

## PAPER

# Deep Learning Influences on Higher Education Students' Digital Literacy: The Meditating Role of Higher-order Thinking

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## ABSTRACT

Digital literacy has emerged as a core competency in the 21st century society, and deep learning and higher-order thinking have been discussed as effective ways to improve digital literacy. Therefore, this study aimed to verify the influence of deep learning and higher-order thinking skills on higher education students' digital literacy. Structural Equation Modeling was used to analyze the data gathered from 687 undergraduate and higher vocational students using a convenient sampling technique. The findings indicate that deep motivation and deep strategy were significantly positively correlated with students' digital literacy. In such a structural relationship, digital literacy was additionally moderated by higher-order thinking. Nevertheless, students who have customarily used digital devices for more than five years could not be explained by this structural equation model. Lastly, this conclusion highlighted that educators should consider students' digital experiences level, guide in selecting and applying deep learning, develop higher-order thinking, and improve their digital literacy.

## KEYWORDS

digital literacy, deep learning, deep motivation, deep strategy, higher-order thinking

## 1 INTRODUCTION

Although education and technology have always been intertwined, as new digital technologies emerge, the education industry has recently encountered new opportunities and challenges. With the COVID-19 pandemic leading to mandatory online classes, teachers and students alike recognize the importance of digital literacy for effective online class participation [1], [2]. Therefore, higher education faces a significant challenge in developing students' digital literacy and meeting the needs of digital social development. Moreover, as digital natives, 75% of young people worldwide use digital information and only 63% in Asia-Pacific [3], so the level of digital literacy among students may vary and should be considered.

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Previous works of literature in the field of digital literacy have concentrated on the framework of digital literacy [4], [5], [6], the relationship between online learning and digital literacy [7], [8] [9], and how to improve digital literacy [10], [11], [12], [13]. More specifically, when increasing digital literacy, students also need to develop learning approaches [8], [14], motivation [15], [16], and critical thinking [17], [18].

In addition to improving digital literacy, fostering higher-order thinking among students of all academic levels was considered an important educational task [19], [20]. Higher-order thinking was described as critical thinking, creativity, collaboration, and communication (4C) [21], whereas digital literacy was characterized as operation skills and thinking skills [5]. Therefore, building higher-order thinking-based critical thinking abilities is crucial for developing digital literacy to classify information critically and create new knowledge [1], [22].

Moreover, a considerable number of studies found that deep learning was a powerful way to achieve the growth of higher-order thinking skills [23], [24]. For example, Nelson Laird et al. [23] selected three sub-scales from the National Student Engagement Survey (NSSE): reflection learning, integrated learning, and higher-order learning, and discovered that these three dimensions were consistent with the behavior of deep learning approaches. Nevertheless, the precise connection between deep motivation, deep strategies, and higher-order thinking remains unclear.

Previous literature has paid insufficient attention to the interrelationships between deep learning, higher-order thinking, and digital literacy although some researchers have explored the intersection of deep learning and digital literacy [8], [14] [25], deep learning and higher-order thinking [24], [26], [27], and higher-order thinking and digital literacy [1], [22], [28]. Few studies have considered the intersection of all three fields. Moreover, deep motivation and deep strategy are often studied as a whole, and whether the relationship between the two in higher-order thinking and digital literacy is consistent remains to be further studied.

This study aims to understand better the intersection between deep motivation, deep strategy, higher-order thinking, and digital literacy, which will help designers of higher education institutions, policymakers, and government agencies provide important insights to develop effective strategies to cultivate students' higher order thinking skills and digital literacy. Therefore, the following research questions served as the framework for this study:

1. Do students' deep motivation and deep strategy influence their digital literacy?
2. Does higher-order thinking play a mediating role in the influence of digital literacy?

## 2 LITERATURE REVIEW

### 2.1 Digital literacy

With the development of technology, literacy is also constantly developing, such as Internet literacy, media literacy, information literacy, ICT literacy, and digital literacy. Nevertheless, the term "digital literacy" was initially introduced by Gilster [5], who emphasized that individuals must be not only able to acquire information but also be able to evaluate and interpret it.

In exploring the framework of digital literacy, some scholars have argued that digital literacy comprises not only the skills and competencies required for Internet literacy, but also other components. For example, digital literacy covers a broad

variety of complicated cognitive, physical, sociological, and emotional abilities that users require in a digital context. It goes beyond simply knowing how to utilize software or handle digital devices [4]. In addition, Ng [29] argued that digital literacy comprises three overlapping dimensions: technology, cognition, and social emotion.

