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Fostering success in online English education: Exploring the effects of ICT literacy, online learning self-efficacy, and motivation on deep learning

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Abstract
This research explores how motivation and online learning self-efficacy (OLSE) act as mediators in the association between information and communication technology (ICT) literacy and deep learning within the context of online English as a foreign language (EFL) education. A sample of 372 participants were recruited on a voluntary and anonymous basis from a public university in northern China for this study. Confirmatory factor analysis (CFA) was employed to evaluate the reliability and validity of the questionnaires. Subsequently, structural equation modeling (SEM) was conducted to examine the hypothesized model, with both CFA and SEM conducted with AMOS 29.0. The results reveal that ICT literacy, motivation, and OLSE positively and directly predict deep learning in online education. Additionally, ICT literacy also positively predicts deep learning indirectly with motivation and OLSE being significant mediators. The findings underscore the importance of ICT literacy, motivation, and OLSE for EFL learners to achieve deep learning in online EFL education. Drawn from these findings, pedagogical implications for alleviating EFL learners' online deep learning were provided.

Keywords Deep learning · ICT literacy · Online learning self-efficacy · Motivation · EFL learners · Online English education

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1 Introduction

In recent years, the accessibility of the internet has accelerated the growth of online learning (Dong, 2024). Despite online education's strength in transcending time and space limitations, some language students encounter varied challenges (Bai & Gu, 2022; Derakhshan et al., 2022; Resnik & Dewaele, 2023) and are only able to engage in surface learning during their online courses (Cifuentes et al., 2011). This underscores the need to prompt students to shift towards deep learning (Sølvik & Glenna, 2022). Deep learning involves the meaningful construction of knowledge through the integration of ideas, chunking of information, personal reflection, evidence-based analysis, and critical evaluation of content. It is a core competency necessary for innovation, creation, and sustainable development in modern society (Esteban-Guitart & Gee, 2020; Rose, 2016).

Deep learning of a language, specifically, has been defined as "[d]eep, reflective language learning" (Tochon, 2013, p. 359), which entails applying higher-order skills such as metacognitive strategies and the contextual use of language skills (Tragant et al., 2013). It is characterized by the ability to connect new information with prior knowledge, comprehensively explore different aspects of the material, and establish meaningful connections between the learning content and personal experiences (Aharony, 2006). The degree to which second language (L2) learners engage in the language learning process is a prerequisite for deep language learning (Chasetareh et al., 2023). This involves engaging with texts, presenting chosen topics, and interacting with others (Tochon, 2013), as well as adopting cognitive, metacognitive, social, language use, and learning management strategies (Jiang et al., 2022; Zhan et al., 2021). By employing these strategies, learners can actively engage with the language and acquire knowledge and skills (such as critical thinking and effective communication skills) at a deeper level, leading to lasting and meaningful language learning outcomes (Jiang et al., 2022).

Deep learning offers substantial advantages when students engage in learning tasks, as it relates to students' academic performance (Chasetareh et al., 2023) and ability improvement (Wang & Zhang, 2019). Understanding the antecedents of deep learning strategies is essential as they determine how information is processed, encoded, and retained in long-term memory (Núñez & León, 2016). However, psychological factors influencing deep learning have not yet been extensively explored in L2 research, despite their widespread examination in general education. These factors include intrinsic motivation to learn, autonomy support, emotional exhaustion, teacher gender, deep learning motivation, self-efficacy, perceived peer support, and perceived teacher autonomy support (Núñez & León, 2016; Hu & Yeo, 2020; Song et al., 2022; Zhao & Qin, 2021). Among these factors, motivation is widely recognized as a crucial force that drives and encourages learners to acquire knowledge (Entwistle, 2013). This factor holds significance as it is linked with deep learning and reduced superficial information processing among college students (Vansteenkiste et al., 2004). Key components of motivation, such as challenge and curiosity, exert positive effects on secondary students' adoption of deep learning strategies (Chan et al., 2012). Motivated learners can actively seek connections among different knowledge domains with sustained interest throughout the learning journey, ultimately facilitat-

ing deep learning (Jiang, 2022). Despite motivation being recognized as a critical force driving knowledge acquisition in general education contexts, its role in promoting deep learning within online L2 education is not yet well-understood.

Another construct which potentially affects the level of deep learning of L2 learners in online English education is online learning self-efficacy (OLSE). Defined as an individual's confidence, perception, and belief in their capacity to effectively accomplish a predetermined objective (Bandura, 1977), self-efficacy assumes particular significance in online settings due to the novel nature of the educational mode (Derakhshan & Fathi, 2023; Han & Geng, 2023; Lange, 2024). Research has consistently highlighted the pivotal role of OLSE as a determinant of students' learning outcomes in online contexts (Zimmerman & Kulikowich, 2016). Moreover, studies have consistently shown that learners with higher levels of self-efficacy demonstrate greater effort in challenging situations compared to those with lower self-efficacy (Hatlevik & Bjarn, 2021; Lange, 2024). It is suggested that self-efficacious learners are better equipped to sustain engagement in deep learning, resulting in comprehensive knowledge acquisition over an extended period (Chasetareh et al., 2023). However, despite its importance, this critical factor has received less attention when it comes to predicting L2 learners' deep learning, especially in an online environment.

