement.

Additionally, to our best knowledge, no studies have been documented to explore the mediating influence of VIE (e.g., Lee & Lee, 2020). Whether VIE can function as a mediator in the relationships between L2 motivation, digital literacy, and GenAI-IDLE engagement, especially when L2 motivation is viewed as a dual-component model, remains an open question that requires future investigations. Taken together, the nine hypotheses are clearly demonstrated in [Figure 2](#).

Figure 2

The Hypothesized Structural Model



Methodology

We employed a structural equation model to investigate how Chinese EFL learners' L2 motivation, digital literacy, and VIE influence GenAI-IDLE.

Research Context and Participants

This study was conducted within a Chinese EFL context. Participants were recruited from four Chinese universities through a convenience sampling approach (Creswell & Creswell, 2017). The research team distributed a digital poster containing a QR code that linked to the online questionnaire via the social media platforms Tencent QQ and WeChat. Additionally, three university instructors assisted with disseminating the survey to their students under the researcher's supervision between January and July 2025. To be eligible for participation, individuals had to meet two criteria: (1) they were currently enrolled in a Chinese higher education institution; and (2) they were identified as English as a Foreign Language (EFL) learners. To ensure data quality and authenticity, several procedural safeguards were implemented. First, the survey platform automatically blocked repeated entries from the same IP address, preventing duplicate submissions. Second, responses exhibiting straight-lining patterns (i.e., identical answers/selections across all items of the questionnaire) were excluded. Third, any questionnaire completed in under 60 seconds was deemed invalid and excluded from the dataset. A response flow was provided in the [Appendix E](#).

A total of 568 questionnaires were used for the analysis. Given space limitations, [Table 1](#) displays participants' background information. These descriptive details provided insight into foundational technological conditions supporting GenAI-IDLE practices. We obtained the ethics approval from the third author's institutional review board (ethics number: REF4025-HNU-37842). All participants were informed about the purpose of the study, the voluntary participation, and the confidentiality of their responses. Participants could withdraw from the study at any time. All participants provided their informed consent to voluntarily participate in this study.

Table 1

Participants Background Information

Background information		<i>N</i>	Percent (%)
Gender	Male	108	19%
	Female	460	81%
Age	< 18	4	0.7%
	18-22	562	99%
	>22	2	0.3%
Academic program	Arts and Humanities	292	51.4%
	Social Sciences	7	1.2%
	Science and Engineering	12	2.1%
	Health Sciences	31	5.5%
	Miscellaneous other disciplines	226	39.8%
	One type of digital device	19	3.3%
Ownership of digital devices	Two types of digital devices	347	61.1%
	Three types of digital devices	171	30.1%
	Over three types of digital devices	31	5.5%
Mobile data availability	Sufficient mobile data	537	94.5%
	Difficulties in obtaining adequate data	31	5.5%

Data Collection and Analysis

Data were collected through a questionnaire administered by Wenjuanxing, a widely used online survey platform in China (see [Appendices A–D](#)). The questionnaire was presented in both English and Chinese and began with a mandatory informed consent question. In the present study, we used back-translation and team reconciliation. Forward translation was performed by two bilingual researchers in Language Education and Applied Linguistics, while a third researcher in Translation Studies conducted the back-translation; any discrepancies were resolved through a reconciliation meeting involving all parties. Participants who indicated their willingness to participate by selecting “Yes” were allowed to complete the subsequent sections of the survey. The questionnaire consisted of two main sections: demographic details and psychometric measurement scales. The scale section contained 36 items designed to evaluate five key constructs: Ideal L2 Self, Ought-to L2 Self, Digital Literacy, VIE, and GenAI-IDLE. Participants responded to each item using a six-point Likert scale, where 1 indicated strongly disagree and 6 indicated strongly agree. A comprehensive outline of the components included in each scale was provided below:

(a) L2 Motivation scale (12 items): This study measured the ideal and ought-to L2 selves of Chinese EFL learners using the L2MSS scales, a tool originally developed by Dörnyei (2009) and subsequently validated by You et al. (2016) within the Chinese context. We adopted this scale that was validated by Liu et al. (2024a) in AI-IDLE contexts. A panel of three CALL specialists reviewed the items for content validity. Six items measuring the Ideal L2 Self dimension were retained (Cronbach’s $\alpha = .89$), indicating a great internal consistency. One example item is, “I can imagine myself talking to foreign friends in informal situations in English in the future.” Similarly, the Ought-to L2 Self scale comprised six items and demonstrated solid reliability (Cronbach’s $\alpha = .87$), with an example item such as “I learn English to meet the expectations of people around me.”

(b) Digital Literacy scale (9 items): To assess respondents’ Digital Literacy, we adapted scales from Prior et al. (2016) and Ng (2012) for the present research context. Because Prior et al.’s scale was associated with Information and Communication Technology (ICT), we modified the statements of their Digital Literacy scale to suit the informal learning context. For instance, “I have good ICT skills” was modified into the item “I have good digital technology skills.” The items were reviewed by two experts in CALL and Applied Linguistics to confirm the content validity of the scale. The nine-item unidimensional scale demonstrated excellent internal consistency in our sample, with a Cronbach’s alpha of .89. An example item is “Digital technologies enable me to collaborate better with my peers on project work and other language-learning activities.”

(c) Virtual Intercultural Experience (VIE) scale (7 items): We utilized the seven-item VIE scale developed and validated by Lee and Lee (2020), which was designed for use in IDLE contexts. The scale demonstrated strong reliability in this study, achieving a Cronbach’s alpha of .84. A representative item from the scale is: “I use technology to help myself understand and appreciate the target culture better.”

(d) GenAI-IDLE scale (8 items): The GenAI-IDLE scale, consisting of eight items, was originally created and validated by Liu et al. (2024a, 2025) to assess the frequency and variety of L2 learners’ engagement with GenAI tools (e.g., ChatGPT and DeepSeek) for English learning outside formal classroom settings. In the present study, the scale showed a high level of internal consistency, with a Cronbach’s alpha of .92, indicating high reliability. An example item was “I interact autonomously with AI-powered chatbots to acquire personalized English learning tips and strategies.”

