



Navigating Digital Learning Landscapes: Unveiling the Interplay Between Learning Behaviors, Digital Literacy, and Educational Outcomes

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Abstract

In the swiftly evolving realm of education, digital learning has emerged as a transformative force, revolutionizing how learners and educators interact with knowledge. This paper delves into the intricate interplay between digital learning abilities, instructional design, and learner support, particularly within the context of blended learning, where traditional educational paradigms merge with technological advancements. Blended learning, the fusion of in-person and digital instruction, necessitates a delicate equilibrium to unleash its full potential. We explore the multifaceted attributes that underpin self-regulation within these environments, such as authenticity, personalization, and scaffolding. Moreover, we investigate how blended learning's effectiveness transcends various educational domains, from vocational schools to mathematics education and entrepreneurship training. The paper underscores the significance of comprehensive learner support and skillful instructional design. It highlights the symbiotic relationship between blended learning and the cultivation of digital literacy, encompassing not just technical prowess but also critical thinking and purposeful digital engagement. As educators embrace these insights, they stand poised to create dynamic educational experiences that empower students for the digital age.

Keywords Digital learning · Blended learning · Instructional design · Self-regulation · Learner support · Digital literacy · Educational outcomes

Introduction

The development of digital economy assessment tools and their piloting in various national contexts have yielded a wealth of interesting experiences, and one of the main goals of this article is to give just-in-time learning from those

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experiences. The improvement of the data that can be shared and utilized to support diagnostic counsel and the design of a following digital strategy are related goals that share lessons on how to use these technologies effectively to improve the quality of diagnostic advice (Bustard et al., 2022; Hanna, 2020). A comprehensive evaluation methodology will eliminate the uncertainty and duplication that have raised expenses for aid organizations and the countries they deal with.

In this paper, we advocate for the inclusion of the “digitalized” economy within the broadest possible parameters. The process or ecosystem that transforms all economic sectors and establishes the digital economy in its broadest sense is what we refer to as “digital transformation” (Hanna, 2020; Sewpersadh, 2023; Sinatoko Djibo et al., 2023). The production and use of digital technologies in both the public and commercial sectors are included in this wide definition of the digital economy, which encapsulates the benefits of digital technology for the entire economy. Since it has long been understood that the majority of the advantages of digital technologies derive from their widespread adoption and application in the economy in both the digital and analog worlds, this definition is particularly pertinent to developing nations and the Sustainable Development Goals in educational departments. It emphasizes the gradual adoption of digital technologies across all economic sectors and sees the digital economy as an “evolutionary” process (Hanna, 2020; Santoso et al., 2023; Woraphiphat & Roopsuwankun, 2023; Zhang & Chen, 2023).

With the popularization of information-based and intelligent applications of education and teaching, digital learning did not change the nature of education but put forward the demand for digital transformation (Feng et al., 2019; Wang & Li, 2023). Learners are required not only to master traditional literacy skills but also to have a broader ability to understand, evaluate, integrate, apply, and create knowledge with the help of digital technologies for acquiring professional knowledge, enhancing professional capabilities, and providing guarantees and conditions for the realization of continuous learning, lifelong learning, and innovation in the digital era. Therefore, digital learners shall apply Internet+ thinking and the inherent qualities of digital technology, namely, contemporariness, openness, and innovation, to the learning process and gain certain digital ability or digital competence (digital literacy) for effective learning. Digital literacy has not been clearly defined in detail. Learners are required to “adopt effective digital technology means and methods to quickly obtain information and master comprehensive skills and cultural literacy to evaluate, integrate, and exchange information.”

The connotations of digital literacy have been discussed in the existing literature (Wu et al., 2022), including mastering and utilizing the professional skills of digital technology, namely, “hard skills,” to cope with the trends of the gradual digitization of professional skills and the gradual specialization of digital skills; mastering and utilizing comprehensive literacy of emotions, attitudes, qualities, and values for adapting to digital social life, such as critical thinking, analytical and problem-solving skills, and innovative thinking, as well as digital “soft skills” in self-management such as self-motivation, adaptability, and active learning, which provide theoretical perspective and practical dimension for the implementation of the research on digital learning abilities (Sewpersadh, 2023; Sinatoko Djibo et al., 2023; Zhang & Sheng, 2019).

Although the discussions on the connotations of digital literacy focus on different perspectives and have not yet reached an agreement, the ability dimension of digital literacy and its corresponding development strategies are generally dissected from the perspectives of digital initiative (knowledge, technology, strategy), digital thinking (thinking mode and practical attitude), and digital humanity (digital values).

Moreover, a bridge from macro policy call to micro education and teaching practice is built, especially for the research on digital learning abilities of blended learners, and action guides are also provided. As a vital learning method in the digital era, blended learning is a digital learning process (Qin & Du, 2022; Wang et al., 2022). In the process of resorting to online and offline self-regulated learning behaviors by blended learners with the help of digital technologies, the correlation between learning behavior, learning effect, and digital literacy of blended learners remains unclear, and the digital learning ability model of blended learners has not been constructed (Shen et al., 2022), which affects the overall development of digital learning abilities of digital learners. To this end, with the blended teaching of the course of *College Public English* as an example, from the perspective of the ability dimension of digital literacy, the learning behavior data of blended learners on Chaoxing Xuexitong APP (hereinafter referred to as “Learning Platform”) and U Campus APP (hereinafter referred to as “U Campus APP”) are used as the research carriers to explore the learning behavior characteristics of digital literacy of blended learners, to analyze the relationships between digital literacy, learning behavior, and learning effect of blended learners, and to build a digital learning ability model of blended learners, thereby providing an optimized digital learning practice path for blended learners to improve digital literacy and learning effect.

Related Works

In the rapidly evolving landscape of education, digital learning has emerged as a transformative force, reshaping the way both students and educators engage with knowledge. The proliferation of digital learning environments has opened new avenues for instruction and learning, underscoring the paramount importance of effectively navigating these digital spaces. As traditional educational paradigms meld with technological advancements, the ability to adeptly traverse digital learning landscapes becomes a pivotal skill set for fostering enriched learning experiences (Picciano, 2017). This confluence of traditional and digital learning, often referred to as blended learning, has prompted researchers and educators to explore the intricate interplay between digital learning abilities, instructional design, and learner support (Kim & Maloney, 2020). At the crux of this exploration lies the endeavor to cultivate self-regulation within blended learning environments. Scholars have delved into the multifaceted dimensions of blended learning, investigating how authenticity, personalization, learner control, scaffolding, interaction, and reflective cues synergistically cultivate learners’ capacity for self-regulation (e.g., Chen, 2023; Taylor, 2023; Yang, 2019). A constellation of studies has underscored the pivotal attributes that facilitate self-regulation, thereby paving the way for the creation of blended learning environments that are finely attuned to the learners’ self-regulatory

requisites. Amidst this exploration, researchers have also probed the dynamic terrain of implementing blended learning across diverse educational contexts (e.g., Wijaya & Weinhandl, 2022). Studies have meticulously dissected the impact of blended learning in vocational schools, mathematics education, language acquisition, and entrepreneurship training (e.g., Alshahrani, 2023; Khachatryan, 2020). These inquiries have not only spotlighted the potency of blended learning in elevating student engagement and academic achievement but have also highlighted the indispensable role of comprehensive learner support. This support encompasses a spectrum of strategies ranging from tailored course offerings and preparatory assessments to the provision of study skills and seminar opportunities, all working in concert to bolster the learners' educational journey. Integral to the fabric of effective blended learning is the art of instructional design, which emerges as a linchpin in harnessing the full potential of this pedagogical approach. Striking a harmonious equilibrium between digital and in-person instruction while meticulously aligning with learners' objectives and needs emerges as a central facet of this discipline (Addy et al., 2023). The fusion of pedagogical approaches, adeptly orchestrated, serves as a conduit for achieving desired learning outcomes and propelling students toward digital literacy. This literacy, encompassing not only technical prowess but also critical thinking and purposeful digital engagement, solidifies the symbiotic relationship between blended learning and digital literacy enhancement (Barbero, 2020; Dudenhoffer, 2020).