Online learning hinges on learners possessing information and communication technology (ICT) literacy, vital for efficiently accessing, organizing, and evaluating a diverse array of information, thus fostering effective learning (Lei, 2021). It is posited that students' academic engagement may be influenced by the presence of technologies and their familiarity with available facilities (Bond & Bedenlier, 2019). Attaining a high level of ICT literacy may thus be essential for achieving deep learning in an online academic setting. Moreover, students' level of ICT literacy significantly shapes their educational experiences and influences their psycho-emotional responses to learning (Fraillon et al., 2019), alongside impacting the long-term sustainability of their learning outcomes (Hatlevik et al., 2018). Additionally, ICT literacy empowers learners by providing them with the autonomy to navigate their learning process independently, enabling them to seek information autonomously (Figura & Jarvis, 2007). This autonomy fosters intrinsic motivation, as individuals feel empowered and engaged in their learning journey (Ting, 2015). Similarly, ICT literacy may enhance OLSE by equipping learners with technical skills, information management abilities, communication proficiency, and adaptability to online learning tools necessary for success in online learning environments. This enhancement can bolster learners' confidence in their ability to actively participate in online learning activities (Hatlevik et al., 2018; Li et al., 2022).

Despite the significant strides made in deep learning, notable research gaps persist regarding the factors influencing deep learning among English as a Foreign Language (EFL) learners in online settings. Firstly, the specific relationships among individual factors such as self-efficacy, motivation, and ICT literacy, and their collective impact on facilitating deep learning in online EFL instructional settings remain inadequately understood. While extensive research exists in general education, empirical studies examining these relationships within the domain of EFL education are lacking. Secondly, although the literature recognizes the significance of psychological factors like motivation and OLSE in promoting deep learning, their roles as mediators between

ICT literacy and deep learning remain largely unexplored in the context of online EFL education. Consequently, there is a pressing need for research elucidating the interplay between ICT literacy, motivation, OLSE, and deep learning in online EFL contexts to inform pedagogical practices aimed at fostering success in online English education. In light of these gaps, the current study aims to develop a theoretical model of deep learning within an online EFL context by exploring the potential relationships between EFL learners' ICT literacy, OLSE, motivation, and the attainment of deep learning in an online learning environment. Through examining these associations, the study seeks to provide insights into the mechanisms underlying deep learning in online EFL education and contribute to the development of effective instructional strategies aimed at enhancing students' learning outcomes in online language learning contexts.

2 Literature review

2.1 Deep learning

Deep learning, originally characterized by its emphasis on cognitive comprehension and application, enables students to achieve a meaningful understanding of course materials and enrich their learning experiences (Marton & Säljö, 1976). Building upon this foundation, Entwistle and Ramsden (1983) further developed deep learning theory by proposing that it occurs when students actively engage in exploring and resolving complex problems within unfamiliar contexts, drawing upon their prior knowledge and connecting it with new information. Moreover, contemporary research highlights the importance of factors such as students' motivation, sense of connection and identity with the world, and the supportive role of teachers in providing scaffolding (Fullan et al., 2019; Tochon, 2013). In the twenty-first century, deep learning is increasingly associated with developing learners' proficiency in critical thinking, problem-solving, innovative thinking, effective communication, and collaborative skills (Esteban-Guitart & Gee, 2020). In the realm of online education, deep learning necessitates learners to acquire core academic content, collaborate effectively, communicate proficiently, engage in academic thinking, and employ critical thinking to solve complex problems (Czerkawski, 2014).

While prior studies have underscored the significant benefits of deep learning, associating it with enhanced self-efficacy (Hu & Yeo, 2020), L2 achievement (Chasetareh et al., 2023), and meaning-making (Doménech & Gómez, 2014), only a limited amount of research has delved into deep learning, either exclusively within online environments (e.g., Zhao & Liu, 2022) or exclusively in language learning contexts (e.g., Chasetareh et al., 2023; Zhan et al., 2021). Although this study shares similarities with previous research in exploring deep learning, it sets itself apart by focusing on both the online learning environment and its specific application to English language education. The existing research on deep learning in online language education is sparse and primarily centers on theoretical model development (e.g., Jiang, 2022), the influence of socio-economic background (e.g., Aharony, 2006), and the impact of new technologies (e.g., Tochon et al., 2014). However, unlike these previous works,

the current study uniquely concentrates on examining the effects of learners' individual differences (i.e., ICT literacy, OLSE, and motivation) on deep learning within the realm of online English language education.

2.2 ICT literacy and deep learning

ICT literacy refers to the proficient use of digital technology, communication tools, and networks to address problems and manage information effectively (Katz & Macklin, 2007). It is a composite construct comprised of the integration of technical cognitive abilities, social values, and processing skills (Kereluik et al., 2013). Insufficient ICT literacy can hinder students by distracting them from their learning objectives or limiting their participation when faced with technological challenges (Siddiquah & Salim, 2017). Conversely, students with advanced ICT literacy can effectively navigate these obstacles, allowing them to actively engage in learning activities and acquire knowledge (Lei et al., 2021). The widespread use of technology in online education has brought increased attention to the positive impact of ICT on deep learning (Beckett & Miller, 2006; Tochon et al., 2014). In this context, ICT literacy is considered essential for learners to effectively utilize technology and promote deep learning in online education. Insufficient ICT literacy may lead to difficulties and uncertainty in learning, potentially compromising the continuity and effectiveness of online learning (Rohatgi et al., 2016). Similarly, Callo and Yazon (2020) found that students' online learning capabilities, technology familiarity, and prior experience significantly influenced their readiness for online learning. Given these findings, it is reasonable to hypothesize:

Hypothesis 1 ICT literacy positively predicts deep learning in online EFL education.

2.3 Motivation as a mediator

Motivation, defined as a state of cognitive and emotional arousal driving learners to pursue established goals (Williams & Burden, 1997), plays a pivotal role in shaping attitudes and behaviors toward learning across educational settings (Fairchild et al., 2005). In language learning, motivation is recognized as a crucial determinant of successful language acquisition (Ellis, 1994). Moreover, demonstrating interest and enthusiastic commitment to the learning process are essential for facilitating deep learning (Biggs, 1987). Previous research suggests a significant relationship between students' ICT literacy and their learning motivation. Enhanced ICT literacy is associated with improved self-directed problem-solving abilities during online learning, fostering autonomy and enhancing the overall learning experience, which in turn encourages active participation (Ryan & Deci, 2000). Figura and Jarvis (2007) further indicate that possessing skills and strategies related to computer-mediated communication in L2 learning correlates with increased autonomy and motivation. Additionally, students demonstrate an independent and self-motivated approach to learning through the use of new web-based tools and collaborations, driven by their ICT literacy (Ting, 2015).