In order to adjust to the evolution of education in the digital era and realize the sustainable and fair development of digital education, international organizations and various countries have taken a series of actions. For example, the European Union (EU) released the digital competency framework from 2013 [30] to 2022 version [2]. The 2022 framework divides digital competencies into five categories: information and data literacy, communication and collaboration, innovation, safety, and problem-solving.

## 2.2 Deep learning

Marton and Säljö [31] found that there are two main types of student engagement in the learning process: deep learning and surface learning. More specifically, deep learning is characterized by understanding and processing information, participating in high-quality activities, combining old and new knowledge, processing tasks, and solving problems. In contrast, surface learning is more likely to participate in low-level cognitive tasks and is less likely to create complicated associations between knowledge from books and real-world experiences.

Furthermore, Biggs [32] outlined three important learning approaches: deep, surface, and achieving, and pointed out the motivations and strategies involved in each learning approach. Deep motivation is the term for an individual's innate interest in the knowledge and abilities acquired in a particular field. In contrast, the deep strategy involves active and extensive reading, connecting with prior knowledge, and seeking to comprehend the underlying concepts and principles.

Previous studies have mostly concentrated on the association between deep learning and academic achievement [32], [33], [34]. However, more recent work examining deep learning has concentrated on the following: comparing deep learning with machine learning [35], examining the relationship between deep learning and higher-order thinking [26], [27], problem-solving [36], and digital literacy [8], [14].

## 2.3 Higher-order thinking

Higher-order thinking can be traced back to Bloom's [37] Taxonomy of the Cognitive Domain, which classified cognitive goals from lower-order to higher-order, including knowledge, comprehension, application, analysis, synthesis, and evaluation. Then, Anderson and Krathwohl [38] modified Bloom's Taxonomy and made several improvements: remembering, understanding, applying, analyzing, evaluating, and creating.

Studies on higher-order thinking are depicted differently. For example, Lewis and Smith [19] pointed out that higher-order thinking skills are the process by which a person associates new knowledge with information retained in memory and reorganizes it to achieve a specific goal or find possible responses to a difficult scenario. According to the classification of educational objectives as analysis, synthesis, assessment, and creativity, higher-order thinking refers to the mental activity or cognitive abilities formed at a higher cognitive level [39]. On the other hand, Yang and Zhao [20] classified remembering as lower-order thinking and understanding, applying,

analyzing, evaluating, and creating as higher-order thinking according to Bloom's classification of educational goals.

Moreover, there are several methods and strategies for developing higher-order thinking in the classroom [17], [40]. For example, Reece [17] put forward that teaching should provide the following three stages to support the improvement of higher-order thinking: the first stage was the acquisition of skills; the next step was to incorporate the newly acquired knowledge and abilities into one's way of thinking; the third stage was to apply the combined skills to new situations. Moreover, Limbach and Waugh [40] offered a five-step strategy for fostering higher-order thinking, which included determining learning goals, teaching through inquiry, practicing prior to assessment, reviewing and improving, and providing feedback and learning evaluation. These five processes provided an easy way for educators to increase students' higher-order thinking skills.

## 2.4 The relationship among variables

Based on previous research, deep learning and information literacy are significantly positively correlated, and students' information literacy levels increase as they utilize deep learning more frequently [14]. However, students' performance largely depends on their level of motivation and how well they apply the appropriate learning strategies in the right situations [41], [42]. Moreover, Heinström [8] analyzed three information-seeking modes; fast surfing, broad scanning, and deep diving, and found that the deep strategy can motivate students to deep diving, achieving goals and leading to good results. In light of this, it is reasonable to assume that:

H1: Students' deep motivation contributes positively to their digital literacy.

H2: Students' deep strategies contribute positively to their digital literacy.

Based on the existing literature, it is evident that higher-order thinking and digital literacy are interrelated and have a reciprocal relationship [1], [22]. More specifically, digital literacy can enhance students' critical thinking and, eventually, learning based on higher-order thinking skills. Contrarily, critical thinking skills can increase students' digital literacy. Novitasari et al. [22] emphasized that higher-order thinking is important in building digital literacy. Consequently, it is reasonable to assume the following:

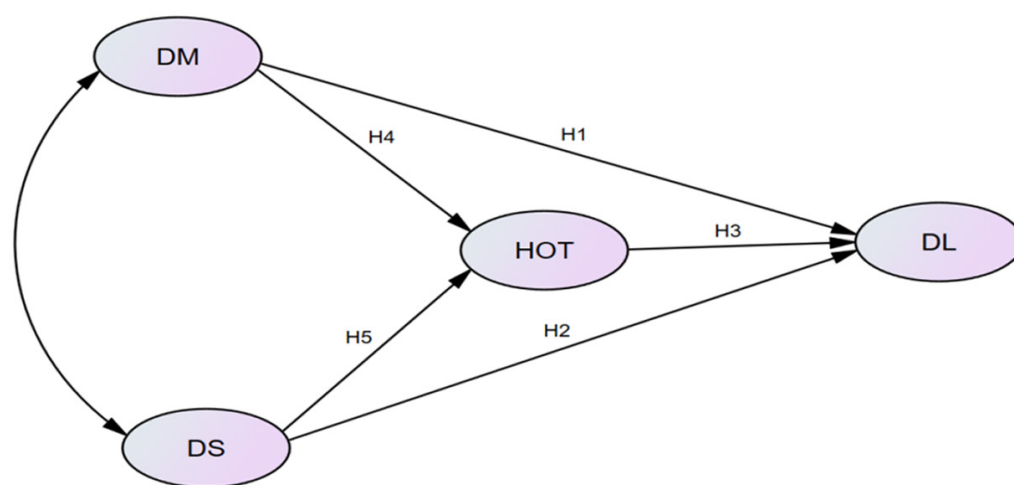
H3: Students' higher-order thinking contributes positively to their digital literacy.

Deep learning is a pedagogical approach that emphasizes using higher-order thinking skills to promote learners' acquisition of knowledge and skills [24], [26]. For example, Lee and Choi [26] surveyed 487 undergraduate students from seven South Korean universities and, using a structural equation model, concluded that promoting motivation and strategies can facilitate higher-order thinking in the background of a technologically advanced learning environment. Similarly, Wang and Cui [27] conducted a survey on 515 students of different majors and grades from six universities in northeast, north, east, south, and central China. The results showed that deep strategies significantly affect higher-order thinking skills. Hence, it is plausible to assume the following:

H4: Students' deep motivation contributes positively to their higher-order thinking.

H5: Students' deep strategies contribute positively to their higher-order thinking.

This research aimed to investigate the impact of deep motivation and deep strategies on students' digital literacy, with higher-order thinking serving as the mediating variable. Deep motivation is an individual's intrinsic interest in acquiring knowledge and skills within a particular domain. In contrast, deep strategies are defined as the selection of appropriate techniques and methods to design, train, and optimize learning. Higher-order thinking refers to the cognitive processes that involve complex mental skills such as analysis, synthesis, evaluation, and creativity to understand and solve problems. Digital literacy is characterized as encompassing not only technologies that use digital devices, but also cognitive, social, and emotional abilities. Figure 1 provides an illustration of the proposed model.



**Fig. 1.** Research model

Notes: DM, Deep motivation; DS, Deep strategy; HOT, higher-order thinking; DL, Digital literacy.

### 3 METHODOLOGY

#### 3.1 Participants

The research survey was conducted during the first semester of the academic year 2022. The participants came from two different kinds of Chinese institutions: a regular university and a higher vocational college. Higher vocational colleges, encompassing vocational colleges, technical colleges, and higher vocational schools, refer to higher education institutions that primarily provide vocational and technical training to equip students with specialized skills and practical knowledge required to excel in specific trades or professions [43]. In contrast, regular universities prioritize theoretical knowledge and intellectual abilities to prepare students for successful careers. Because the first author and her colleagues are affiliated with these two institutions, the students were specifically chosen for the survey to facilitate the sampling process. Additionally, the study obtained ethical approval from both institutional review boards, and the researchers adhered to ethical principles while conducting research with human subjects.

The data collection process for this study was conducted during the Covid-19 pandemic lockdown period, when all educational institutions in China were closed. To overcome this challenge, an online survey was utilized to gather data, with

voluntary participation. The survey was conducted in the following steps: Firstly, the researchers sought and obtained approval from multiple teachers for the study. Secondly, the teachers informed the students about the survey's purpose, duration, and nature of the information that would be collected. They also explained how the data would be collected, stored, and accessed, ensuring that no personal information would be disclosed in the survey. Lastly, the participants were directed to complete the survey on Questionnaire Star, a widely used platform for conducting online surveys.

During the study, the survey was available for a duration of two weeks, during which a total of 734 surveys were collected. To ensure the overall quality of the sample, the study followed two criteria. Firstly, surveys that were completed too quickly (in under five minutes) were considered invalid and consequently removed from the analysis. Secondly, the study excluded surveys from participants who exhibited straight-lining behavior, which refers to answering the questions in the same manner for most or all of the survey questions. Following the elimination of invalid surveys, the study retained 687 valid surveys, resulting in an effective response rate of 93.6%. These procedures were implemented to maintain the study's standards of rigor and ensure the reliability and validity of the collected data.