We analyzed the data with SPSS 29.0 and AMOS 29.0, adopting a five-step structural equation modeling (SEM) procedure as outlined by Collier (2020) and Kline (2023). First, data were cleaned and screened to eliminate responses completed in under 60 seconds and to delete identical answers across all items of the questionnaire. Second, the normality of the data was checked by evaluating skewness and kurtosis for each construct, along with their means and standard deviations. Third, Cronbach’s alpha (α) coefficients were calculated to determine the internal consistency (i.e., reliability) of the subscales. Fourth, confirmatory factor analysis (CFA) was performed to assess the construct validity of the measurement

model. Convergent and discriminant validity were examined by using CFA. Finally, a structural equation model was tested to examine the relationships among L2 motivation, digital literacy, VIE, and GenAI-IDLE.

Results

We presented our research findings based on the data analysis. Initially, we used descriptive statistics to provide an overview of the participants' self-reported levels for all key variables: ideal L2 self, ought-to L2 self, digital literacy, VIE, and GenAI-IDLE. Next, we assessed the reliability and validity of the data. Finally, we conducted a structural and mediation model analysis to address our research questions.

Descriptive Statistics

In [Table 2](#), the descriptive statistics revealed the participants' self-reported levels of participation in GenAI-IDLE activities, along with their L2 motivation, digital literacy, and VIE. Adhering to Kline's (2023) guidelines, the skewness and kurtosis values for all items were within the acceptable thresholds of less than $|3|$ and $|8|$, respectively, confirming that the data did not significantly deviate from normality (see [Table 2](#)). The Pearson Correlation Matrix was presented in [Table 2](#) and [Figure 3](#). In addition, as illustrated in [Figure 4](#), violin plots showed distributional characteristics of data, while the embedded boxplot showed the interquartile ranges (25%-75%). The blue star marked the mean values. The width of each colored violin demonstrated variability of responses, implying different degrees of dispersion and allowing for easy comparisons.

Table 2

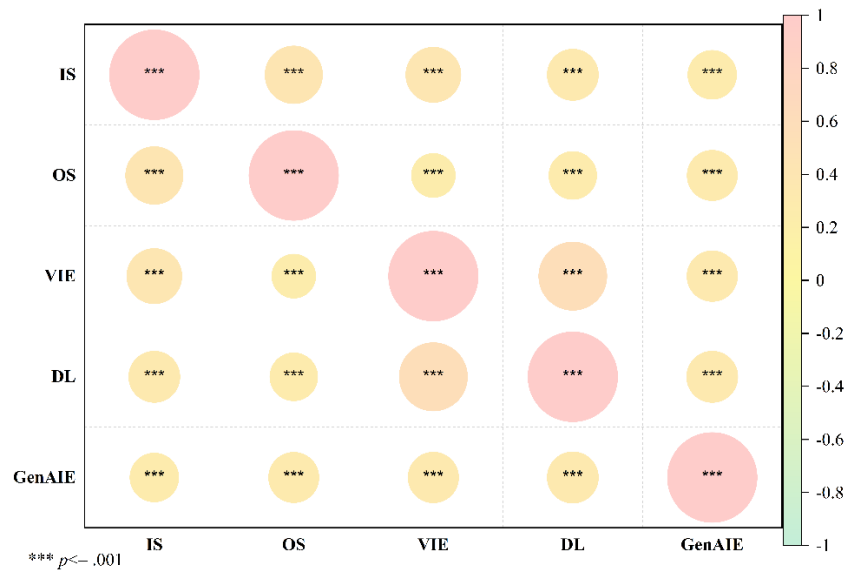
Descriptive Statistics and Pearson Correlation Matrix

	ILS	OLS	DL	VIE	GenAI-IDLE
ILS	1.00	.41 ***	.33 ***	.38 ***	.30 ***
OLS	.41 ***	1.00	.29 ***	.24 ***	.32 ***
DL	.33 ***	.29 ***	1.00	.58 ***	.33 ***
VIE	.38 ***	.24 ***	.58 ***	1.00	.32 ***
GenAI-IDLE	.30 ***	.32 ***	.33 ***	.32 ***	1.00
Mean	4.13	3.96	3.75	3.31	4.25
SD	1.07	1.19	1.02	1.18	1.08
Kurtosis ($< |8|$)	0.11	0.02	0.11	-0.16	0.23
Skewness ($< |3|$)	-0.40	-0.45	-0.16	0.09	-0.60

Note. ILS = Ideal L2 Self, OLS = Ought-to L2 Self, DL = Digital Literacy, VIE = Virtual Intercultural Experience, GenAI-IDLE = GenAI-mediated Informal Digital Learning of English, *** $p < .001$.

Figure 3

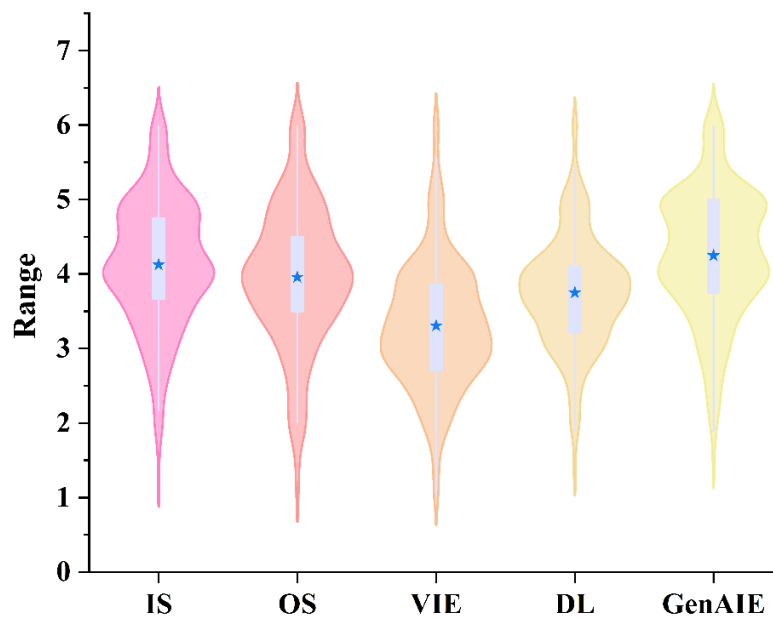
Correlation Matrix of Each Variable



Note. *** $p < .01$; IS = Ideal L2 Self, OS = Ought-to L2 Self, VIE = Virtual Intercultural Experience, DL = Digital Literacy, GenAI-E = GenAI-mediated Informal Digital Learning of English.