Extensive research has consistently shown a positive link between learners' motivation and their engagement in deep learning (Chasetareh et al., 2023; Putarek et al., 2019; Vansteenkiste et al., 2004). Chan et al. (2012) found that intrinsic motivation, particularly aspects such as embracing challenges and curiosity, significantly facilitated the adoption of deep learning approaches among secondary school students. Similarly, Núñez and León (2016) conducted a study with 276 undergraduate students in Spain, revealing that intrinsic motivation positively predicted deep learning. Poondej and Lerdpornkulrat (2016) investigated the relationship between students' motivational goal orientation and their use of deep learning strategies among 494 college students in Thailand, finding a significant positive association. Additionally, Zhan et al. (2021) partially examined this link in the Chinese EFL context, demonstrating that both instrumental and intrinsic motives promoted EFL learners' engagement in deep language learning. Based on these empirical findings, it is hypothesized:

Hypothesis 2 ICT literacy positively predicts motivation in online EFL education.

Hypothesis 3 Motivation positively predicts deep learning in online EFL education.

Hypothesis 4 Motivation mediates the relationship between ICT literacy and deep learning in online EFL education.

2.4 OLSE as a mediator

According to Social Cognitive Theory (SCT), self-efficacy directly influences the dynamic psychological processes involved in learning activities, thereby impacting learning outcomes (Rooij et al., 2017). Supported by self-efficacy, students are more likely to feel confident in their learning abilities, enabling them to tackle challenging tasks and persist in the face of setbacks until learning goals are achieved. This importance of possessing adequate self-efficacy levels is particularly pronounced in contexts characterized by complex and unfamiliar learning experiences, such as online education (Cho et al., 2010). Operationally, OLSE refers to L2 learners' perception of their ability to effectively acquire knowledge and perform tasks within online environments (Derakhshan & Fathi, 2023).

Four key antecedents are believed to influence self-efficacy, namely (1) observational or vicarious learning by observing successful performances of others, (2) physiological states involving signs of distress, (3) previous experiences of mastery, and (4) social persuasion through encouragement from others (Bandura, 1982). Previous studies have consistently shown that mastery experiences in ICT play a vital role in shaping students' self-efficacy, which, in turn, significantly impacts their academic performance (Usher & Pajares, 2008; Valentine et al., 2004). Specifically, students with higher levels of ICT literacy often have greater computer experience (Li et al., 2022), leading to increased proficiency in completing online educational tasks, fostering positive learning experiences, and ultimately nurturing higher levels of self-efficacy (Hatlevik et al., 2018). Moreover, a comprehensive study conducted by Li et al. (2022) further validated the significant relationship between ICT literacy and

learners' OLSE. Most recently, Feng (2023) conducted a study involving 987 Chinese EFL university students and discovered a noteworthy relationship between digital literacy and OLSE. Specifically, the data revealed that 92% of variations in Chinese students' OLSE could be significantly anticipated based on their digital literacy ($\beta = 0.916$, $p < 0.001$). This finding underscores the substantial impact of ICT literacy on students' perceptions of their abilities to effectively engage in online learning activities. Despite the growing importance of ICT literacy in online education, there has been relatively limited scholarly exploration into the potential predictive role of EFL students' ICT literacy in their self-efficacy within online contexts (Feng, 2023).

Students with higher levels of self-efficacy in online learning tend to exhibit greater confidence in achieving their goals or completing tasks, leading to increased motivation and consistent effort over time (Hatlevik & Bjarn, 2021). However, findings from Bassi et al. (2007) suggest that students with high academic self-efficacy may lean towards shallow learning strategies, indicating a nuanced relationship between self-efficacy and learning approaches. Zhao and Qin (2021) emphasize that higher self-efficacy levels correlate with a greater focus on fulfilling psychological needs, which fosters the adoption of deep learning behaviors conducive to academic growth. This link has also been supported by Zhan et al. (2021) in their study among Chinese undergraduates, highlighting the importance of self-efficacy in facilitating deep learning in EFL education. Moreover, recent research by Zhao and Liu (2022) provides further evidence of the predictive role of OLSE in deep learning within online environments. Overall, high ICT literacy empowers learners to feel more confident in their learning abilities in online EFL education, thereby promoting deep learning.

Hypothesis 5 ICT literacy positively predicts OLSE in online EFL education.

Hypothesis 6 OLSE positively predicts deep learning in online EFL education.

Hypothesis 7 OLSE mediates the relationship between ICT literacy and deep learning in online EFL education.

2.5 The present study

According to Expectancy-value Theory (EVT, Atkinson, 1957; Wigfield & Eccles, 2000), motivation towards a specific behavior or action hinges on two primary factors: the perceived likelihood of accomplishing the desired outcome through that action and the significance attributed to that outcome. In the EFL context, language learning motivation aligns with the value placed on learning, while self-efficacy aligns with the expectation of success in EVT (Zhan et al., 2021). EVT further suggests that expectations for success and the perceived value of a task are shaped by a multitude of individual and environmental factors, including abilities, past experiences, beliefs, goals, and cultural influences (Leaper, 2011). Considering these insights, this study investigates how students' ICT literacy influences OLSE and motivation. Grounded in EVT and empirical evidence, the study explores the relationship between ICT lit-

eracy and deep learning in online EFL education, with motivation and OLSE serving as mediators figure 1.