The majority of participants in the study were born after the 1990s, thus fulfilling Prensky's [44] criteria for being digital natives, defined as individuals born after the widespread adoption of digital technology. In terms of the student demographic information, there were 404 (58.8%) male students and 283 (41.2%) female students. In total, 349 of them (50.8%) came from an ordinary university, and 338 (49.2%) came from a higher vocational college. In the category of the academic year, 173 of them (25.2%) were freshmen, 272 (39.6%) were sophomores, 130 (26%) were juniors, and 112 (24%) were seniors.

As far as digital devices are concerned, 0% have none, 28.2% have 1 digital device, 36.8% have 2 devices, 21.6% have 3 devices, and 13.4% have 3 or more devices. Daily time spent on digital devices, 17 (2.5%) of less than 1 hour, 101 (14.7%) of 1–3 hours, 255 (37.1%) of 3–6 hours, and 314 (45.7%) of more than 6 hours. In terms of digital devices usage period, 373 people (54.3%) have used digital devices for less than 5 years, and 314 people (45.7%) have used them for more than 5 years. It is worth noting that according to the ITU [3], approximately 75% of individuals aged 10 and above own a mobile phone, and the digital device usage period refers to the duration between the initial and current usage of a digital device.

## 3.2 Measures

**Digital literacy.** Ng [29] developed the scale to explore undergraduate students' digital literacy. The original scale had 17 items with a Likert scale with a range of 1 (strongly disagree) to 5 (strongly agree). These items were divided into 4 categories: attitudes towards ICT for learning (DLA 7 items), technical (DLT 6 items), cognitive (DLC 2 items), and social-emotional (DLS 2 items). According to the result of factor analysis, 5 items from two dimensions were retained. The technical dimension included 3 items: DLT11 (knowledge of various technologies), DLT12 (ability to use ICT for learning and create artifacts that demonstrate comprehension), and DLT13 (proficiency in using ICT). The cognitive dimension included 2 items: DLC14 (confidence in evaluating online material) and DLC15 (awareness of web-based issues such as cyber safety, search problems, and plagiarism).

**Deep learning.** The Study Processes Questionnaire (SPQ) developed by Biggs et al. [45] was used to measure students' learning approaches. Moreover, the survey is split into two parts: deep learning and surface learning, each of which includes motivation and strategy. On a Likert scale with a maximum score of 5, deep motivation (DM 5 items) and deep strategy (DS 5 items) were adopted (such as "I believe that once I get into a topic, it may be really exciting to me"; "I find that studying academic issues may be just as interesting as reading a good book or seeing a good movie"; "I put myself to the test on crucial issues until I totally comprehend them"). Given that their factor loading was less than 0.5, item numbers DM4, DM5, and DS5 were eliminated from the items.

**Higher-order thinking.** Yang and Zhao [20], based on Bloom's [37] educational objective classification theory, made a comprehensive analysis of the concept, composition, and evaluation framework of college students' higher-order thinking skills. Combined with the actual situation of Chinese college students, 5 levels and 17 skills were adopted, including understanding (HOTU 7 items), applying (HOTAP 2 items), analyzing (HOTAN 3 items), evaluating (HOTE 2 items), and creating (HOTC 3 items). On the basis of the results of the factor analysis, three items of the analysis dimension and evaluating dimension are retained: HOTAN11 (I can distinguish relevant/important from irrelevant/unimportant information), HOTAN12 (I can draw systematic and internally consistent links between the information offered), and HOTE13 (I can evaluate and select solutions).

### 3.3 Procedures

The research consisted of three phases, with the preliminary phase focused on a pilot study aimed at improving the survey's quality. During the pilot survey, both reliability analysis and exploratory factor analysis were conducted. Items with poor internal consistency, as determined by a Corrected Item-Total Correlation (CITC) value less than 0.4, or a significant change in Cronbach's Alpha if Item Deleted (CAID) after item deletion, were removed. Additionally, items with factor loadings below 0.5 were eliminated. This process resulted in a refined set of scales with acceptable reliability and structural validity suitable for use in formal research.

In the second stage, the official survey was distributed through the online platform. The teacher of participants distributed a survey online link before class and informed the purpose of the survey. Moreover, the descriptive statistics, reliability, and correlation analyses were carried out using the SPSS 26 program. In addition, the structural equation model (SEM) was employed using Amos 26 program to analyze the direct and indirect interactions between variables.