Figure 4

Data Distributions of L2 Motivation, Digital Literacy, VIE, and GenAI-IDLE



Note. IS = Ideal L2 Self, OS = Ought-to L2 Self, VIE = Virtual Intercultural Experience, DL = Digital Literacy, GenAI-E = GenAI-mediated Informal Digital Learning of English.

Reliability and Validity Checking

As recommended by Kline (2023), the Cronbach's α values for all five variables were .89 (Ideal L2 Self), .87 (Ought-to L2 Self), .89 (Digital Literacy), .84 (VIE), and .92 (GenAI-IDLE), which all exceeded the .70 benchmark (see Table 3), indicating excellent internal consistency.

Table 3

Reliability and Convergent Validity of the Constructs in the Measurement Model

Constructs	Items	Factor loading (In CFA)	Cronbach's α (> .7)	AVE (> .5)	CR (> .7)
Ideal L2 Self	IS1	.58	.89	.59	.90
	IS2	.77			
	IS3	.88			
	IS4	.72			
	IS5	.83			
	IS6	.79			
Ought-to L2 self	OS1	.61	.87	.54	.87
	OS2	.64			
	OS3	.84			
	OS4	.76			
	OS5	.73			
	OS6	.81			
Digital Literacy	DL1	.65	.89	.51	.89
	DL2	.69			
	DL3	.81			
	DL4	.82			
	DL5	.67			
	DL6	.69			
	DL8	.72			
	DL9	.62			
	DL7	.50			
Virtual Intercultural Experience	VI1	.69	.84	.60	.88
	VI2	.78			
	VI3	.74			
	VI4	.83			
	VI5	.83			
GenAI-IDLE	AI1	.78	.92	.64	.93
	AI2	.80			
	AI3	.78			
	AI4	.86			
	AI6	.79			
	AI7	.77			
	AI8	.81			
	AI5	.50			

Construct validity was assessed through convergent and discriminant validity. In line with Collier (2020), convergent validity was examined using composite reliability (CR) and average variance extracted (AVE). Discriminant validity was examined by comparing the square root of each construct's AVE with the inter-construct correlations. As shown in Table 3, all constructs showed CR values exceeding the recommended threshold of .70 and AVE values surpassing the .50 benchmark (Hair et al., 2009). Factor loadings of items retained can be seen in Table 3. It should be noted that four items (DL7, VIE6, VIE7, and GenAI-IDLE5) with factor loadings below .50 were removed during the CFA (see Appendices A–D).

As displayed in Table 4, the square roots of the AVEs were higher than the corresponding correlation coefficients, thereby confirming discriminant validity. In addition, due to the limitation of self-reported survey, we further examined the common-method variance to ensure the validity. Common method bias was examined using Harman's single-factor test, which showed that the first factor explained 28.25% of the variance—far below the 50% benchmark suggested by Fuller et al. (2016). Thus, this indicates that common method bias was unlikely to pose a serious concern in this study.

Table 4

The Discriminant Validity of L2 Motivation, Digital Literacy, VIE, and GenAI-IDLE

Constructs	The square root of AVE and squared correlation coefficient matrix				
	Ideal L2 Self	Ought-to L2 Self	Digital Literacy	VIE	GenAI-IDLE
Ideal L2 Self	.77				
Ought-to L2 Self	.41	.74			
Digital Literacy	.31	.28	.71		
VIE	.33	.20	.51	.78	
GenAI-IDLE	.30	.32	.32	.28	.80

Note. The bolded values along the diagonal represent the square root of AVE.

The measurement model incorporated five constructs and their corresponding observed indicators to enhance the construct validity of the adapted questionnaire using AMOS 29. To assess the fit between the measurement model and the data, eight fit indices were employed, including the chi-square to degrees of freedom ratio (χ^2/df), Incremental Fit Index (IFI > .9), Tucker-Lewis Index (TLI > .9), Comparative Fit Index (CFI > .9), Parsimony Goodness-of-Fit Index (PGFI > .5), Parsimonious Normed Fit Index (PNFI > .5), Root Mean Square Error of Approximation (RMSEA \leq .08), and Root Mean Square Residual (RMR \leq .08) as suggested by Kline (2023). As presented in Table 5, all indices met the suggested thresholds, indicating a satisfactory fit between the measurement model and the dataset. Consequently, the questionnaire demonstrated excellent construct validity.

Table 5

Model Fit Indices of L2 Motivation, Digital Literacy, VIE, and GenAI-IDLE

	χ^2/df	IFI	TLI	CFI	PGFI	PNFI	RMSEA	RMR
The first measurement model	3.666	.884	.873	.884	.716	.776	.069	.063
The finalized measurement model	3.233	.900	.900	.903	.730	.791	.063	.060
The first structural model	3.516	.896	.886	.895	.723	.787	.067	.052
The finalized structural model	3.083	.914	.905	.914	.737	.802	.061	.049
Benchmark values (Kline, 2023)	< 5	> .9	> .9	> .9	> .5	> .5	\leq .08	\leq .08
Evaluated	Good	Good	Good	Good	Good	Good	Good	Good