3 Method

3.1 Participants

A total of 372 participants were enrolled from a public university in northern China on a voluntary and anonymous basis. The university provided online English language courses for students in different grade levels. Convenience sampling was adopted in the study to recruit the participants who attended the online English courses. There were 214 female students (57.5%) and 158 male students (42.5%) with their ages ranging from 18 to 25 (M=21, SD=1.66) years old. The sample covered all undergraduate academic years with 35 (9.4%) freshmen, 113 (30.4%) sophomores, 117 (31.5%) juniors, and 107 (28.8%) seniors. Among these participants, 140 (37.6%) students majored in English while 232 (62.4%) were non-English major students. All the participants in the study were native Chinese speakers who had acquired English as a foreign language and demonstrated proficiency by successfully passing the English test of the national college entrance examination.

3.2 Instruments

The composite questionnaire consisted of two sections: (1) demographic information such as gender, age, grade, major and English proficiency; and (2) the four constructs (22 items in total), namely, motivation (5 items), OLSE (5 items), ICT literacy (7 items), and deep learning (5 items). The participants were asked to rate each item on a 5-point Likert scale, which ranged from "strongly disagree" (1) to "strongly agree" (5).

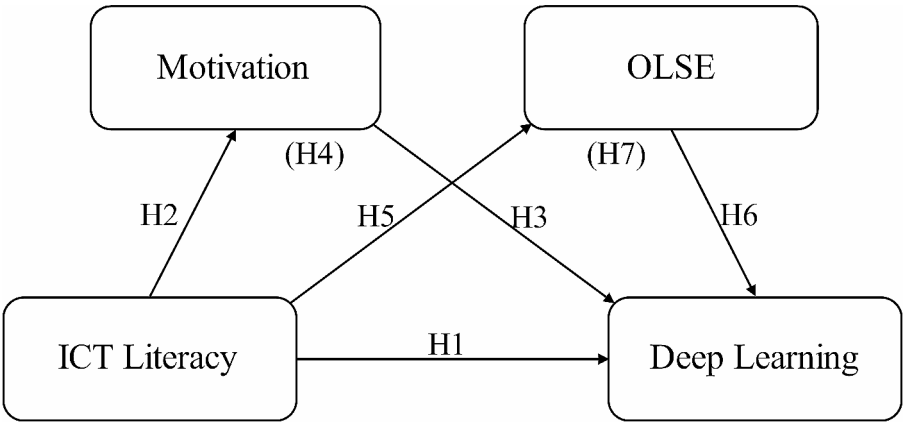

Fig. 1 Hypothetical model. *Note* OLSE = Online Learning Self-efficacy

3.2.1 Online learning self-efficacy

Zhao and Liu's (2022) five-*item Online Learning Self-Efficacy Scale* was adapted to measure EFL learners' self-efficacy. The questionnaire was a modified version originally designed by Sherer et al. (1982). The scale was slightly modified to fit an EFL context. A sample item is "I think I can think and master in-depth knowledge in an online English learning environment." The scale used in the study demonstrated good internal consistency, as indicated by a Cronbach's alpha coefficient of 0.859.

3.2.2 Motivation

To evaluate the motivation of EFL learners, the researchers in this study modified the five-item *Deep Learning Motivation Scale*, which was derived from the revised two-factor Study Process Questionnaire (R-SPQ-2 F; Biggs et al., 2001). A minor modification was made to adapt it to an online EFL context. A sample item is "I find that at times studying English online gives me a feeling of deep personal satisfaction." The scale used in this study demonstrated good internal consistency, as evidenced by a Cronbach's alpha coefficient of 0.874.

3.2.3 ICT literacy

The *Information Communications Technology Literacy Scale* (Li et al., 2022) was adapted to measure EFL learners' ICT literacy. The seven-item scale was an abridged and modified version based on the 2018 International Computer and Information Literacy Study of the International Association for the Evaluation of Educational Achievement (Fraillon et al., 2019). A sample item is "I can make any type of presentation (e.g., Microsoft PowerPoint, WPS, and other programs)." In this study, the scale exhibited a high level of internal consistency, as indicated by a Cronbach's alpha coefficient of 0.877.

3.2.4 Deep learning

A five-item *Deep Learning Scale* designed by Zhao and Liu (2022) was adapted to measure students' deep learning. The scale was reformulated based on the revised two-factor Study Process Questionnaire (R-SPQ-2 F; Biggs et al., 2001). A minor justification was made to make it suitable for an EFL context. A sample item is "During online English learning, I can apply theories or concepts to real problems or new situations." In this study, the scale demonstrated favorable internal consistency with a Cronbach's alpha coefficient of 0.869.

3.3 Data collection

The questionnaire was initially translated into Chinese and subsequently translated back into English. Two experts in translation and applied linguistics were requested to review and scrutinize the translated version of the original questionnaire. The translated questionnaire underwent an initial pilot test involving 63 students to assess

its clarity, comprehensibility, and appropriateness for the target population. The reliability analysis yielded favorable results for all measured constructs in the study. Specifically, the internal consistency was high for motivation (Cronbach's $\alpha = 0.903$), online learning self-efficacy (OLSE) (Cronbach's $\alpha = 0.873$), ICT literacy (Cronbach's $\alpha = 0.889$), and deep learning (Cronbach's $\alpha = 0.896$). During the pilot test, participants were asked to provide feedback on the questionnaire, including comments on the clarity of instructions, the relevance of items, and any difficulties encountered in responding to the questions. Based on the feedback received from the pilot test, necessary revisions and adjustments were made to improve the questionnaire's quality and suitability for the study population. In the main research, data were collected with the assistance of an online questionnaire platform http://www.wjx.cn/. Participants were firstly informed of the research objectives before the administration of questionnaires and then ensured that the responses to the questionnaires would be treated confidentially and could be withdrawn at any time. All participants consented to be involved in the study voluntarily. Around 10–15 min were needed for the respondents to fill out the questionnaires. Throughout the data collection process, the researchers strictly followed ethical standards.