Lastly, multi-group structural equation modeling was employed to test the research model's applicability to diverse groups. Specifically, the AMOS 26 program was used, offering six different models for conducting multi-group analysis. As Byrne [46] described, these models include the Unconstrained Model, Measurement Weights Model, Structural Weights Model, Structural Covariances Model, Structural Residuals Model, and Measurement Residuals Model. The Unconstrained Model allows for all parameters to vary among different groups. In contrast, the Measurement Weights Model requires the measurement weights parameters in the measurement model to be equivalent across groups. The Structural Weights Model restricts the equality of both the measurement weights and structural weights parameters across groups in both the measurement and structural models. Moreover, the latter models constrain the parameters of the former models. This study focused on examining differences

in the path coefficients among different groups of students' digital device usage periods. Therefore, the Unconstrained Model, Measurement Weights Model, and Structural Weights Model were the models analyzed.

## 4 RESULTS

### 4.1 Reliability and validity

Firstly, internal consistency, convergent validity, and discriminant validity were utilized to assess the reliability and validity of the constructs in the measurement model. As a result, the construct reliability (CR) values varied from .746 to .913, and Cronbach's alpha coefficients were all higher than 0.7, showing acceptable levels of internal consistency for all variables. Moreover, except for deep motivation, the average variance extracted (AVE) values (from .618 to .770) were within an acceptable range. However, Fornell and Larcker [47] asserted that even if AVE is less than 0.5 but CR is greater than 0.6, a construct's convergent validity might still be considered suitable. Therefore, deep motivation's AVE value (.496) and CR value (.746) were also suitable (See Table 1).

**Table 1.** Measurement of constructs

Variables	Items	Loadings	Cronbach's Alpha	CR	AVE
Deep motivation	DM1	.730	.747	.746	.496
	DM2	.730			
	DM3	.650			
Deep strategy	DS1	.860	.860	.865	.618
	DS2	.850			
	DS3	.720			
	DS4	.700			
Higher-order thinking	HOTAN11	.890	.909	.909	.770
	HOTAN12	.910			
	HOTE13	.830			
Digital literacy	DLT11	.780	.912	.913	.677
	DLT12	.830			
	DLT13	.860			
	DLC14	.800			
	DLC15	.840			

Moreover, discriminant validity was examined to ensure that all of the variables (deep motivation, deep strategy, higher-order thinking, and digital literacy) were distinct from one another. The square root of each variable's AVE value should be bigger than all of the correlation values of the variable [47]. Hence, the square root of AVE values for each variable was shown in Table 2, which were larger than the other correlation coefficients between the variables. Therefore, Tables 1 and 2 demonstrate the structure has high reliability and validity.



**Table 2.** Discriminant validity

Variables	DM	DS	HOT	DL
DM	.704			
DS	.510	.786		
HOT	.350	.350	.877	
DL	.420	.420	.640	.823

## 4.2 Correlation analysis

Table 3 displayed all the research variables' Means, Standard Deviations (SD), Skewness, Kurtosis, and Correlation coefficients. The mean values varied from 2.676 to 3.651, with SD ranging from .734 to 1.103. In addition, the normality of the variables was examined using Skewness and Kurtosis. As a multivariate normal distribution, all variables met Skewness < 2 and Kurtosis < 7 [48]. Consequently, the variables were considered appropriate for structural equation modeling (SEM) analysis. Moreover, according to the correlation analysis results, there was a significant relationship between all the research variables below the significance level of .001.

**Table 3.** Correlation analysis and descriptive statistics (N = 678)

Variables	DM	DS	HOT	DL
DS	.423***			
HOT	.304***	.313***		
DL	.353***	.377***	.589***	
Mean	2.704	2.676	3.651	3.450
SD	.918	1.103	.806	.734
Skewness	.264	.146	.025	.072
Kurtosis	-.097	-.746	-.292	.321

Note: \*\*\*p < .001.

## 4.3 Hypothesis analysis

The results revealed a good structural model fit with  $\chi^2/df = 2.35$ , CFI = .98, GFI = .96, TLI = .98, and RMSEA = .04. As a result, the proposed model suited the empirical data well. Furthermore, Table 4 showed that the five proposed relationships and the structural model were significant in the predicted direction. As a result, all of the suggested hypotheses were accepted.

According to the research results (See Figure 2), deep motivation ( $\beta = .160, p < .001$ ) and deep strategy ( $\beta = .150, p < .001$ ) both had a direct effect on digital literacy. Thus, hypotheses 1 and 2 were accepted. In addition, higher-order thinking significantly influenced digital literacy ( $\beta = .530, p < .001$ ), demonstrating that hypothesis 3 was also accepted. Hypotheses 4 and 5 were prepared to distinguish the direct effect of deep motivation and deep strategy on higher-order thinking. The results showed

that both deep motivation and deep strategy support the improvement of higher-order thinking, and that deep motivation's influence ( $\beta = .240, p < .001$ ) was stronger than deep strategy's ( $\beta = .220, p < .001$ ). Therefore, hypotheses 4 and 5 were also approved.