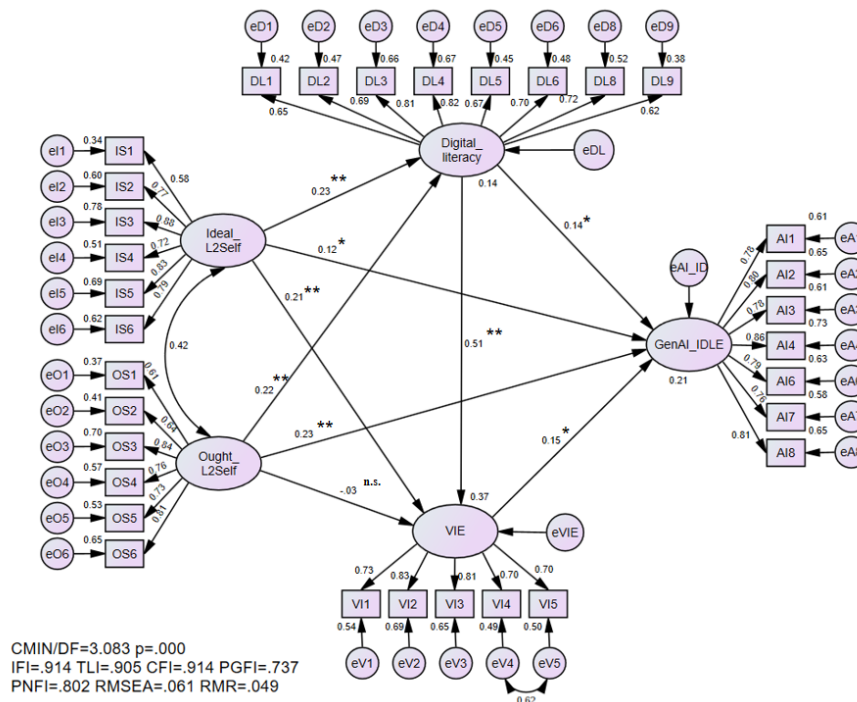
Note. To precisely compare the subtle differences observed between the initial and final measurements, we reported the corresponding data to three decimal places.

The Structural Equation Model and Mediation Model Measurement

Two rounds of structural equation modeling (SEM) analyses were performed in AMOS 29 to test the study's hypotheses. In the initial analysis, the proposed structural model showed inadequate fit with the data, as three of the eight fit indices (IFI, TLI, and CFI) failed to meet the established criteria. As such, model modification was undertaken by examining modification indices (MI) following Collier's (2020) guidance. First, from the statistical perspective, based on the MI results, one pair of error terms (eV4-eV5) within the VIE construct were allowed to covary to reduce item redundancy and improve model fit (see Figure 5). Second, from a content perspective, as the two items had content overlap [i.e., I use technology to connect with (non-native/native) speakers of the language], they can be paired. The revised structural model subsequently exhibited a satisfactory fit, with all fit indices falling within acceptable thresholds. Path analysis of the final model confirmed eight of the hypothesized relationships. Specifically, in Table 6, Ideal L2 Self directly and positively predicted Digital Literacy (H3: $\beta = .23, p = .001$, Bias-corrected bootstrap 95% confidence intervals (hereafter BCCI) [.13, .32]), VIE (H6: $\beta = .21, p = .001$, BCCI [.12, .31]), and GenAI-IDLE (H1: $\beta = .12, p = .020$, BCCI [.02, .22]). Similarly, Ought-to L2 Self was a significant positive predictor of Digital Literacy (H4: $\beta = .22, p = .003$, BCCI [.11, .32]) and GenAI-IDLE (H2: $\beta = .23, p = .001$, BCCI [.12, .34]), but had no predictive power over VIE (H7: $\beta = -.03, p = .610$, BCCI [-.12, .07]). Additionally, Digital Literacy positively and significantly impacted both VIE (H8: $\beta = .51, p = .001$, BCCI [.43, .59]) and GenAI-IDLE (H5: $\beta = .14, p = .045$, BCCI [.02, .25]), and VIE was a positive and significant predictor of GenAI-IDLE (H9: $\beta = .15, p = .031$, BCCI [.04, .24]). As the R^2 values in Figure 5 show, Ideal L2 Self and Ought-to L2 Self collectively accounted for 14% of variance in Digital Literacy. These two variables, along with Digital Literacy, jointly explained 37% of the variance in VIE. All four variables, Ideal L2 Self, Ought-to L2 Self, Digital Literacy, and VIE, together explained 21% of the variance in GenAI-IDLE (Plonsky & Ghanbar, 2018).

Figure 5

The Structural Equation Model of L2 Motivation, Digital Literacy, VIE, and GenAI-IDLE



Note. $p^{**} < .01, p^* < .05$; n.s. = non-significant; VIE = Virtual Intercultural Experience, GenAI-IDLE = GenAI-mediated Informal Digital Learning of English.

Table 6*Standardized Hypotheses Testing Results of Paths and Direct, Indirect, and Total Effects*

Paths	β	p	BCCI 95%		Results
			Lower bound	Upper bound	
H1: Ideal L2 Self → GenAI-IDLE	.12*	$p = .020$	.02	.22	Supported
H2: Ought-to L2 Self → GenAI-IDLE	.23**	$p = .001$	.12	.34	Supported
H3: Ideal L2 Self → DL	.23**	$p = .001$	.13	.32	Supported
H4: Ought-to L2 Self → DL	.22**	$p = .003$	.11	.32	Supported
H5: DL → GenAI-IDLE	.14*	$p = .045$	.02	.25	Supported
H6: Ideal L2 Self → VIE	.21**	$p = .001$	.12	.31	Supported
H7: Ought-to L2 Self → VIE	-.03 ^{n.s.}	$p = .610$	-.12	.07	Unsupported
H8: DL → VIE	.51**	$p = .001$	.43	.59	Supported
H9: VIE → GenAI-IDLE	.15*	$p = .031$	.04	.24	Supported
Indirect effects					
Ind1: Ideal L2 Self → DL → GenAI-IDLE	.03	$p = .027$	.01	.07	Partial mediation
Ind2: Ideal L2 Self → DL → VIE → GenAI-IDLE	.02	$p = .013$	.01	.04	Partial mediation
Ind3: Ideal L2 Self → VIE → GenAI-IDLE	.03	$p = .018$	.01	.07	Partial mediation
Ind4: Ought-to L2 Self → DL → GenAI-IDLE	.03	$p = .025$	.01	.06	Partial mediation
Ind5: Ought-to L2 Self → DL → VIE → GenAI-IDLE	.01	$p = .017$	.01	.03	Partial mediation
Ind6: Ought-to L2 Self → VIE → GenAI-IDLE	-.00	$p = .473$	-.02	.01	No mediation
Total effects					
Total1: Ideal L2 Self → GenAI-IDLE = Ind1 + Ind2 + Ind3 + H1	.20	$p = .002$	.10	.31	
Total2: Ought-to L2 Self → GenAI-IDLE = Ind4 + Ind5 + Ind6 + H2	.27	$p = .001$	.15	.33	