As the nexus of digital learning abilities, instructional design, and learner support continues to evolve, insights gleaned from this body of research illuminate a path toward the creation and cultivation of blended learning environments that transcend traditional boundaries. Armed with the knowledge of attributes that nurture self-regulation, the transformative potential of blended learning across varied disciplines, and the nuanced intricacies of instructional design, educators stand poised to orchestrate engaging, effective, and digitally enriched educational experiences that fortify students for the demands of the digital age.

Fostering Effective Blended Learning Environments: Navigating Digital Learning Abilities, Instructional Design, and Learner Support

Digital learning has become increasingly prevalent in educational settings, offering new opportunities for teaching and learning. The ability to effectively engage with digital learning environments and technologies is crucial for students and educators. The literature on digital learning abilities encompasses various aspects of blended learning, self-regulation, learner support, and instructional design. Several studies have focused on identifying the attributes that support self-regulation in blended learning environments (e.g., Eggers et al., 2021; van Laer & Elen, 2017). These attributes include authenticity, personalization, learner control, scaffolding, interaction, cues for reflection, and cues for calibration (Rasheed et al., 2021; van Laer & Elen, 2019, 2020). The findings of these studies can inform the design of blended learning environments that meet learners' self-regulatory needs.

Studies have also examined the implementation and impact of blended learning in different educational contexts. For example, research has explored the

implementation and impact of blended learning in vocational schools (Handayani et al., 2020), mathematics education (Josua & Sibanda, 2022; Syahrawati et al., 2022; Viebig, 2022), paragraph writing skills (Maulida et al., 2022), and entrepreneurship education (Chaeruman & Maudiarti, 2018; Viebig, 2022). These studies provide insights into the effectiveness of blended learning in enhancing student engagement, academic achievement, and critical and creative skills. The literature also highlights the importance of learner support in blended learning environments. Learner support includes meeting the needs of all learners, providing choices at the course level, offering preparatory tests, facilitating study skills, and ensuring access to seminars and tutorials (Reimers et al., 2020). Additionally, the attributes of authenticity, personalization, and interaction contribute to learner support in blended learning environments (Laer & Elen, 2017).

Moreover, instructional design plays a crucial role in the success of blended learning. Studies have emphasized the need for precise planning and effective integration of online and face-to-face instruction (Chaeruman et al., 2018). It is important to consider the objectives and needs of learners and optimize the strengths of each pedagogical approach (Coyle et al., 2019). Furthermore, the appropriate blend of blended learning strategies should be determined to achieve the desired learning outcomes (Alam et al., 2022). Likewise, digital literacy is another important aspect of digital learning abilities, encompassing not only technical skills but also critical thinking, information literacy, and the ability to use digital technology purposefully in education (Kaeophanuek et al., 2019). Blended learning can contribute to the development of digital literacy by providing opportunities for learners to engage in critical inquiry, research, and the production of digital work (Faloon, 2020).

The literature on digital learning abilities provides valuable insights into the attributes that support self-regulation, implementation, and impact of blended learning, learner support, instructional design, and digital literacy. These findings can inform the design and implementation of effective blended learning environments that enhance student engagement, learning outcomes, and digital literacy skills.

Navigating the Terrain of Blended Learning: Factors Influencing Success and Pedagogical Benefits

Blended learning is a pedagogical approach that combines traditional face-to-face instruction with online learning experiences. It is a widely accepted understanding that integrating both modalities, online and face-to-face learning, ensures flexibility in access to and use of knowledge (Byrka, 2017). Blended learning has become increasingly popular in various educational contexts, including teacher training programs (Castro, 2019), higher education (Evans et al., 2019), and language teaching (Rojabi, 2019). One of the key benefits of blended learning is that it allows students to experience learning in ways they are most comfortable with while also challenging them to learn in other ways. This multimodal approach recognizes learners' preferences and needs and aims to design instruction that meets those needs (Picciano, 2019). Blended learning also offers opportunities for increased student engagement, as it promotes interactions between students, their peers, teachers, and course materials (Pachêco-Pereira et al., 2020).

Several studies have examined the impact of blended learning on student learning experiences. For example, a study conducted at an offshore campus of an Australian university found that students perceived their learning experiences to be beneficially impacted as a result of the blended learning environment (Bouilheres et al., 2020). Another study found that blended learning courses encouraged student autonomy and participation, which are key tenets of blended learning (Lai et al., 2016). Additionally, a study in taxation courses found that blended learning enhanced student engagement and learning experiences (Setiyani et al., 2020). The success of blended learning depends on various factors. One important factor is the learner's perception of blended learning. Understanding learners' perceptions can help design a more detailed and realistic strategy to meet their educational needs (Bouilheres et al., 2020). It is also crucial to consider the learner's readiness for and perceived behavioral control over blended learning, as these factors directly impact their self-efficacy and motivation (Almulla, 2022).

Furthermore, the teacher's perception and beliefs about blended learning play a significant role in its implementation and effectiveness (Bruggeman et al., 2022). Teacher educators' beliefs about blended learning can influence their design choices and the realization of those beliefs in practice (Bruggeman et al., 2021). ICT self-efficacy, organizational support, and attitudes toward blended learning are also important factors that influence the use of blended learning by teachers. Teachers with higher ICT self-efficacy are more likely to use blended learning in their instruction (Ye et al., 2022). Organizational support for blended learning and positive attitudes toward blended learning are also predictors of teachers' use of blended learning (Kintu et al., 2017).

Blended learning is a pedagogical approach that combines face-to-face instruction with online learning experiences, offering flexibility, promoting student engagement, and enhancing learning experiences (Singh et al., 2021). The success of blended learning depends on factors such as learner and teacher perceptions, readiness, self-efficacy, and organizational support. Understanding these factors can help design effective blended learning strategies that meet the educational needs of students.

Methodology

Through an integrative review process combining experimental and non-experimental research with theoretical and empirical data, this study adopted a methodical approach to compiling and synthesizing prior research (Baber et al., 2019; Zhang & Sheng, 2019). Due to the integration of four literature streams—GBS, CRM, service innovation, and business models—this study employed a concept-centric methodology rather than a chronological or author-centric one (Boland, 2020; Mishra & Tripathi, 2021). In this study, the learning effect is embodied in the following aspects: the improvement of technical skills, the cultivation of professional quality, the change of learning attitude, the cultivation of learning interest, the enhancement of learning abilities, and the shaping of craftsmanship.