3.4 Data analysis

Before conducting statistical analyses, preprocessing procedures, including outlier and missing value inspections, as well as normality tests, were carried out. To evaluate the reliability and validity of the questionnaires, this study employed confirmatory factor analysis (CFA). Descriptive and Pearson bivariate correlation analyses for the data were performed using SPSS 26.0. Subsequently, structural equation modeling (SEM) was employed to examine the hypothesized model, with both CFA and SEM conducted in AMOS 29.0. To address the issue of non-normally distributed variables in a large sample size, maximum likelihood (ML) was selected as the estimation method, which provides resistance to unbiased estimation (Hau & Marsh, 2004). Model goodness-of-fit was evaluated based on several criteria, including $\chi^2/df < 3$, Tucker-Lewis Index (TLI) and Comparative Fit Index (CFI) ≥ 0.90, and Standardized Root Mean Square (SRMR) and Root Mean Square Error of Approximation (RMSEA) ≤ 0.08 (Kline, 2011). Lastly, a bootstrap analysis consisting of 5,000 samples and bias-corrected 95% confidence intervals was conducted to examine the mediation effects.

4 Results

4.1 Preliminary analysis

Data cleaning results revealed that no missing values were detected in the dataset since an online questionnaire with forced choices was adopted. In addition, no violated multicollinearity and normality problem was identified. Finally, a total of 372 samples were reserved for further analysis. Descriptive statistics (see Table 1) shows

Table 1 Descriptive statistics ($N=372$)

Variable	Mean	SD	95%CI		Skewness	Kurtosis
ICT literacy	3.71	0.56	3.65	3.76	-0.028	-0.453
Motivation	3.67	0.69	3.60	3.74	-0.986	1.571
OLSE	3.46	0.65	3.38	3.53	-0.902	1.463
Deep learning	3.51	0.67	3.45	3.58	-0.709	1.114

Note OLSE=Online Learning Self-efficacy

Table 2 Correlation, reliability, and validity of constructs

	AVE	CR	Cronbach's α	ICT literacy	Motivation	OLSE	Deep learning
ICT literacy	0.505	0.877	0.877	**0.711**			
Motivation	0.593	0.879	0.874	0.389***	**0.770**		
OLSE	0.624	0.893	0.859	0.403***	0.423***	**0.790**	
Deep learning	0.612	0.887	0.869	0.443***	0.558***	0.603***	**0.782**

Note AVE=average variance extracted; CR=composite reliability; numbers in bold fonts are square roots of the AVE; off diagonals are correlation statistics. OLSE=Online Learning Self-efficacy. ***$p<0.001$

that the skewness and kurtosis values of all data were falling within the acceptable range of ±2 (Roever & Phakiti, 2017).

Pearson's correlation was calculated (see Table 2), indicating positive correlations between all the constructs at the p-level of 0.001. Specifically, ICT literacy was moderately linked with motivation ($r=0.389$), self-efficacy ($r=0.403$), and deep learning ($r=0.443$). Similarly, such a moderate relationship was also indicated between motivation and self-efficacy ($r=0.423$), whereas deep learning exhibited a relatively high association with motivation ($r=0.558$) and self-efficacy ($r=0.603$).

According to Hair et al. (2019), it is recommended to use factor loading, Cronbach's Alpha (α), and composite reliability (CR) for assessing reliability. In our study, the factor loading values were acceptable, all exceeding the minimum threshold of 0.60 (see Fig. 2). As presented in Table 2, the CR values for all constructs were satisfactory, each exceeding the cut-off value of 0.7. Additionally, the value of AVE exceeded the threshold of 0.50, exhibiting good convergent validity (Byrne, 2016). The square root of AVE was greater than the correlation coefficients between all constructs, revealing that each measure has good discriminant validity (Fornell & Larcker, 1981).

The initial measurement model was slightly modified by adding a path between residual items labeled e9 and e11 to improve the model fit with the guidance of the MI value as well as the theoretical framework (see Fig. 2). More specifically, the two residual items were correlated as they both referred to students' intrinsic motivation for EFL learning. After the modification, the measurement model exhibited a satisfactory fit to the data ($\chi^2/df=1.685$; TLI=0.965; CFI=0.969; RMSEA=0.043; SRMR=0.037).