Note. BCCI = Bias-corrected bootstrap 95% confidence intervals. ** $p < .01$; * $p < .05$; n.s. = non-significant; H = Hypothesis; Ind = Indirect; DL = Digital Literacy; VIE = Virtual Intercultural Experience; GenAI-IDLE = GenAI-mediated Informal Digital Learning of English.

To evaluate the mediating roles of Digital Literacy and VIE in the relationship between L2 motivation and GenAI-IDLE, we ran a bootstrapping test with 2,000 samples at a 95% confidence level in AMOS 29. As Table 6 indicates, Digital Literacy was a significant partial mediator for both the association between Ideal L2 Self and GenAI-IDLE (Ind1: $\beta = .03$, $p = .027$, BCCI [.01, .07]) and the link between Ought-to L2 Self and GenAI-IDLE (Ind4: $\beta = .03$, $p = .025$, BCCI [.01, .06]), as both bounds were above zero (Collier, 2020). VIE also acted as a partial mediating role in the relationship between Ideal L2 Self and GenAI-IDLE (Ind3: $\beta = .03$, $p = .018$, BCCI [.01, .07]), but it did not mediate the association between Ought-to L2 Self and GenAI-IDLE (Ind6: $\beta = -.00$, $p = .473$, BCCI [-.02, .01]). Furthermore, a chain mediating effect was observed for Digital Literacy and VIE in the relationship between Ideal L2 Self and GenAI-IDLE (Ind2: $\beta = .02$, $p = .013$, BCCI [.01, .04]) and between Ought-to L2 Self and GenAI-IDLE (Ind5: $\beta = .01$, $p = .017$, BCCI [.01, .03]) (Collier, 2020).

Discussion

This study used the SEM to investigate the interplay between L2 motivation, digital literacy, VIE, and GenAI-IDLE engagement among Chinese university EFL students.

RQ1: In what ways, if any, does L2 motivation (ideal L2 self and ought-to L2 self) affect Chinese EFL students' digital literacy and virtual intercultural experience?

This study shows that participants' ideal L2 selves and ought-to L2 selves positively and significantly predict their digital literacy, which echoes Wang et al.'s (2025) observation that Chinese EFL students who have higher levels of motivation are more likely to use GenAI tools for language learning purposes, thereby enhancing their digital literacy. These findings also align with previous studies (Kang & Kim, 2024; Rad et al., 2024). The medium effect size [ideal L2 self: $\beta = .23$; ought-to L2 self: $\beta = .22$; Collier, (2020)] also supports the view that the higher students' L2 motivation is, the higher their digital literacy is. In addition, the finding demonstrates that respondents' ideal L2 selves positively influence their VIE, supporting *Hypothesis 6*, which is consistent with previous research on the relationship between L2 motivation and intercultural communicative competence in L2 settings (Lee & Lee, 2020; Mirzaei & Forouzandeh, 2013). However, the study reveals that students' ought-to L2 selves lack predictive power over their VIE, which diverges from Lee and Lee's (2020) observation regarding the significant predictive role of L2 motivation in South Korean EFL university students' L2 willingness to communicate (WTC). One possible explanation for this novel finding is that students' ought-to L2 selves are primarily shaped by externally imposed obligations and societal expectations, which may operate differently across cultural and educational contexts (Zou et al., 2025d). Chinese EFL university students may perceive ought-to L2 selves more as peripheral obligations and exam-oriented requirements, which may not facilitate them to autonomously engage with virtual-intercultural activities beyond the classroom. Namely, the external pressure or obligations may be less directly connected to intrinsically motivated behaviors, such as proactively seeking intercultural communication chances through GenAI technologies. This pattern can be reflected in the SDT framework. Another possible interpretation is that the mediating variable (i.e., digital literacy) may weaken the direct and predictive effect of ought-to L2 self on VIE, thereby causing the direct link between ought-to L2 self and VIE to become non-significant. While learners' ideal L2 selves satisfy autonomy-competence-relatedness elements by promoting self-directed digital learning activities and meaningful intercultural interaction, their ought-to L2 selves may fail to meet the need for autonomy and lead to limited chances for relatedness in digital learning settings.

RQ2: In what ways, if any, do their L2 motivation (ideal L2 self and ought-to L2 self) interact with digital literacy and virtual intercultural experience to shape their GenAI-IDLE engagement?

This study reveals that digital literacy enables greater VIE and investment in GenAI-IDLE practices, as evidenced by the significant predictive effect of digital literacy on VIE and GenAI-IDLE in the SEM model. These findings not only align with the study of Cui et al. (2025) in terms of digital literacy's ability in influencing the motivated learning behavior in GenAI-IDLE contexts but also offer evidence for the crucial role of digital literacy in predicting digital learning practices (Li & Thien, 2025). Moreover, the study discloses that students with more VIE are more likely to engage with GenAI-IDLE activities beyond the classroom, which echoes Lee and Markey's (2014) observation that L2 learners who experience the effectiveness of intercultural communication via digital tools are more willing to devote themselves to engaging with informal digital exchanges. This insight aligns with previous studies on the association between intercultural communicative competence and informal digital learning (Avgousti, 2018; Ismailov, 2021; Lee & Lee, 2020).