A bootstrapping method (2000 samples) was used for mediation analysis, bias-corrected confidence estimates, and 95% confidence intervals for indirect effects to examine the influence of deep motivation and deep strategy on digital literacy. As shown in Table 5, higher-order thinking was mediated between deep motivation and digital literacy. The indirect effect value was .110 (SE = .030, Bias-corrected 95% CI = [.060, .170]) and the confidence interval did not contain 0, and  $p < .001$ . Higher-order thinking was mediated between deep strategy and digital literacy. The indirect effect value was .080 (SE = .020, Bias-corrected 95% CI = [.040, .120]) and the confidence interval did not contain 0, and  $p < .001$ .

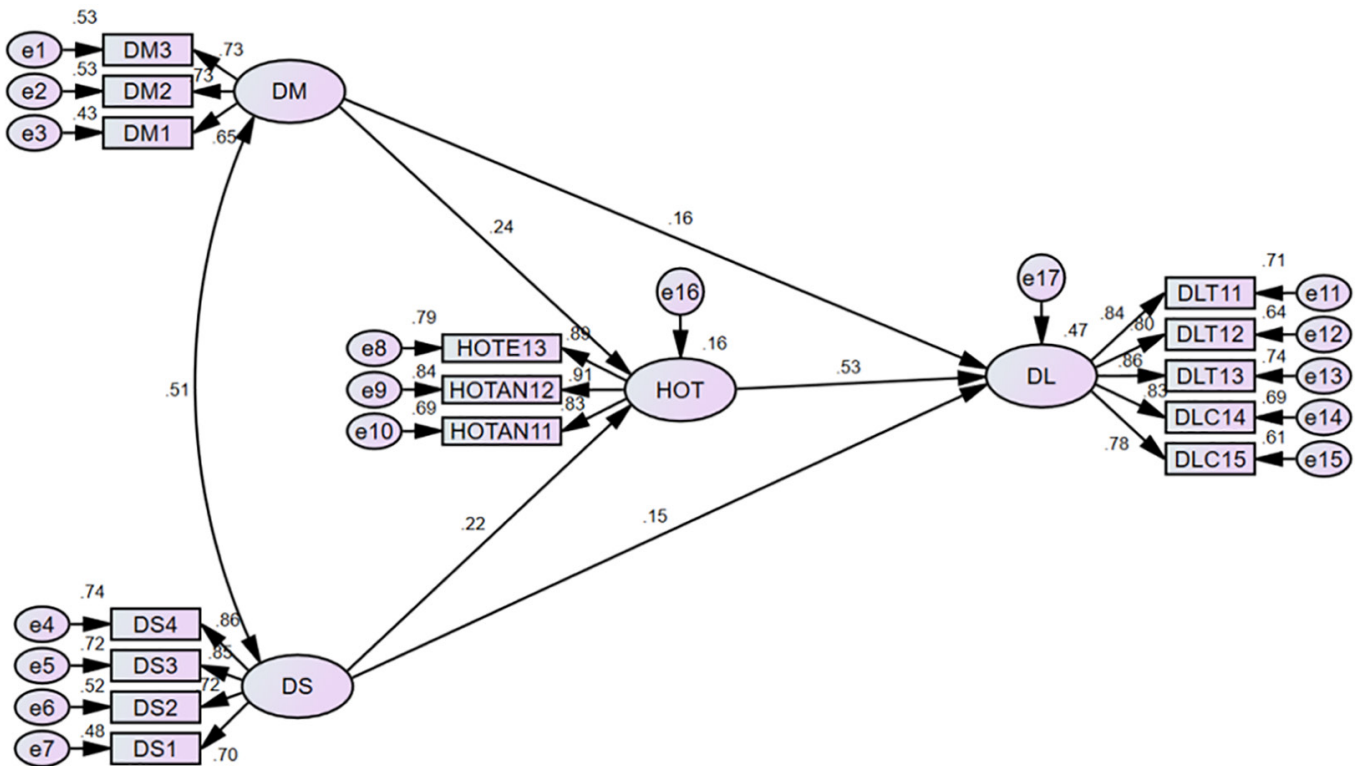


Fig. 2. Path diagram and standardized estimate

Table 4. Results of the hypothesis test

Hypotheses	Path	$\beta$	B	S.E.	C.R.	P	Testing Result
H4	DM → HOT	.240	.210	.050	4.380	<.001	Support
H5	DS → HOT	.220	.150	.030	4.380	<.001	Support
H1	DM → DL	.160	.140	.040	3.420	<.001	Support
H2	DS → DL	.150	.100	.030	3.610	<.001	Support
H3	HOT → DL	.530	.510	.040	13.500	<.001	Support