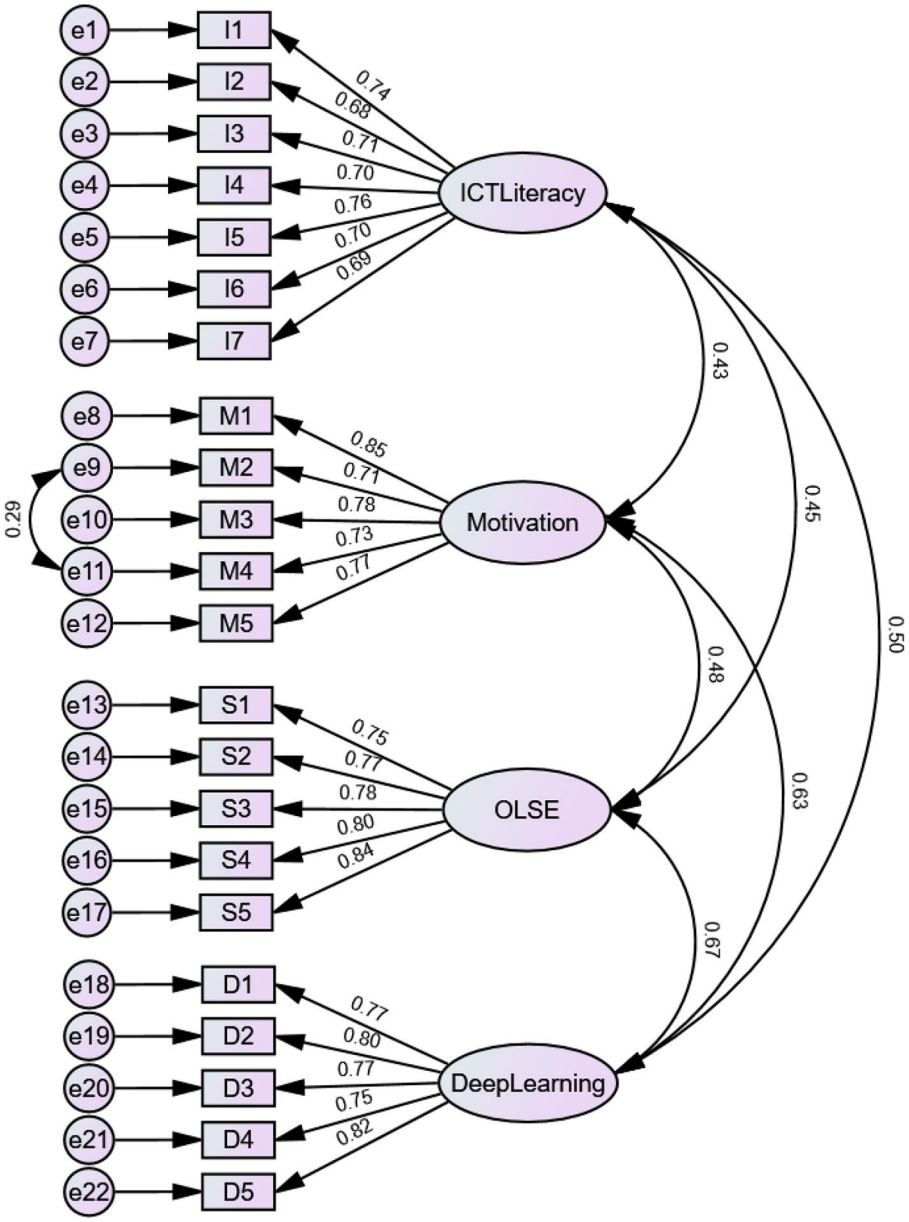

Fig. 2 Measurement model. *Note* OLSE = Online Learning Self-efficacy

4.2 Path analysis

The SEM model exhibited a good model fit to the data ($\chi^2/df = 1.849$; TLI = 0.956; CFI = 0.961; RMSEA = 0.048; SRMR = 0.068). Figure 3 presented the SEM model with standardized estimates, in which all factor loadings exceeded the 0.5 threshold

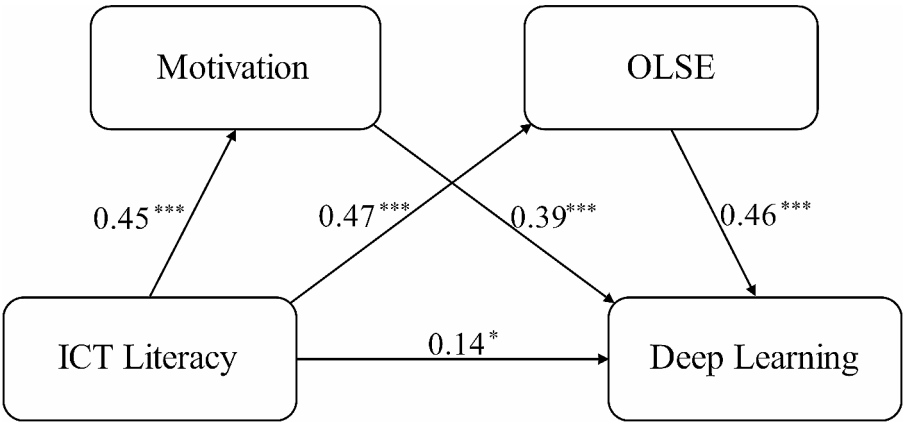

Fig. 3 Structural equation model. *Note* OLSE = Online Learning Self-efficacy. *** $p < 0.001$; * $p < 0.05$

Table 3 Path coefficients of SEM

Path relationship	β	Weight	S.E.	C.*R*.	*P*
ICT literacy → OLSE	0.472	0.573	0.077	7.445	***
ICT literacy → Motivation	0.453	0.623	0.087	7.141	***
ICT literacy → Deep learning	0.137	0.163	0.065	2.498	0.012
OLSE → Deep learning	0.462	0.452	0.058	7.749	***
Motivation → Deep learning	0.387	0.334	0.050	6.749	***

Note OLSE = Online Learning Self-efficacy. *** $p < 0.001$

Table 4 Mediation effects

	Unstandardized Estimate	Standardized Estimate	Boot SE	Bias-Corrected 95%CI	
				Lower	Upper
Total effects	0.631	0.531***	0.058	0.404	0.632
Direct effects	0.163	0.137*	0.066	0.007	0.270
Indirect effects	0.468	0.393***	0.049	0.299	0.488
Motivation as the mediator	0.208	0.175***	0.037	0.106	0.250
OLSE as the mediator	0.259	0.218***	0.037	0.149	0.292

Note OLSE = Online Learning Self-efficacy. *** $p < 0.001$; * $p < 0.05$

value. As shown in Table 3, the results of path analysis indicated that ICT literacy positively predicted motivation ($\beta = 0.453$, $p < 0.001$) and OLSE ($\beta = 0.472$, $p < 0.001$). Meanwhile, deep learning was positively predicted by ICT literacy ($\beta = 0.137$, $p < 0.05$), motivation ($\beta = 0.387$, $p < 0.001$), and OLSE ($\beta = 0.462$, $p < 0.001$).