Furthermore, we also find that students' ideal L2 selves make a significant and positive impact on their proactive usage of GenAI for language learning beyond the classroom, which aligns with existing research (Liu et al., 2024b, 2024c; Zou et al., 2025a, 2025g), supporting *Hypothesis 1*. On this basis, it

could be suggested that the ideal L2 self is regarded as a stable motivational driver for students' autonomous participation in out-of-class English learning. In addition, this study reveals that students' ought-to L2 self positively predicts GenAI-IDLE activities, supporting *Hypothesis 2*, which is reminiscent of the case conducted by Zou et al. (2025a) on the positive link between the ought-to L2 self and IDLE. However, this insight is inconsistent with Liu et al.'s (2024a) findings that Chinese university students with high extrinsic motivation may diminish their proactive participation in AI-IDLE activities. One potential interpretation is that the timing of measurement and data collection may have influenced participants' responses. Liu and colleagues (2024a) collected their research data between July 2023 and October 2023, shortly after the release of new GenAI technologies in late 2022. Consequently, while most participants may have possessed a basic level of digital literacy (covering AI literacy) to navigate GenAI-IDLE activities, they may be hesitant to use GenAI tools publicly. It may result from strict regulations imposed by some Chinese universities that restricted students' use of GenAI during that period (Information Center, 2023). As a result, although participants experience external expectations or study pressure (i.e., the ought-to L2 self) to engage with language learning activities, their actual use of GenAI technologies for language learning purposes may have been limited because of ethical considerations for using GenAI tools. In contrast, our present study collected data between January 2025 and July 2025, during which many Chinese universities have retracted previous restrictions on GenAI usage for learning and have been reforming and revising their curriculum standards and educational cultivation goals (Wei, 2024) and Chinese government policies promoting the integration of GenAI in education (China Education Daily, 2025 ; The Ministry of Education and Eight Other Departments, 2025). Increasingly, instructors have incorporated GenAI technologies into course teaching and provided a series of guidance and training of GenAI usage to enhance students' digital/AI literacy. Such developments may have enhanced learners' strategic and autonomous utilization of GenAI for language learning, thereby facilitating the translation of their ought-to L2 selves into GenAI-IDLE engagement (Zou et al., 2025d).

Finally, the study has uncovered that the partial mediating roles of both digital literacy and VIE in the association between the ideal L2 self and GenAI-IDLE engagement. The ideal L2 self indirectly and positively influences GenAI-IDLE engagement through both digital literacy and VIE as mediators, aligning with prior insights that learners' (GenAI-)IDLE engagement is affected by intrinsic aspirations or instrumental self-promotion (Liu et al., 2024b; Zou et al., 2025a, 2025g). In addition, Digital literacy and VIE play a chain mediating role in the relationship between the ideal L2 self and GenAI-IDLE engagement. These findings indicate that the ideal L2 self shapes GenAI-IDLE through multiple channels. Moreover, this study highlights that while students' VIE could not separately mediate the relationship between the ought-to L2 self and GenAI-IDLE engagement, their digital literacy and VIE jointly play a chain mediating role in the link between the ought-to L2 self and GenAI-IDLE engagement. This finding casts a light on how learners' digital literacy and VIE serve as a pathway through which Chinese EFL students' external motivation can be translated to their GenAI-IDLE endeavors. Consistent with Avgousti's (2018) observation of how the multimodality functions of digital tools become impactful for facilitating learners' intercultural communication in the context of technology-mediated language learning. In addition, the study finds that the interaction between learners' ought-to L2 selves and GenAI-IDLE engagement is mediated by their digital literacy. It echoes previous studies in terms of the crucial role of digital literacy in negotiating learners' extrinsic motivation and maintaining their self-directed language learning effort (Li & Thien, 2025; Sun & Shi, 2024).

Finally, the research findings also demonstrate that GenAI-IDLE engagement is inherently related to the three elements of SDT (i.e., autonomy, competence, and relatedness). First, many GenAI-IDLE behaviors present a high degree of "autonomy", as learners autonomously seek personalized guidance and select learning topics (e.g., an item aligned with "autonomy" element - "I interact autonomously with AI-powered chatbots to acquire personalized English learning tips and strategies."). Second, GenAI-IDLE also supports learners' competence by offering scaffolded practices opportunities and simulated language conversation tasks that improve their linguistic mastery (e.g., an item aligned with "competence" element: "I interact with AI-powered chatbots to practice my English writing skills beyond the classroom."). Third,

GenAI-IDLE reflects that interactive nature of AI chatbots offers a sense of social presence and communicative engagement, thereby meeting learners' relatedness needs via conversational exchanges (e.g., an item aligned with "relatedness" element: "I engage in English conversations with AI-powered chatbots on various topics to increase my exposure to English beyond the classroom."). Taken together, the GenAI-IDLE engagement fully captures SDT's autonomy, competence, and relatedness, suggesting it satisfies learners' three core psychological needs of the SDT.

Pedagogical Implications

Building on these findings, this study yields several pedagogical implications. First, recognizing the positive impact of L2 motivation on digital literacy, language teachers can encourage students to create a digital portfolio (e.g., Padlet) where they can delineate their intrinsic aspirations and extrinsic expectations to showcase their L2 motivation and demonstrate how these digital portfolios are aligned with future visions (Lam & Tsang, 2025). For example, in a writing session, teachers can organize students to draft professional emails or blog posts for delivering their thoughts to some imagined international audiences by using GenAI tools for reflection. Second, given the power of L2 motivation as an influential motivator for fueling GenAI-IDLE, teachers should encourage students to design a "Future English-self Project," in which they create some videos or posters that portray themselves as future English users (Zou et al., 2025c). In addition, teachers can assign students to use GenAI technologies to prepare for their high-stake English-speaking exams or simulate job interviews with AI chatbots. Thus, students' ideal L2 selves and ought-to L2 selves can be enhanced through AI integration approaches, thereby facilitating their GenAI-mediated independent language learning outside the classroom. Third, concerning the predictive roles of digital literacy and VIE in GenAI-IDLE, teachers can organize students to work in a group to use AI-powered communication tools to conduct virtual collaborative projects with international peers (e.g., intercultural storytelling). This approach helps students improve their digital literacy and promote their intercultural communication competence, thereby fostering their participation in GenAI-IDLE activities (Shadiev et al., 2025). Finally, regarding the chain mediating role of digital literacy and VIE in the association between L2 motivation and GenAI-IDLE, teachers could conduct classroom workshops where students can critically evaluate outputs from diverse GenAI technologies. Teachers can design some online exchanges scenarios where students envision their ideal images for using English to express. These approaches could help students see how their digital and intercultural skills improve and inspire them to engage in GenAI-IDLE practices.