The research process started with searching the connotations of digital literacy, considering the educational needs of blended learners. The current study represents

various tables that discuss the perspective of digital literacy, variables of blended learning behaviors, descriptive statistics on learning behaviors of blended learners, ANOVA of blended learning behavior, and Pearson correlations of the blended learning effect.

Research Perspective

Drawing upon the existing research on the connotations of digital literacy, namely, digital initiative (knowledge, technology, strategy), digital thinking (thinking mode and practical attitude), and digital humanism (digital values), and considering the educational and teaching needs of cultivating and enhancing digital learners' adaptability and innovation in the digital era, the digital literacy dimensions in this study are divided into digital technology application ability under the tool dimension, self-regulated continuous learning ability under the practice dimension, and innovation ability under the thinking mode in the digital era (Bustard et al., 2022; Hua, 2020; Lan et al., 2020). Their basic properties are shown in Table 1, which presents data related to blended learning behaviors in the context of digital literacy.

Research Objectives and Methods

With the learning process of the course of *College Public English* by blended learners as the research object, this study covers three aspects: before class, during class, and after class, and involves the learning behaviors of online network learning and offline classroom learning. Blended learners actively participate in resource push (online) before class, explanation of key difficulties (offline) and in-class tasks (online) during class, and supporting tasks (online) after class to realize personalized adaptive learning and deep learning. In essence, it is a learning experience in which learners apply digital technologies skillfully and freely. Learners acquire not only common, standardized, and universal knowledge in the digital transmission of traditional knowledge but also complete self-regulated learning with individual differential starting points and individual development needs under the effective interaction between man and technology (Bao et al., 2021; Zhang & He, 2020).

According to the corresponding learning behavior data of learners in the learning process, the learning behavior differences of the blended learners are analyzed in this study. K-means clustering is adopted for classifying blended learners' digital literacy and exploring the performance of digital learning ability under different digital literacy categories. After that, linear regression equations are used for constructing the learners' digital learning ability equation model.

Research Data

The data used herein are taken from the blended learning process of the course of *College Public English* based on the Learning Platform and U Campus APP. Due to the learning behaviors of different links of blended teaching, corresponding learning behavior data are generated respectively. To be specific, before class, corresponding

Table 1 Blended learning behavior data from the perspective of digital literacy

Dimensions of digital literacy	Performance of digital literacy	Links to the course	Carrier of the course	Learning behaviors	Data on learning behaviors
Tool dimension	Initiative of digital technology application	Before class	Learning Platform	Pre-class independent resources and video learning	1. Viewing progress (%) of pre-class resources and videos
Practice dimension	Self-regulation behavior in digital technology application practice	During class	Learning Platform	Pre-class task online test	2. Pre-class test score
				Independent activity	3. In-class independent task score (real time)
		The whole learning processes	Learning Platform	Random group activity	4. Individual performance in in-class group activities (time limited)
				Effective unit discussions initiated	5. The average number of effective discussions initiated
Innovative thinking dimension	Self-reflection, initiative questioning, and exploration in digital technology application practice	After class	U Campus APP	First-time unit task performance	6. First-time score of post-class unit task
				Unit task revision performance	7. Revision score of post-class unit task

pre-class learning progress (proportion) and pre-class homework scores are generated through the completion of independent video learning and pre-class knowledge online tests. During class, online real-time self-exploratory tasks are solved, and time-limited random group exchange and discussion are conducted around the key points and difficulties of the unit through case analysis and brainstorming, and the independent activity scores and group activity performance scores are generated accordingly. After class, learners engage in an independent study on the U Campus APP and complete assigned listening, speaking, reading, and writing tasks within the specified period without frequency limits. The highest score will be recorded as the U Campus unit score. Since the unit exercise tasks and unit test tasks on the U Campus APP are highly and intelligently matched with the knowledge and skills of the textbook, and the learning effect is instantly feedbacked, the learners not only master knowledge accurately but also take into account the individual differences and development needs of learners.

Behavioral Data of Blended Learning from the Perspective of Digital Literacy Dimension and their Acquisition

In the study on digital learning ability with the course of *College Public English* as an example, the data acquired from blended learning behaviors from the perspective of digital literacy are shown in Table 1. As can be seen, the learning process of blended learners reflects their digital literacy, which is realized through self-regulated continuous learning on digital platforms and in digital spaces with learning behaviors as carriers. The intricate journey of blended learners through the realm of education vividly exemplifies the depth of their digital literacy. This profound digital acumen comes to fruition as they engage in a harmonious symphony of self-regulated and perpetually evolving learning experiences across various digital platforms and within the boundless expanse of digital spaces. These digital domains not only serve as the backdrop but also as the very crucible where their educational metamorphosis transpires, with their adeptness in navigating these realms becoming the cornerstone upon which their academic success is built. Within this dynamic landscape, learning behaviors stand as the steadfast carriers of their aspirations, propelling them forward on this transformative expedition. These behaviors are not static but are rather dynamic catalysts, pushing them to explore, adapt, and innovate. With each interaction and engagement, they sculpt their digital identity, constructing a narrative of adaptability and growth.

Results

Based on the data on blended learning behaviors, the present situation of learners' digital literacy under blended learning behaviors and the influence of each link of learning behavior on the learning effect is discussed. In this study, the total achievement (learning effect) of blended learning is taken as the dependent variable, and the learning behavior data of the course of *College Public English* on the Learning

Platform and U Campus APP are used as the independent variable. Seven factors, such as viewing progress (%) of pre-class resources and videos, pre-class test score, in-class independent task score, individual performance in in-class group activities (within the specified time), the average number of effective discussions initiated, and first-time and revision scores of a post-class unit task, are selected as quantitative indicators of learning behaviors. Details of the variables selected are shown in Table 2, which outlines the variables related to blended learning behaviors, along with their names and corresponding quantitative indicators.

According to the above seven quantitative indicators of learning behaviors, seven learning behaviors under the three dimensions of learners' digital literacy are identified: learning behaviors under the tool dimension, learning behaviors under the practice dimension, and learning behaviors under the innovative thinking dimension. Based on the learning behavior data of 69 blended learners of the course of *College Public English* in the first semester of the academic year 2022–2023 on the Learning Platform and U Campus APP, after sorting the data by the software EXCEL, SPSS is imported to analyze the behavior characteristics of learners' digital literacy by clustering and to construct a quantitative equation model between learners' digital literacy behavior and learning effect. Being comprehensive, abstract, and diverse, the learning effect also determines the quantification complexity of the learning effect. In this study, the learning effect is embodied in the following aspects: the improvement of technical skills, the cultivation of professional quality, the change of learning attitude, the cultivation of learning interest, the enhancement of learning abilities, and the shaping of craftsmanship. In order to reduce the complexity and simplify the data processing, the relationship between learning behavior and learning effect is constructed based on the consensus of education and teaching to reveal the learning effect with academic performance. However, academic performance is only a part of the learning effect, and there is neither an equivalent relationship nor strict causality between the two.

Learning Behaviors of Blended Learners

Descriptive statistics show that blended learning behaviors differ under the blended learning mode and that blended learning behaviors reflect digital literacy to some degree. Table 3 presents descriptive statistics on the learning behaviors of blended learners at each stage. As can be seen, blended learners have considerable differences in relevant variables before class and slight differences in relevant variables after class. Therefore, there are differences in blended learning behaviors under the blended learning mode. Meanwhile, the blended learning behaviors also objectively reflect the different dimensions of digital literacy of blended learners.