**Table 5.** Mediating effects of bootstrapping

Path	Point Estimate	Product of Coefficients		Bootstrap 2000 Times 95% CI Bias-Corrected		
		SE	Z-Value	Lower	Upper	P
DM → HOT → DL	.110	.030	3.667	.060	.170	<.001
DS → HOT → DL	.080	.020	4.000	.040	.120	<.001

#### 4.4 Multi-group comparison analysis

This study applied a multi-group analysis to compare the path coefficients of the students' digital devices usage period. The samples were divided into groups of less than five years and more than five years, and the two groups' structural equation models were constructed. Table 6 provides the fit indices for the Unconstrained Model, Measurement Weights Model, and Structural Weights Model. It is evident that all of the indicators satisfied the model fitness requirements. The comparison of the fit indices between the Measurement Weights Model and Structural Weights Model showed that it was lower than .050, indicating a significant difference in the path coefficients between the two models ( $\Delta\chi^2 = 13.210$ , and  $\Delta p = .020$ ).

**Table 6.** Fit indices of the multi-group analysis model by digital devices usage period

Model	$\chi^2$	$\chi^2/df$	P	TLI	CFI	RMSEA
Unconstrained	301.760	1.800	.000	.970	.980	.030
Measurement Weights	310.400	1.730	.000	.970	.980	.030
Structural Weights	323.600	1.760	.000	.970	.980	.030

As shown in Table 7, the five path coefficients of the two multi-group models were compared. The critical ratios for differences determined the specific differences between the parameters. If the critical ratio for the two corresponding paths is above 1.96, the parameter difference is significant [46]. The two path coefficients were significantly different (from deep strategy to higher-order thinking).

**Table 7.** Critical ratio value of parameter difference in digital devices usage period

Path	a1	a2	a3	a4	a5
b1	1.710				
b2		-2.740			
b3			.850		
b4				.470	
b5					1.150

Notes: a = less than 5 years; b = more than 5 years; a1 and b1: DM → HOT; a2 and b2: DS → HOT; a3 and b3: HOT → DL; a4 and b4: DM → DL; a5 and b5: DS → DL.

Further analysis was conducted on the significantly different path coefficients, and the results were given in Table 8. In the group of 'less than five years', the standardized

path coefficient of deep strategy to higher-order thinking is .340, and  $p < .001$ , while in the group of ‘more than five years’, the standardized path coefficient is .060, and  $p = .380$ . Therefore, higher education students with less than five years of digital device usage can better improve higher-order thinking with deep strategies. However, the finding also revealed that deep strategies are not a predictor of higher-order thinking for students with more than five years of digital device usage.

**Table 8.** Standardized coefficient of path

Path	Digital Devices Usage Period	$\beta$	S.E.	C.R.	P
DS → HOT	less than 5 years	.340	.240	.050	<.001
	more than 5 years	.060	.040	.050	.380

## 5 DISCUSSION

This study examined the interrelatedness of deep motivation, deep strategies, higher-order thinking, and digital literacy in higher education students. Structural equation modeling was utilized to analyze the proposed model, and the results indicated that the degree to which students exhibit deep motivation and employ deep strategies were both significant predictors of higher-order thinking and digital literacy. As such, all proposed paths in the model were found to be confirmed. These findings may have important implications for educational practice, as they suggest that fostering deep motivation and deep learning strategies may effectively promote digital literacy and higher-order thinking in higher education students.

The first conclusion is that deep learning should be promoted since it significantly fosters digital literacy. As Heinström [8] mentioned, deep motivation and deep strategies affect information-seeking outcomes and the ability to judge critical information. Moreover, online learners’ motivation and use of appropriate learning strategies during the learning process can directly affect their success [15]. Therefore, by encouraging the development of deep motivation and deep strategies, educators may be able to support students’ digital literacy development and enhance their overall success in the online learning environment.