Conclusion

This study examined the relationships between Chinese university EFL students' ideal L2 self, ought-to L2 self, digital literacy, VIE, and GenAI-IDLE engagement. This research provides two core contributions: it delineates the chain mediating role of digital literacy and VIE in linking the L2 motivation with GenAI-IDLE engagement, and it further extends the application of SDT by demonstrating educational psychology in GenAI-mediated informal language environments. This integration advances motivational theory (i.e., L2MSS) in technology-mediated language learning by illustrating how learners' GenAI-IDLE engagement can satisfy three core elements of SDT and activate self-based motivational factors. Nevertheless, it should be acknowledged that some limitations remain in the present study. First, the cross-sectional design limits the ability to capture dynamic trajectories of these factors in GenAI-IDLE engagement. Future investigations are therefore encouraged to adopt longitudinal approaches to examine their developmental patterns over time. Second, while the quantitative approach taken in the present study provided broad structural insights, future research employing mixed-methods designs could yield more nuanced and in-depth insights into the intricate interplay among motivational, technological, and cultural factors in GenAI-IDLE contexts. Third, since the present study focused exclusively on Chinese EFL learners, future inquiries may consider incorporating participants from diverse national and regional backgrounds and employing comparative or cross-cultural designs to further explore how motivational, technological, and cultural factors shape GenAI-IDLE engagement

across nations. Fourth, as learners' demographic variables may play moderating roles in the relationships among L2 motivation, digital literacy, VIE, and GenAI-IDLE practices, we call for future studies that consider exploring the moderation paths of demographic variables (e.g., gender, proficiency, or institution). Finally, learners' engagement with GenAI-IDLE practices is likely influenced not only by their motivational, technological, and cultural stances but also by other individual differences (e.g., cognitive, metacognitive variables). We advocate for future research that integrates these diverse individual differences to establish a more holistic ecosystemic model of how L2 learners utilize GenAI technologies for IDLE purposes.

Acknowledgements

We are thankful to all participants who willingly took part in this research. We are greatly grateful for the editors and anonymous peer reviewers' valuable, insightful, and constructive feedback on our study. We sincerely appreciate Paul Dalton (as an English native speaker, affiliated with Manchester Metropolitan University, UK) for his dedication to proofreading and polishing our manuscript. Additionally, this work is funded by the Hunan Province Key Teaching Reform Project for Regular Undergraduate Universities: *Research on Innovative Approaches and Models of College Foreign Language Education and Instruction in the Context of Generative Artificial Intelligence* (Project No. 202502002177) to the third author: Xueyun He. This work is also supported by the Education Reform Project of Hengyang Normal University: *Interesting Guidance and Practical Training: Research and Practice on Improving Student Engagement in Interdisciplinary Elective Courses—A Case Study of the Mobile Photography Course* (Grant No. JYKT202515) to the third author: Xueyun He. For the purpose of open access, Minlin Minny Zou has applied a Creative Commons Attribution (CC BY) licence to any Minlin Minny Zou (affiliated with University of Exeter, UK) Accepted Manuscript version arising from this submission. Generative AI did not contribute to the conception of any ideas presented in this article. The authors are solely responsible for any limitations and errors.

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Appendix A. L2 Motivation scale (Dörnyei, 2009; You et al., 2016)

(12-item scale, Likert 6-point) (1 Strongly disagree – 6 Strongly agree)

Ideal L2 self		Factor-loading	Residual	Note
Definition: Ideal L2 self represents the motives growing out of personal desires for growth, accomplishments, and positive outcomes associated with learning English.				
IS1	Whenever I think about my future career, I imagine myself using English. 每当我想到我未来的职业时，我都会想象自己在使用英语。	.58	.66	
IS2	I can imagine myself doing business with foreigners through English. 我可以想象我与外国人通过英语交流做生意的场景。	.77	.41	
IS3	I can imagine myself speaking English with international friends or colleagues. 我可以想象自己与国际朋友或同事说英语。	.88	.23	
IS4	I can imagine myself as a person who is able to speak English. 我可以想象自己是一个能够说英语的人。	.72	.49	
IS5	I can imagine myself talking in English with foreign friends in informal situations in the future. 我可以想象得出自己将来在非正式场合上和外国朋友用英语交谈的情形。	.84	.30	
IS6	I can imagine myself having discussions in English when living or travelling abroad. 我可以想象自己在国外生活或旅行时用英语进行讨论。	.79	.38	
Ought-to L2 self		Factor-loading	Residual	Note
Definition: Ought-to L2 self comprises the motives related to the attempts to meet external expectations and avoid negative consequences that may arise from not learning English.				
OS1	If I don't learn English, it will have a negative impact on my life. 如果我不学英语，会对我的生活产生负面影响。	.61	.63	
OS2	Learning English is important to me because people around me think I should learn it. 学英语对我来说很重要，因为我身边的人认为我应该学好它。	.64	.59	
OS3	Learning English is important to me because it will give me social recognition. 学英语对我来说很重要，因为这样可以获得社会的认可。	.84	.30	

OS4	Learning English is important to me because I want to gain recognition from my teachers and classmates. 学英语对我来说很重要，因为我想获得老师同学对我的认可。	.76	.43
OS5	Learning English is important to me because an educated person should be able to use English. 学英语对我来说很重要，因为一个受过教育的人应该能够使用英语。	.73	.47
OS6	Learning English is important to me because other people will respect me more if I have knowledge of English. 学英语对我来说是重要，因为如果我有英语知识，其他人会更尊重我。	.81	.35

Appendix B. Digital literacy scale (Prior et al., 2016; Ng, 2012)

(9-item scale, Likert 6-point) (1 Strongly disagree – 6 Strongly agree)