A slight difference in the active application of digital technologies in the sample indicates that the blended learners take the initiative to adopt digital technologies easily. However, there is an enormous difference in the use of digital resources to complete the assigned tasks before class. In offline face-to-face teaching during class, real-time classroom tasks and discussions distributed by digital platforms are utilized to test learners' time management and self-regulation of concentration and

Table 2 Variables of blended learning behaviors

Types of variables	Name of variable	Quantitative indicators of blended learning behaviors
Dependent variable	Learning effect	The total score of all the activities taken on the Learning Platform and U Campus APP
Independent variable	Blended learners' digital technology application ability	1. Viewing progress (%) of pre-class resources and videos
	Blended learners' self-regulated ability in digital technology application practice	2. Pre-class test score
	Blended learners' self-regulated ability in digital technology application practice	3. In-class independent task score (real time)
	Blended learners' self-reflective ability in digital technology application practice	4. Individual performance in in-class group activities (within the specified time)
		5. The average number of effective discussions initiated
		6. First-time score of post-class unit task
		7. Revision score of post-class unit task

Table 3 Descriptive statistics on learning behaviors of blended learners

Variable	N	Min.	Max.	Mean	S.D.
1 Viewing progress (%) of pre-class resources and videos	69	0	1	0.89	0.16
2 Pre-class test score	69	5.10	98.70	75.70	19.770
3 In-class independent task score	69	4.00	107.00	75.91	27.61
4 Individual performance in in-class group activities	69	6.70	100.00	89.06	23.50
5 The average number of effective discussions initiated	69	3.00	15.00	13.29	2.78
6 First-time score of post-class unit task	69	28.00	92.00	73.13	14.84
7 Revision score of post-class unit task	69	30.00	98.00	77.68	15.63
Total achievement (learning effect) of blended learning	69	30.00	96.00	79.30	14.44
Cases	69				

initiative. The average value of completing online tasks independently and on time was found to be 75.91. In contrast, the average value of participating in classroom discussions within the specified time is 89.06, much higher than the completion effect of independent tasks, indicating that blended learners have strong social interaction awareness and problem-solving awareness of sharing and collaboration. After class, learners use the U Campus APP for further content consolidation and ability transfer applications. It can be seen that the learners' minimum value has improved. Learners have gained a certain sense of self-reflection and self-correction. Through multiple rounds of self-encouraged feedback on the learning contents of the U Campus APP, learners' minimum, maximum, and average values have been improved. In the repeated exploration of the learning process that focuses on the identification and solving of problems, not only the learners' sense of responsibility and problem-solving awareness are cultivated, but also the continuity and autonomy of learning are ensured. The maximum and minimum numbers of active questions throughout the learning process of any unit in the course are 15 and 3, respectively, with an enormous difference, which suggests that the learners have a certain awareness of active questioning and collaborative answering.

ANOVA of Blended Learning Behavior and the Impact of Digital Literacy

Blended learning behavior results from the K-means model reveal three types of digital literacy learners. Due to the absence of specific categories of data labels, the classification method does not apply in this study, so clustering is adopted for grouping similar learners together and then figuring out the impact of digital literacy of blended learners on the blended learning effect. K-means clustering is utilized here to further explore blended learning behavior data. The extracted learning behavior data are standardized before the K-means clustering, considering their different order of magnitude. First, the data of each indicator are standardized by subtracting the mean value from these data, which are then divided by the samples' standard deviation. After the standardized transformation, each indicator has a mean value of 0 and a standard deviation of 1. On the one hand, it eliminates the influence

of different dimensions of each indicator's data; on the other hand, it reduces the bias in clustering analysis. After the K-means clustering of student behaviors using SPSS, the generated ANOVA (variance analysis) and clustering results are shown in Tables 4 and 5, respectively. For the practical significance of the analytic results, after referring to previous research, the data of online learning behaviors are utilized for presetting the digital literacy types of learners into three categories. After three iterations, the significance level of each indicator is obtained. Table 4 presents the results of an ANOVA (analysis of variance) analysis conducted on different indicators of blended learning behaviors.

Below is the breakdown of the information presented in the table:

1. Indicators of blended learning behaviors: this column lists the different behaviors or activities that are being analyzed to understand the impact of blended learning. Blended learning refers to a combination of traditional in-person classroom instruction and online learning.
2. Clustering mean square error (MSE) and degrees of freedom (df): this column presents the mean square error and degrees of freedom associated with the clustering effect. Clustering refers to grouping or categorizing data points based on certain criteria. In the context of this table, it likely relates to the way the data was organized or grouped for analysis.
3. Error mean square error (MSE) and degrees of freedom (df): this column provides the mean square error and degrees of freedom associated with the error term. The error term represents the variability in the data that is not explained by the factors being analyzed in the study.
4. *F* value: the *F* value is a ratio of the variance between groups to the variance within groups. It is used to test the null hypothesis that there are no significant

Table 4 ANOVA of blended learning behavior

Indicators of blended learning behaviors		Clustering		Error		<i>F</i>	Sig
		Mean square error	df	Mean square error	df		
Before class	Pre-class independent resources and video learning	5.00	2	0.88	66	5.69	0.01
	Pre-class task online test	22.43	2	0.35	66	64.01	0.00
During class	In-class independent task performance	23.36	2	0.32	66	72.45	0.00
	Individual performance in in-class group activities	19.02	2	0.45	66	41.91	0.00
	Effective discussions initiated	7.86	2	0.79	66	9.92	0.00
After class	First-time performance of a post-class unit task	14.24	2	0.60	66	23.78	0.00
	Revision performance of a post-class unit task	15.54	2	0.56	66	27.80	0.00

Table 5 Clustering results of blended learning behavior (final cluster centers)

	Clustering		
	1	2	3
Pre-class independent resources and video learning Zscore	-1.27252	0.28872	-0.33296
Pre-class task online test Zscore	-2.33333	0.55607	-0.66262
In-class independent task performance Zscore	-2.29660	0.59525	-0.74588
Individual performance in in-class group activities Zscore	-2.90315	0.46563	-0.38225
Effective discussions initiated Zscore	-0.06111	0.27027	-0.51713
First-time performance of post-class unit task Zscore	-1.13763	0.41124	-0.59695
Revision performance of post-class unit task Zscore	-0.17158	0.45943	-0.86678
Zscore	-2.35803	0.59889	-0.74183
Number of learners per category	4	43	22
Total number of learners	69		

differences between the means of the groups. A larger F value suggests a greater difference between group means.

5. Sig.: this is the p value associated with the F test. The p value indicates the probability of obtaining the observed results if the null hypothesis (no significant difference between group means) is true. A p value less than a predetermined significance level (often 0.05) indicates that the differences between groups are statistically significant.

The table is divided into three sections based on when the behaviors were observed during the learning process:

1. Before class

- Pre-class independent resources and video learning: the F value is 5.69 with a p value of 0.01. This suggests a statistically significant difference in pre-class independent resource usage and video learning behavior among the groups.
- Pre-class task online test: the F value is 64.01 with a p value of 0.00. This indicates a significant difference in pre-class task online test performance among the groups.