4.3 Mediation results

The examination of the mediation effect involved a bootstrap analysis comprising 5,000 samples and bias-corrected 95% confidence intervals. Table 4 demonstrated that ICT literacy had significant total effects (0.531, $p < 0.001$, 95% CI: 0.404–0.632)

on deep learning. Furthermore, the indirect effects of ICT literacy on deep learning mediated via motivation (0.175, $p<0.001$, 95% CI: 0.106–0.250) and OLSE (0.218, $p<0.001$, 95% CI: 0.149–0.292) were significant, as evidenced by non-zero values within the 95% confidence intervals. Additionally, the direct effect (0.137, $p<0.05$, 95% CI: 0.007–0.270) of ICT literacy on deep learning was also statistically significant as no zero was contained in the 95% confidence intervals.

5 Discussion

Enlightened by empirical findings and drawing on EVT, this research examined the mediating role of motivation and OLSE in the relationship between ICT literacy and deep learning in online EFL education. This is the first study that investigated the simultaneous effects of these factors on online deep learning within the field of L2 research.

First, the findings of this study affirm Hypothesis 1, indicating that EFL learners' ICT literacy significantly and directly predicts deep learning in online education. This aligns with the conclusions drawn from prior research (Beckett & Miller, 2006; Callo & Yazon, 2020; Tochon et al., 2014), which suggested that students proficient in online tools and computer technology are more likely to engage in deep learning within web-based learning environments. Essentially, ICT literacy can be regarded as the prerequisite for EFL learners' access to deep learning in an online context. Particularly in the context of potential disruptions inherent in online learning, such as technical glitches (Nora & Snyder, 2008), possessing robust ICT literacy equips learners with the necessary skills to actively engage in the learning process with unwavering focus and participation. This finding also resonates with Lei et al. (2021), indicating that students who possess advanced ICT literacy can adeptly utilize their skills to promptly tackle technological hurdles as they emerge. This capability enables them to seamlessly engage in learning activities and absorb new knowledge without interruption. Furthermore, proficient online research abilities empower students to navigate and utilize digital resources effectively, enabling self-directed learning experiences that significantly enhance their overall academic outcomes (Ng, 2018).

Second, this study unveiled a positive correlation between EFL learners' motivation and deep learning, thereby corroborating Hypothesis 3. This aligns with previous research (Chan et al., 2012; Chasetareh et al., 2023; Poondej & Lerdpornkulrat, 2016; Putarek et al., 2019; Vansteenkiste et al., 2004), which consistently emphasizes motivation as a crucial driver propelling students toward deep learning. Additionally, these findings underscore the pivotal role of motivation in guiding and sustaining the extensive process of language acquisition (Dörnyei, 2006; Ellis, 1994; Gardner, 1985; Tochon, 2013). Therefore, heightened levels of learning motivation, as suggested by Jiang (2022), can act as a catalyst for deep language learning, highlighting its significance as a fundamental component of language acquisition. In addition, the positive relationship between motivation and deep learning observed in this study can be understood through the lens of EVT (Wigfield & Eccles, 2000), where learners' beliefs about the value of language learning act as driving forces behind their engagement in deep learning behaviors. Specifically, learners who perceive language

learning as valuable are more likely to invest effort in mastering the language, leading to deeper levels of engagement and ultimately, deeper learning outcomes (Núñez & León, 2016). This finding also corroborates the conclusions drawn by Zhan et al. (2021), highlighting that motivation serves as a critical factor in shaping L2 learners' attitudes and behaviors towards language learning, influencing their willingness to engage in the cognitive processes necessary for deep learning to occur.

Third, this study demonstrated that EFL learners' ICT literacy not only positively influenced motivation (supporting Hypothesis 2) but also indirectly impacted deep learning through motivation as a mediator (supporting Hypothesis 4). This finding aligns with previous research (Figura & Jarvis, 2007; Ryan & Deci, 2000; Ting, 2015), which suggests that EFL learners with higher levels of ICT literacy tend to exhibit greater motivation for deep learning in online education. EVT (Wigfield & Eccles, 2000) provides further insight into this finding, suggesting that learners' perceptions of the value of a task are influenced by their personal abilities and past experiences. This could be attributed to the fact that students proficient in ICT are better equipped to utilize online resources and tools effectively, thus enabling greater autonomy in their learning process (Figura & Jarvis, 2007). Additionally, advanced ICT literacy helps overcome obstacles to accessing online educational resources, thereby promoting learners' resilience and emotional stability (Li et al., 2022) and ultimately enhancing motivation for deep learning.

Fourth, this study indicated that EFL learners' OLSE positively influenced deep learning, confirming Hypothesis 6. This finding aligns with previous research (Bassi et al., 2007; Hatlevik & Bjarn, 2021; Zhan et al., 2021; Zhao & Liu, 2022), which suggests that self-efficacy can enhance learners' deep learning. According to SCT (Bandura, 1977, 1982), self-efficacy is closely linked to learning behaviors and academic performance. Students with high self-efficacy tend to set self-learning goals, proactively address academic challenges, and maintain their learning efforts over time (Cooper, 2014), all of which are associated with deep learning and improved academic performance (Zhao & Qin, 2021). Moreover, this study reinforces Zimmerman and Kulikowich's (2016) findings that OLSE significantly influences students' learning outcomes in online environments. This suggests that EFL learners who are confident in their ability to succeed in online education are more likely to motivate themselves to actively participate in the learning process (Derakhshan & Fathi, 2023), thereby facilitating deep learning. This observation is also consistent with the tenets of EVT, which posits that learners' perceptions of feasibility of a task significantly influence their motivation and subsequent engagement (Wigfield & Eccles, 2000). In the context of language learning, learners who perceive themselves as capable of achieving proficiency are more likely to engage in deep learning strategies.