Digital literacy		Factor-loading	Residual	Note
Definition: Digital literacy not only associates with reading and writing practices via digital media, but also involves new ways of engaging, relating, thinking, being, and meaning (Jones & Hafner, 2021; Liu, 2025).				
DL1	I know to solve my own technical problems. 我知道自己解决技术问题。	.65	.59	
DL2	I can learn new technologies easily. 我可以轻松学习新技术。	.68	.54	
DL3	I keep up with important new technologies. 我了解重要的新技术。	.80	.36	
DL4	I know about a lot of different technologies. 我了解许多不同的技术。	.80	.35	
DL5	I have the technical skills I need to use digital technologies for language learning (e.g., blogs, Facebook, and YouTube) that demonstrate my understanding of what I have learned. 我拥有使用数字技术进行语言学习所需的技术技能（如博客、Facebook 和 YouTube），这能证明我对所学知识的理解。	.68	.54	
DL6	I am confident with my search and evaluate skills in regard to obtaining information from the Web. 在从网络获取信息方面，我对自己的搜索和评估技能有信心。	.72	.49	
DL7	Digital technologies enable me to collaborate better with my peers on project work and other language-learning activities. 数字技术使我能够在项目工作和其他语言学习活动中更好地与同伴合作。	.50	.75	Removed
DL8	I have good digital technology skills. 我拥有良好的数字技术技能。	.73	.47	
DL9	I am familiar with issues related to web-based activities (e.g., cyber safety, search issues, plagiarism). 我熟悉与网络活动有关的问题（如网络安全、搜索问题、剽窃）。	.63	.61	

Appendix C. Virtual Intercultural Experience scale (VIE) (Lee & Lee, 2020)

(7-item scale, Likert 6-point) (1 Strongly disagree – 6 Strongly agree)

Virtual intercultural experience		Factor-loading	Residual	Note
Definition: VIE is defined as the experience of L2 learners with intercultural interactions and communication practices via virtual digital technologies (e.g., social media applications or AI chatbots).				
VI1	I chat with others in English via social media (e.g. Facebook, KaKaoTalk, Line, WeChat, WhatsApp). 我通过社交媒体（如 Facebook、KaKaoTalk、Line、微信、WhatsApp）与他人用英语聊天。	.70	.51	
VI2	I write comments in English on Facebook. 我在 Facebook 上用英语写评论。	.77	.40	
VI3	I share English contents online. 我在网上分享英语内容。	.75	.44	
VI4	I use technology to connect with native speakers of the language (e.g. American, British). 我使用技术与母语为英语的人联系（例如美国人、英国人）。	.82	.33	
VI5	I use technology to connect with non-native speakers of English all over the world (e.g. Japanese, Korean). 我使用技术与世界各地的非英语母语者（如日本人、韩国人）建立联系。	.82	.33	
VI6	I use technology to help myself understand and appreciate the target culture better. 我利用科技帮助自己更好地理解 and 欣赏目标文化。	.27	.93	Removed
VI7	I use technology to help myself to increase my ability to interact with the target culture. 我利用科技帮助自己提高与目标文化互动的能力。	.31	.90	Removed

Appendix D. GenAI-IDLE scale (Liu et al., 2024a, 2025)

(8-item scale, Likert 6-point) (1 Strongly disagree – 6 Strongly agree)

GenAI-mediated informal digital learning of English		Factor-loading	Residual	Note
Definition: AI-IDLE is defined as how L2 English learners leverage AI technologies for self-guided and self-directed language learning beyond the classroom.				
AI1	I engage in English conversations with AI-powered chatbots on various topics to increase my exposure to English beyond the classroom. 我与人工智能驱动的聊天机器人就各种话题进行英语对话，以增加我在课堂之外接触英语的机会。	.79	.38	
AI2	I use AI-powered speech recognition tools to practice speaking English and receive immediate feedback on my fluency and intonation beyond the classroom. 我使用人工智能驱动的语音识别工具练习英语口语，并在课堂之外获得有关我的流利程度和语调的即时反馈。	.81	.35	
AI3	I play AI-powered language learning games to expand my English vocabulary. 我玩人工智能驱动的语言学习游戏，以扩大我的英语词汇量。	.78	.40	
AI4	I interact autonomously with AI-powered chatbots to acquire personalized English learning tips and strategies. 我与人工智能驱动的聊天机器人自主互动，获取个性化的英语学习技巧和策略。	.86	.27	
AI5	I use new AI technologies autonomously to find and obtain English learning resources. 我自主使用新的人工智能技术来查找和获取英语学习资源。	.48	.77	Removed
AI6	I autonomously engage in discussions with AI-powered chatbots to deepen my understanding of English language and culture. 我自主与人工智能驱动的聊天机器人进行讨论，以加深对英语语言文化知识的理解。	.80	.36	
AI7	I interact with AI-powered chatbots to practice my English writing skills beyond the classroom. 我与人工智能驱动的聊天机器人互动，练习课外英语写作技能。	.77	.41	
AI8	I use AI technologies to simulate real-life English language use situations beyond the classroom. 我使用人工智能技术模拟课堂以外的真实英语语言使用场景。	.80	.36	

Note: The items with lower factor loading were removed after Confirmation Factor Analysis (CFA).

Appendix E. Response flow and exclusion rules

E.1 Screening workflow

1. Entries were collected via QQ and WeChat platforms under the supervision of the researchers.
2. The survey platform automatically blocked repeated entries from the same IP address, preventing duplicate submissions.
3. Responses exhibiting straight-lining patterns (i.e., identical answers/selections across all items of the questionnaire) were excluded.
4. Any questionnaires completed in under 60 seconds were deemed as invalid data and excluded from the dataset.
5. The remaining dataset was then used for the subsequent data analysis.

E.2 Removals for each step

Step	Rule	Removed (<i>n</i>)	Remaining (<i>n</i>)
1	Initial entries	0	597
2	Exact duplicates	0	597
3	Straight-lining patterns	15	582
4	Very short completion times	14	568
5	Final analytic dataset	0	568

Note. *n* = numbers. [Table E1](#) reports the number of removals for each step.

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