2. During class

- In-class independent task performance: the F value is 72.45, with a p value of 0.00. This indicates a significant difference in in-class independent task performance among the groups.
- Individual performance in in-class group activities: the F value is 41.91 with a p value of 0.00, suggesting a significant difference in individual performance during in-class group activities.
- Effective discussions initiated: the F value is 9.92 with a p value of 0.00, indicating a significant difference in the initiation of effective discussions.

3. After class

- First-time performance of a post-class unit task: the F value is 23.78 with a p value of 0.00, indicating a significant difference in the first-time performance of a post-class unit task among the groups.
- Revision performance of a post-class unit task: the F value is 27.80 with a p value of 0.00, suggesting a significant difference in the revision performance of a post-class unit task among the groups.

In summary, the table provides information about the statistical significance of differences in blended learning behaviors across different stages of the learning process. The significant p values indicate notable differences in the behaviors being analyzed, suggesting that the various stages of blended learning impact student performance and engagement.

Table 5 shows the results of the clustering analysis conducted on blended learning behavior data. The data has been categorized into three clusters labeled 1, 2, and 3. Each row in the table represents a specific aspect of behavior or performance related to blended learning, and each column represents one of the three clusters. The table provides information about the z-scores for various metrics, the number of learners in each category, and the total number of learners considered in the analysis.

Metrics and Clusters

- Pre-class independent resources and video learning Zscore: this metric represents the z-scores of learners' engagement with independent resources and video learning before the class starts. A lower negative z-score in Cluster 1 (-1.27252) suggests below-average engagement, while Cluster 2 (0.28872) and Cluster 3 (-0.33296) show relatively higher engagement levels.
- Pre-class task online test Zscore: this metric indicates the z-scores of learners' performance in online tests conducted before the class. Cluster 1 (-2.33333) has the lowest performance, Cluster 2 (0.55607) is in the middle, and Cluster 3 (-0.66262) has the highest performance.
- In-class independent task performance Zscore: this metric shows the z-scores of learners' performance in independent tasks during the class. Cluster 1 (-2.29660) has the lowest performance, Cluster 2 (0.59525) is in the middle, and Cluster 3 (-0.74588) has the highest performance.
- Individual performance in in-class group activities Zscore: this metric represents the z-scores of learners' individual performance within in-class group activities. Cluster 1 (-2.90315) has the lowest performance, Cluster 2 (0.46563) is in the middle, and Cluster 3 (-0.38225) has the highest performance.
- Effective discussions initiated Zscore: this metric indicates the z-scores of learners' ability to initiate effective discussions. Cluster 1 (-0.06111) has slightly below-average scores, Cluster 2 (0.27027) is somewhat above average, and Cluster 3 (-0.51713) is below average.
- First-time performance of post-class unit task Zscore: this metric shows the z-scores of learners' performance in the first attempt of post-class unit tasks.

Cluster 1 (-1.13763) has lower performance, Cluster 2 (0.41124) is better, and Cluster 3 (-0.59695) is again lower in performance.

- Revision performance of post-class unit task Zscore: this metric represents the z-scores of learners' performance in revised attempts of post-class unit tasks. Cluster 1 (-0.17158) has relatively low performance, Cluster 2 (0.45943) is better, and Cluster 3 (-0.86678) is the lowest.
- Zscore: this row provides the average z-scores for each cluster across all metrics. Cluster 1 has an average z-score of -2.35803 , Cluster 2 has 0.59889 , and Cluster 3 has -0.74183 .

The significance level of each blended learning behavior indicator is less than 0.05, indicating that the indicator variables reject the assumption that there is no difference between the categories. Therefore, these indicator variables can distinguish the categories well, and considerable differences between the categories are identified. By analyzing the characteristics of the clustering center values of each indicator for the learning behaviors of three preset types of learners' digital literacy (Table 5), it can be seen that the indicators all show a trend: Category 2 > Category 3 > Category 1, and that the number of learners in each category is shown below, 43 in Category 2, accounting for 62.3%; 22 in Category 3, accounting for 31.9%; 4 in Category 1, accounting for 5.8%.

The table shows the clustering results of blended learning behavior based on various metrics, suggesting that distinct groups of learners have different behavior and performance patterns in the blended learning environment. Cluster 1 generally exhibits lower performance and engagement, Cluster 2 shows intermediate performance, and Cluster 3 demonstrates higher performance and engagement. The number of learners in each cluster provides insight into the distribution of these behavioral patterns among the total learners considered for the analysis.

Pearson Correlation Analysis of the Blended Learning Effect

Correlation analysis and its results show that the blended learning effect is positively correlated with the variables of learning behaviors. In order to further analyze the current status of digital literacy reflected in the blended learning behaviors in different links, the correlation of major variables is analyzed to explore the influence of learners' digital literacy on the overall achievement (learning effect) of blended learning.

Table 6 presents Pearson correlation coefficients that depict the relationships between various factors related to blended learning. Pearson correlation measures the strength and direction of a linear relationship between two variables. The values range from -1 to 1 , where -1 indicates a perfect negative correlation, 1 indicates a perfect positive correlation, and 0 indicates no correlation between the variables. The table also provides significance levels for each correlation coefficient, indicating whether the observed correlations are statistically significant.

The correlation coefficient between "pre-class independent resources and video learning" and "pre-class task online test" is 0.296^* . This positive correlation suggests that students' performance on pre-class online tests tends to improve as they

Table 6 Pearson correlations of the blended learning effect

	Pre-class independent resources and video learning	Pre-class task online test	In-class independent task performance	Individual performance in in-class group activities	Average number of effective discussions initiated	First-time performance of a post-class unit task	Revision performance of a post-class unit task	Total achievement (learning effect) of blended learning
Pre-class independent resources and video learning	1							
Pre-class task online test	0.296*	1						
In-class independent task performance	0.349**	0.788**	1					
Individual performance in in-class group activities	0.138	0.671**	0.895**	1				
Average number of effective discussions initiated	0.265*	0.511**	0.472**	0.363**	1			
First-time performance of a post-class unit task	0.296*	0.307*	0.426**	0.243*	0.400**	1		
Revision performance of a post-class unit task	-0.074	0.532**	0.349**	0.325**	0.322**	0.044**	1	
Total achievement (learning effect) of blended learning	0.309**	0.819**	0.944**	0.858**	0.556**	0.463**	0.416**	1

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

engage more with pre-class resources and videos. Also, the correlation coefficient between “in-class independent task performance” and “individual performance in in-class group activities” is 0.895**. This strong positive correlation indicates that students who perform individually in in-class tasks also tend to excel in group activities. Likewise, the correlation coefficient between “average number of effective discussions initiated” and “first-time performance of a post-class unit task” is 0.400**. This positive correlation suggests that students actively participating in discussions will likely perform better on their first attempt at post-class unit tasks. Finally, the correlation coefficient between “revision performance of a post-class unit task” and “total achievement (learning effect) of blended learning” is 0.416**. This positive correlation implies that students who perform better in revising their post-class unit tasks also tend to achieve a higher overall learning effect from blended learning.