Finally, the study revealed that EFL learners' ICT literacy positively impacted OLSE, supporting Hypothesis 5, and that OLSE mediated the prediction of ICT literacy to deep learning in online education, supporting Hypothesis 7. These findings underscore the significance of ICT literacy in L2 education, where it has been acknowledged as essential for effective teaching and learning (Lotherington & Jenson, 2011). This aligns with prior research by Usher and Pajares (2008), who found that learners' proficiency in using ICT could foster a sense of self-efficacy toward online learning, consistent with SCT. SCT posits that self-efficacy is influenced by

personal, environmental, and behavioral factors (Bandura, 1977, 1982), wherein ICT literacy serves as a personal factor, and online education acts as an environmental factor shaping students' self-efficacy beliefs and behaviors. These findings are also consistent with previous research by Zimmerman and Kulikowich (2016) and Cho and Kim (2013), suggesting that OLSE is influenced by various technology-related factors, including users' ICT literacy. The interplay between ICT literacy and OLSE can be attributed to the inherent association between OLSE and technology, with ICT literacy emerging as a significant predictor in this study (Feng, 2023). Higher ICT literacy may improve students' participation and task management by overcoming technological barriers, leading to a positive online learning experience, a sense of achievement, and ultimately improved OLSE (Li et al., 2022). Improved OLSE, in turn, may lead to higher expectations for online learning outcomes, utilization of diverse learning strategies, and a greater inclination toward achieving deep learning in an online environment. This finding enhances our understanding of OLSE by demonstrating its association with EFL learners' ICT literacy and its role in predicting online deep learning.

6 Implications and conclusion

This study sheds light on the critical role of ICT literacy, motivation, and OLSE in predicting learners' deep learning in online EFL education. Specifically, the findings suggest that EFL learners' high levels of ICT literacy serve as a prerequisite for accessing deep learning in an online context. Furthermore, motivation and OLSE emerged as significant predictors of deep learning and both were found to be positively influenced by ICT literacy. The study also demonstrated the mediating role of motivation and OLSE in the relationship between ICT literacy and deep learning. These findings contribute to a better comprehension of the complex interplay between these factors in online EFL education.

The findings of this study yield important implications for online EFL instruction. Given the significant role of ICT literacy in facilitating deep learning, EFL instructors are advised to prioritize the integration of ICT-based assignments and training initiatives into their teaching practices. For instance, teachers can incorporate activities that require students to create digital presentations, collaborate on online platforms for language practice, engage in virtual language exchanges with native speakers or start conversations in chatbots powered by GenAI. These activities offer valuable opportunities for students to enhance both their language skills and ICT proficiency simultaneously. Furthermore, activities such as dubbing English movies using computer apps or online platforms can provide students with enriching enactive and vicarious learning experiences. Through active involvement with ICT tools in knowledge construction, learners not only improve their technological skills but also cultivate greater confidence and belief in their ability to succeed in online learning environments (Kuo et al., 2021). Moreover, to enhance OLSE, educators should implement targeted interventions and support mechanisms. This can involve providing students with opportunities for skill-building and practice within online learning environments. Additionally, educators should offer scaffolding and guidance to help students

navigate digital tools effectively. Fostering a growth mindset is also crucial, encouraging students to persist and remain resilient in the face of challenges encountered during online learning. By implementing these strategies, educators can empower students to develop confidence in their abilities to succeed in online educational settings. In addition, the influence of EFL learners' motivation on students' deep learning is still worth noting. To foster motivation for deep learning, teachers can design tasks that tap into students' interests, promote autonomy, and offer opportunities for meaningful engagement. Educators can incorporate project-based learning activities, inquiry-based tasks, and collaborative group projects that allow students to explore topics of personal interest, apply their language skills in real-world contexts, and interact with peers in a supportive learning environment. For instance, in an online EFL classroom, teachers can create assignments that require students to research and present on topics related to their hobbies, interests, or cultural backgrounds. This not only allows students to explore subjects they are passionate about but also encourages them to take ownership of their learning process. Additionally, teachers can incorporate interactive activities such as language games, debates, or simulations that promote active participation and foster a sense of enjoyment in the learning process. By providing tasks that are challenging yet achievable and that offer opportunities for collaboration and creativity, teachers can help students develop a positive attitude towards learning and maintain high levels of motivation throughout their language learning journey.

This study has certain limitations that require consideration. Firstly, the adoption of a cross-sectional design restricts the ability to determine causality and generalizability of the findings. To enhance the replicability and extend the generalizability of the findings, future research is recommended to incorporate a longitudinal design across various learning contexts. Moreover, convenience sampling and self-report measures may have increased the possibility of selection bias and social desirability, respectively. To mitigate these issues, future studies may employ a qualitative or mixed-methods approach to triangulate data, providing a more comprehensive understanding of the relationships among the variables under investigation. Lastly, this research analyzed the four single-factor constructs holistically without examining the links among their subconstructs. Future studies can explore these constructs in greater depth by investigating their subcomponents.

In terms of suggestions for future research, it is recommended to explore ways to enhance ICT literacy, motivation, and OLSE over time through teacher and student interviews. Additionally, it is suggested that other personality traits and psychological factors, such as pride, hope, enjoyment, and resilience, could be further examined to investigate their mediating effects between ICT literacy and deep learning from the positive psychology perspective. Furthermore, it remains unclear how these factors contribute to specific aspects of L2 learning, such as reading, listening, writing, etc., which warrants further investigation.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval Informed consent was appropriately obtained from all participants. The authors declare that there is no conflict of interest.

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