Higher-order thinking also contributed significantly to digital literacy, which was the study’s second conclusion. While this finding is consistent with much of the existing literature [1], [22], some differing viewpoints exist. For example, some scholars believe that digital literacy serves as the foundation for increasing higher-order thinking skills [28]. Nevertheless, we prefer the view that digital literacy and higher-order thinking are mutually reinforcing [22]. Even though many higher education students are already adept at using digital devices, it is still crucial to improve their digital literacy level, because digital literacy includes not only skills and cognition, but also social emotions [29], while higher-order thinking is just a manner of thinking [21]. Moreover, students’ critical thinking and their ability to learn using higher-order thinking skills can both be enhanced through digital literacy. Likewise, developing students’ higher-order thinking skills can also increase their digital literacy levels [22]. These findings highlight the importance of promoting higher-order thinking and digital literacy in educational contexts, as these competencies are mutually beneficial and can support students’ success inside and outside the classroom.

In addition, consistent with existing literature [26], the study discovered an indication of a strong positive link between deep motivation, deep strategies, and

higher-order thinking. However, several researchers have suggested that only deep strategies promoted higher-order thinking, and that deep motivation did not affect higher-order thinking [27], [49]. One possible explanation for this discrepancy is that deep motivation represents an internal psychological construct that is not easily observable and may be influenced by external factors. Additionally, it is possible that the participants' motivation gradually decreased over time.

Another interesting finding suggested that the impact of deep motivation on digital literacy was higher than that of deep strategies on digital literacy. Furthermore, the impact of deep motivation on higher-order thinking was also greater than that of deep strategies on higher-order thinking, suggesting that motivation plays a vital role in the learning process and can facilitate the development of more effective academic performance [33].

Lastly, through multi-group comparison analysis, the study also concluded that deep strategies had a positive impact on higher-order thinking among students with less than five years of digital experience, but had no effect on promoting higher-order thinking among students with more than five years of digital experience. This phenomenon may be due to the fact that when faced with the vast amount of information available in the digital world, learners tend to rely on customary and superficial learning strategies. This can be seen as a disadvantage of fragmented surface learning in an era of big Internet data [50]. Therefore, it is necessary not only to discuss the advantages of deep learning and higher-order thinking but also to consider the challenges that learners face in engaging in deep learning.

## 6 CONCLUSION

The present study aimed to investigate the factors influencing higher education students' digital literacy. The results showed that deep motivation, deep strategy, and higher-order thinking positively and significantly impact digital literacy. Based on these results, the study has important educational implications.

The first educational implication of this study is related to the importance of motivation in learning approaches. The study suggests that educators should set reflective questions in the teaching process to stimulate students' learning motivation. This is a specific factor that relates to a particular learning situation. By doing so, students can actively construct digital knowledge systems, raise questions, and enhance their problem-solving skills. As digital citizens with digital consciousness, learners need to be able to develop and apply deep strategies. Teachers can provide teaching intervention and a learning environment that fosters deep learning. For instance, situational, task-driven, and problem-based teaching methods can be used to implement learning activities. Independent inquiry learning, collaborative group learning, and problem-solving activities can also be introduced to help students use complex strategies to complete learning tasks and increase their digital literacy level.

Secondly, to enhance students' digital literacy, developing their higher-order thinking skills is important, which can help them effectively navigate the challenges of learning in a digital and information-rich environment. To achieve this, a systematic teaching approach is necessary to incorporate the development of high-level thinking into specific teaching designs. For instance, the five-step teaching method proposed by Limbach and Waugh [40] provides a useful framework for teachers to improve students' high-level thinking skills. This approach involves determining learning objectives, teaching through questioning, providing opportunities for practice before assessment, reviewing and refining learning, and providing feedback

and assessment of learning. By actively engaging in this process, students can reflect on the meaning of what they are learning, and develop critical digital literacy competencies for exploring and classifying digital information.

The third important implication of this study is the need for educators to assess students' prior digital experiences and adapt their teaching strategies accordingly. As modern educational environments are not easily reformed, it is essential for educators to improve the digital literacy of a considerable number of students. In the classroom, teachers should employ pedagogical approaches that encourage students to reflect on their routine digital practices and engage in learning experiences that expand their external digital experiences. Additionally, policymakers should consider the importance of supporting and supplementing realistic situations that promote the development of digital literacy in educational settings.

The current study has several limitations. First, the participants were chosen randomly from two Chinese universities, making it impossible to extrapolate the findings to other situations. Secondly, while this study used quantitative research methods to analyze the data, measuring deep motivation using only a few items may not be easy. Thus, it is recommended that future studies use qualitative techniques, such as interviews or observations, to gain a deeper understanding of students' motivation. Lastly, this study only focused on the influence of the deep approach on digital literacy, while the other two learning approaches were not considered. Therefore, future research can involve more learning approaches and examine the critical factors of digital literacy to improve higher education students' digital literacy.

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