The total achievement (learning effect) of the dependent variable blended learning is significantly and positively correlated with the respective variables, which can be used as the core indicators of predicting the learning effect and constructing the learning ability model. Specifically, the pre-class test scores are highly correlated with the scores of independent tasks during class, while the scores of independent tasks during class are also highly correlated with the individual performance of the group during class. The pre-class test behavior, in-class independent task behavior, and in-class individual performance behavior of the group are highly and positively correlated with the total achievement (learning effect) of blended learning.

Summary of the Model and Coefficients

The regression analysis shows that the blended learning effect has a high linear regression with the independent task during class, the first performance of the unit task after class, and the test score of learning before class. In order to build a digital learning ability model, specific learning behaviors in each learning link that affect the effect of blended learning shall be determined first. Therefore, with Y as the dependent variable and X_1 , ..., and X_7 as the independent variables, a linear regression model is built in SPSS. Since different variables exert different or no effect on the explained variable, the stepwise regression is adopted, and the regression results are shown in Table 7 and Table 8.

Table 7 presents a summary of a statistical model's results, specifically related to a learning effect in a blended learning environment. The primary focus of the analysis is the “learning effect of blended learning.” The table's purpose is to present the summary results of a statistical model that aims to understand and quantify this learning effect based on various predictors. The “adjusted R square” is a statistical measure representing the proportion of the variance in the dependent variable (learning effect of blended learning) explained by the model's independent variables (predictors). It is a value between 0 and 1, where 1 indicates that all the variability in the dependent variable is explained by the predictors, and 0 indicates that the predictors have no explanatory power. The table presents three different values for adjusted R square: 0.890, 0.904, and 0.912. Each value corresponds to a different model configuration (a, b, and c) that includes different sets of predictors. The adjusted R

Table 7 Model summary^d

Model	<i>R</i>	<i>R</i> square	Adjusted <i>R</i> square	Std. error of the estimate	DW
1	0.944 ^a	0.892	0.890	0.33182921	
2	0.952 ^b	0.907	0.904	0.30938023	
3	0.957 ^c	0.916	0.912	0.29683674	1.621

^aPredictor: (constant), in-class independent task

^bPredictors: (constant), in-class independent task performance, first-time performance of post-class unit task

^cPredictors: (constant), in-class independent task performance, first-time performance of post-class unit task, pre-class task online test

^dDependent variable: learning effect of blended learning

square values indicate the goodness of fit of the models. A higher adjusted *R* square suggests that the predictors in the model are better at explaining the variability in the dependent variable. Comparing the three models, the one with the highest adjusted *R* square (0.912) likely provides the best fit to the data and can be considered the most effective in explaining the learning effect in the blended learning environment.

The predictors are the independent variables used in the model to predict or explain the variation in the dependent variable (learning effect of blended learning). The table presents three different predictor configurations. In configuration (a), only the “in-class independent task” is considered a predictor. In configuration (b), the “in-class independent task performance” and “first-time performance of post-class unit task” are added as predictors. In configuration (c), an additional predictor, “pre-class task online test,” is included along with the predictors from configuration (b). The inclusion of more predictors in the models (moving from configuration a

Table 8 Coefficients^a

Model	Unstandardized coefficients		Standardized coefficients	<i>t</i>	Sig.
	<i>B</i>	Std. error	Beta		
1 (Constant)	−9.012	0.040		0.000	1.000
In-class independent task	0.944	0.040	0.944	23.464	0.000
2 (Constant)	−1.359	0.037		0.000	1.000
In-class independent task	0.877	0.043	0.877	20.612	0.000
First-time performance of a post-class unit task	0.142	0.043	0.142	3.328	0.001
3 (Constant)	5.037	0.036		0.000	1.000
In-class independent task (X3)	0.767	0.059	0.767	13.000	0.000
First-time performance of the post-class unit task (X6)	0.114	0.042	0.114	2.690	0.009
Pre-class task online test (X2)	0.157	0.061	0.157	2.588	0.012

^aDependent variable: learning effect of blended learning

to b and then to c) suggests an attempt to improve the model's predictive power by accounting for more potential sources of variation in the learning effect.

Table 8 presents the coefficients and related statistical information from a regression analysis, likely used to examine the relationship between different independent variables and a dependent variable called the "learning effect of blended learning." The table provides coefficients for different unstandardized and standardized predictors and additional statistical information to assess the significance of these coefficients. The table includes three different models labeled 1, 2, and 3. For each model, the table presents the unstandardized coefficients (*B*) and their standard errors (Std. error). "Beta" refers to the standardized coefficient or beta weight. This is a measure of how much the dependent variable changes (in standard deviation units) for a one-standard deviation change in the independent variable. The presented information suggests that the intercept (constant) and the individual independent variables have associated coefficients in each model, representing the strength and direction of their relationship with the dependent variable ("learning effect of blended learning"). The standardized coefficients (Beta) provide a way to compare the relative impact of different variables on the dependent variable, considering their different scales.

In all cases, the significance values (*p* values) associated with the *t*-tests are very low (typically much less than 0.001), indicating that the coefficients are statistically significant. This suggests that these independent variables have a meaningful impact on the dependent variable in the context of the given analysis.

The proposed model shows a good fitting effect, and the modified determinability coefficient reaches 0.912. The variance analysis (ANOVA) suggests that the significance level of the *F* test is about 0.001, indicating the highly significant linear regression of the blended learning effect *Y* on the independent task *X3* during class, the first performance *X6* of the unit task after class, and the pre-class learning test *X2*. The blended learners' digital learning ability equation model can thus be expressed as $Y = 5.037 + 0.767 \cdot X3 + 0.114 \cdot X6 + 0.157 \cdot X2$.

Discussion

Through the above research on the digital literacy type, learning behavior performance, and learning effect of online learners, it can be found that the digital literacy performance and learning behavior effectiveness of blended learners affect the development of blended learners' digital learning abilities (Hanna, 2020; Mishra & Tripathi, 2021). Due to the simplicity and robust explanation of the regression model, it also explains self-regulation, man-computer interaction autonomy, and individuality of knowledge construction in the development of digital learning abilities of blended learners (Qin & Du, 2022; Zhang & Chen, 2023). In the performance dimension of digital literacy, the initiative and self-regulation of continuous learning of online learners in the digital application environment allow them to enter the state of deep learning, to actively participate in continuous learning through the application of digital platforms and digital resources, to flexibly apply the learned knowledge for independent problem solving, and to independently learn the knowledge and skills required to solve problems (Bustard et al., 2022;

Woraphiphat & Roopsuwankun, 2023). In the regulation dimension of learning behaviors, the learning activities of independent knowledge construction between learners and online resources and between learners and learning platforms are carried out under man-computer interaction, which not only requires intense concentration and active time management skills for continuous learning and active learning (Gao & Hu, 2022; Sinatoko Djibo et al., 2023; Wu et al., 2022) but also requests the learners to equip themselves with digital technology application abilities during the learning process to actively promote the cultivation of learners' learning attitude and learning interest. In this way, the digital learning abilities of learners in the digital era can be evaluated and diagnosed through the digital learning ability model, and the learning effect of digital learners can be optimized.

Utilizing digital technologies within an educational institute is just one aspect of digitalization; it also serves as a tool for putting these cutting-edge business models and long-term strategies into practice for blended learners. According to Zhang and Chen (2023), the term "digitalization" refers to the transformation of current business processes through the use of digital technology. In order to shape the new organizational technology structure, this transition necessitates the timely application of digital technology, which would not have been achievable otherwise. According to some definitions by Zhang and Chen (2023), digital transformation is a significant change that is fueled, established, or supported by digital technology that changes how educational activities or digital learning abilities for learners are conducted. It will gradually use digital initiatives to accomplish extensive management reforms, leading to important changes in an organization or an entire educational sector (Boland, 2020; Hanna, 2020; Wang & Li, 2023).

In general, business and management education aims to prepare students to succeed as employees in businesses, which is the only professional path available to them. Most students are not taught the various abilities that entrepreneurs require in some entrepreneurship classes, like creative problem-solving, knowing how to obtain and use resources, building organizations, networks, and sales, and working well in teams (Baber et al., 2019; Mishra & Tripathi, 2021; Sewpersadh, 2023). Santoso et al. (2021) assert that professors and educators frequently operate in a hypothetical environment rather than address pressing challenges, necessitating a shift in approach in the direction of the Entrepreneurial Learning Model (ELM). According to Santoso et al. (2021), higher education should develop job creators rather than merely job seekers. As a result, learning in higher education should cover entrepreneurial management and business practices, particularly in how they perceive and deal with challenges that may arise during a new company's early stages of development so that it can serve as a catalyst for innovation in the economy and society and serve as a springboard for creating new business ideas (Baber et al., 2019; Boland, 2020; Feng et al., 2019; Gao & Hu, 2022).

Unraveling the Nexus: Exploring the Interplay Between Learning Behaviors, Digital Literacy, and Learning Outcomes in Online Education

There is a certain correlation between online learners' learning behaviors, digital literacy, and learning effects. Specifically, online learners' learning effect is correlated

with their learning behaviors during and after class (namely, digital literacy behaviors), and possessing certain digital literacy (namely, high-quality pre-class learning behaviors with problem-solving awareness) is crucial to the blended learning effect.

As can be seen from the correlation analysis results in Table 3, blended learners are well prepared for pre-class learning and complete pre-class tasks satisfactorily. This move eliminates obstacles to offline classroom learning, enhances confidence and motivation for continuous learning, and provides conditions and guarantees for the independent completion of learning tasks during class. Moreover, it also allows the learners to participate highly in in-class group discussions, cultivate an ardent desire to share and solve problems, and build a sense of responsibility and self-confidence to help the group solve problems and contribute more to the group discussions during class. Meanwhile, combined with the learning behavior analysis corresponding to digital literacy in Table 1 above, learners' blended learning effect is highly correlated with their independent task completion during class, individual performance of the group during class, effective discussions initiated (namely, learners' self-regulation in digital technology application), and learners' pre-class task test (namely, digital technology application initiative). Moreover, learners' blended learning effect is also moderately correlated with self-correction of post-class unit tasks and active inquiry to initiate effective discussions (namely, the reflective ability of digital technology application) and weakly correlated with learners' viewing of pre-class resources and videos and initiative of digital technology application (Sewpersadh, 2023). Compared with the pre-class task test, the learning behavior of viewing pre-class resources and videos is somewhat passive. Although they both account for certain proportions of the total score of the course in terms of learning effect, if the learners' knowledge is attained for fulfilling the assigned task, no problem-solving awareness has been cultivated, and viewing resources and videos will be quite superficial behavior (Mishra & Tripathi, 2021).

Classifying Digital Literacy Models for Effective Online Learning Behaviors

The three types of digital literacy models based on online learning behaviors show that only by closely combining innovative thinking, human–computer collaboration, and self-regulation with online learning behaviors can online learners better display their digital learning abilities, promote the digital learning process, promote the interaction between man and technology, and effectively engage in digital learning.

The variance analysis (ANOVA) results in Table 4 show significant F test scores for all seven variables, indicating that they all play a role in the clustering analysis. Combined with the blended learning behavior data and the specific clustering results corresponding to digital literacy in Table 5, the digital literacy of blended learners can be divided into the following 3 categories, as shown in Table 9. In Category 2, learners can not only make full use of digital learning resources, learning media, and learning platforms to effectively carry out interactive man-resources or man-platform application but also independently apply digital technologies for effective knowledge construction before, during, and after class and realize knowledge consolidation and skill transfer through self-regulation. Also, learners gain a keen sense

Table 9 Category and behavior performance of the digital literacy of blended learners

Category of blended learners		Dimensions of digital literacy					
		Tool dimension		Practice dimension		Innovative thinking dimension	
		Digital technology application ability		Apply digital technologies for effective knowledge construction		Problem-solving consciousness and critical thinking ability	
Category 2 Intelligent learning group		√		√			√
Category 3 Technological application group		√		x			x
Category 1 Innovative thinking group		x		x			√
Category of blended learners	Before class		During class			After class	
	Blended learning behaviors						
	Pre-class independent resources and video learning	Pre-class task online test	In-class independent task performance	Individual performance in in-class group activities	Average number of effective discussions initiated	First-time performance of a post-class unit task	Revision performance of a post-class unit task
Category 2 Intelligent learning group	√	√	√	√	√	√	√
Category 3 Techno-logical application group	√	●	x	√	x	√	x
Category 1 Innovative thinking group	x	●	x	x	√	●	√

“√”: can and be good at, “x”: cannot and not good at, “●”: can but not good at

of collaboration, reflection, and innovation in interacting with digital technology applications. Therefore, the online learners in Category 2 have strong digital learning abilities, hereinafter referred to as the intelligent learning group. Online learners in Category 3 show strong interest and initiative in applying platforms and resources supported by digital technologies to assist learning and are willing to get help in collaborative learning. However, they are unwilling to initiate effective discussion, suggesting that such learners are relatively incompetent at identifying the problems. They are least good at proactively identifying problems and solving them independently.

Consequently, the learning behaviors of such blended learners are superficial, segmented, and fragmented. Despite strong initiative and collaborative spirit in applying digital technologies, they show weak self-regulation ability and digital thinking awareness in digital technology application practice and generally lack the ability to identify and solve problems, with insufficient innovative consciousness. Therefore, Category 3 is hereinafter classified into the technological application group. Online learners in Category 1 are good at solving problems and realizing knowledge consolidation and skill transfer, so they have strong problem-solving consciousness, reflection consciousness, and critical thinking ability. Nevertheless, they are not adept at using digital technologies for knowledge construction in the interactive learning process, which reflects the poor concentration, time management, and collaboration of such learners. Compared with the first two groups, the learners in Category 1 have strong digital thinking abilities but weak independent learning by means of digital technologies, as well as weak initiative in acquiring and applying digital resources. Hence, Category 1 is abbreviated as the innovative thinking group.

Conclusion

In the dynamic landscape of education, the fusion of digital learning and traditional instructional methods has ushered in a new era of pedagogical transformation. This convergence, known as blended learning, encapsulates the essential endeavor of seamlessly integrating digital literacy, instructional design, and learner support to create enriched educational experiences. This research paper has traversed the multidimensional terrain of blended learning, delving into the intricate interplay between digital learning abilities, instructional design strategies, and learner support mechanisms.

Theoretical Implications

The findings mentioned above serve not only to enhance our understanding of the intricate interplay between digital literacy, learning behaviors, and learning outcomes in the realm of online education but also to provide a tangible framework for gauging and evaluating digital literacy performance. This framework, comprised of discernible behaviors and measurable indicators, contributes to the quantifiable assessment of digital literacy. Additionally, the construction of a digital learning ability model for online learners emerges from these findings. This model delineates the developmental trajectory and facets of digital learning prowess. The nurturing and refinement of digital learning abilities hold a dual-purpose significance. Firstly, they empower online learners to assimilate the cognitive paradigms requisite for effective functioning within the digital society. Acquiring this cognitive dexterity equips learners with the aptitude to tackle challenges intrinsic to the digital milieu adeptly. Secondly, fortified digital learning abilities enable learners to confront the dynamism and trials precipitated by digital transformation. The iterative enhancement of digital thinking and innovation capacities emerges as a corollary of this

process. As a result, a foundational underpinning is established, charting the course for fostering, diagnosing, and elevating sustained and lifelong learning proficiencies within the digital and intelligent context. The correlation between knowledge depth and problem-solving agility is conspicuous. Students endowed with profound knowledge not only possess a cognitive framework and systemic perspective but also exhibit agility in integrating novel concepts. The reservoir of knowledge enables them to swiftly decipher solutions when faced with challenges.

Furthermore, these individuals possess the acumen to discern opportunities or conceive fresh insights attributed to their well-rounded knowledge base. Conversely, students exemplifying competence tend to innovate and ideate, building upon their existing skill repertoire. Their capability to refine, augment, or supplant ideas thrives on their preexisting proficiencies. This dichotomy underscores the paramount importance of expertise and erudition, accentuating the propensity for ingenious ideation and creativity. The ability to respond effectively to technological flux and corporate dynamics is conspicuously exemplified among those skilled in crafting web-based applications. This aptitude stems from their familiarity with the evolution of technology and the agility to adapt. The upshot is evident—proficiency in one's domain renders them not only resilient but also uniquely equipped to navigate the fluctuations inherent in their field. Thus, the marriage of expertise and adaptability emerges as a potent formula for sustained excellence. Within organizations, leveraging digital technology to bolster learning endeavors surfaces as a strategic lever. The convergence of blended learning, encompassing conventional and digital methods, manifests as a core competency that organizations can harness. As digital transformation and strategic realignment of business models coalesce, they engender an inseparable synergy resulting from embracing cutting-edge digital tools.

Digital transformation serves as an inevitable tide sweeping through educational institutions, fundamentally altering the organizational bedrock through the infusion of avant-garde digital technologies. This paradigm shift prompts organizations to strike an equilibrium between the legacy and nascent business models as they navigate the trajectory of digital transformation. The pivotal theme that emerges is the imperative for organizations to iteratively calibrate their operational *modus operandi* in tandem with embracing the evolving landscape of digital business.

Policy Implications

In educational policy, this research illuminates pathways for strategic interventions. The insights gleaned from this research carry profound implications for educational policies at various levels. As institutions grapple with the evolving nature of education in a digital age, these implications offer guidance in shaping effective strategies that foster impactful learning experiences. The following are key policy implications derived from this study:

Integration of Digital Literacy in Curriculum Design Educational institutions must recognize the significance of digital literacy as a foundational skill for the modern world. Policymakers should advocate for the integration of digital literacy

competencies into curricula across disciplines and grade levels. By embedding digital literacy skills into the curriculum, students can effectively develop the critical skills needed to navigate, evaluate, and contribute to digital information environments.

Professional Development for Educators Policies should prioritize comprehensive professional development programs for educators to equip them with the skills and confidence needed to facilitate blended learning environments. Educators need training not only in digital tools and platforms but also in instructional design principles that optimize the blend of online and in-person instruction. Continuous training and support can help educators adapt to the evolving digital landscape and maximize the potential of blended learning.

Equity in Access to Digital Resources Policy initiatives should address digital equity by ensuring all students have access to the necessary technology and resources for effective digital learning. This may involve providing underserved communities with devices, internet connectivity, and digital learning materials. By bridging the digital divide, institutions can create an inclusive learning environment where all students have equal opportunities to thrive.

Customized Learning Pathways Policymakers should advocate for the development of flexible learning pathways that accommodate diverse learning styles and paces. Blended learning models allow personalized learning experiences catering to individual strengths and needs. Policies that encourage educators to design adaptable learning experiences can lead to higher student engagement, motivation, and success.

Holistic Learner Support Services Institutions should invest in robust learner support services that extend beyond academic assistance. Policies should emphasize counseling, mentorship, and resources catering to learners' holistic well-being. This support can help students navigate the challenges of blended learning, manage their time effectively, and maintain a healthy balance between online and offline activities.

Assessment Strategies for Digital Learning Policy frameworks should consider revisiting assessment strategies to align with the nature of blended learning. Traditional assessment methods may not fully capture the breadth of skills developed in digital learning environments. Policymakers should encourage the exploration of alternative assessment approaches, such as project-based assessments, e-portfolios, and collaborative evaluations, which better reflect the multifaceted skills nurtured through blended learning.

Collaboration Between Stakeholders Effective implementation of blended learning requires collaboration among stakeholders, including educators, administrators, policymakers, parents, and students. Policies should promote open communication channels and collaboration platforms that facilitate the exchange of ideas, best

practices, and feedback. This collaborative approach can foster a supportive ecosystem that maximizes the benefits of blended learning.

Research and Development Funding Policymakers should allocate funding for research and development initiatives that explore the ever-evolving landscape of digital learning. These funds can support studies on effective instructional design, learner engagement strategies, and the impact of blended learning on diverse educational contexts. Evidence-based practices derived from research can inform policy decisions and shape the future of education.

In essence, the policy implications derived from this research underscore the need for a holistic and forward-thinking approach to education. By prioritizing digital literacy integration, educator training, equity, personalization, support services, assessment innovation, collaboration, and research funding, policymakers can pave the way for a transformative educational landscape that prepares students for success in a digital and interconnected world.

Scope for the Future

This comparative case study provides crucial insight into a number of crucial variables that should be taken into account regarding the digital learning abilities of blended learners, digital transformation, and learning effects through digitization. However, the adoption of learning management systems (LMSs) in higher education institutions, especially with the expansion of online learning on a worldwide scale, and the importance of LMSs to the delivery of this medium of education are also essential for future studies to highlight. Boland (2020) mentioned that the diffusion of innovations theory and a social capital-infused theoretical model of diffusion upheld an effective route for LMS adoption that will face the least resistance and successfully accelerate the procedure and provide a path for strategic thinking for international institutions. However, specific variables will vary from institution to institution. Although LMSs have been widely used in various educational institutions because of their quality, affordability, and accessibility, their acceptance has not been without problems. As a result, more research on the adoption of LMSs is necessary in the future. Also, as the startup culture grows, there is a need for researchers and scholars to highlight more about entrepreneurship education on campus. It takes time for students to become entrepreneurs, even when they have the ambition to do so and have received the necessary cognitive training. They must be provided with or obtain entrepreneurship opportunities from their institution or environment in order to boost that acceleration. In connection with this, entrepreneurship education on campus ought to not only focus on structured teaching in the classroom with its cognition aspect but also needs to be enhanced by giving them a chance to try making a startup on their own so that, at this point, there will be a connection between cognitive knowledge and behavioral knowledge.

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

Declarations

Competing Interests The authors declare no competing interests.

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