The effect of digital technology usage on higher vocational student satisfaction: the mediating role of learning experience and learning engagement

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The fourth industrial revolution and the digital transformation represented by Industry 4.0 have stimulated digital innovations in economic and social spheres, accelerating the structural transformation of the labor market and increasing the demand for high-quality vocational education and training. The influence of digital technology on student satisfaction is acknowledged; nonetheless, the precise mechanisms via which it impacts student satisfaction related to learning experience and learning engagement remain largely unexplored. This study seeks to investigate the impact of digital technology usage on student satisfaction of Chinese higher vocational college students, mediated by learning experience and learning engagement, employing Social Cognitive Theory (SCT) as the theoretical framework. In June and July 2023, 424 participants were chosen from public vocational institutions in Hubei Province, Central China, using the simple random sampling method. Results were analyzed utilizing structural equation modeling (SEM) in AMOS 24.0 and SPSS 26.0. The findings indicated a significant correlation between digital technology usage and student satisfaction. Moreover, the digital technology usage exhibited an indirect and positive correlation with student satisfaction of vocational students through learning experience and learning engagement, respectively. The findings highlight the importance of learning experience as a crucial element connecting digital technology usage to student satisfaction. This study urges administrators and educators to recognize the significance of learning experiences and learning engagement in the use of digital technology, fosters a supportive educational environment through digital resources, facilitates substantial changes in teaching and learning in higher vocational education, and executes strategies to connect academia with industry. This study's distinctiveness lies in its enhancement of theoretical understanding of digital technology usage by investigating the mechanisms via which it affects student satisfaction. This clarifies the complex interconnections among digital technology usage, learning experience, learning engagement, and student satisfaction, emphasizing the mediating roles of learning experience and learning engagement in the Chinese context.

KEYWORDS

digital technology, social cognitive theory, usage behavior, student satisfaction, learning experience, learning engagement, vocational students

Introduction

The issue of digital technology usage has been receiving a great deal of attention in the vocational educational fields during the last two decades (Selwyn, 2021). The reason for this is that the demand for technical and skilled labor has increased owing to the extensive integration of digital technology in commercial industry, social services, and numerous other sectors (Achtenhagen and Achtenhagen, 2019), which has exacerbated an increasing number of vocational colleges are highlighting its potential to augment the technical skills of their students (Indrawati and Kuncoro, 2021). Vocational colleges have gradually recognized the significance of digital technology usage in the learning process, and are attempting to use digital technology, such as Moocs, to satisfy the students' needs, also to enhance the learning effectiveness (Ye et al., 2022).

In October 2022, the Chinese government promulgated the initiative "Promoting the Digitization of Education, building a Learning Society and a Learning Nation with Lifelong Learning for All," mandating that colleges and universities capitalize on the opportunities afforded by the latest scientific and technological revolution and the significant industrial transformation. Consequently, an expanding array of digital technologies, including mobile connectivity, cloud computing, artificial intelligence, big data, virtual reality, and the Internet of Things, is being employed in vocational education to enhance the technical competencies of vocational students in China, thus attaining elevated standards in higher vocational education (Chen et al., 2022; Jinglin, 2020). Many vocational colleges in China implemented digital technology in education, resulting in minimal preparation or experience to inform the execution of digital learning courses (He, 2022; Xibin et al., 2023). Student satisfaction serves as a subjective indication of learning outcomes, reflecting an authentic assessment of educational accomplishment, which is essential for assessing the influence of digital technology on student satisfaction. Student satisfaction during the educational process is considered a temporary condition resulting from the assessment of the learning experience, university services, and facilities (Athiyaman, 1997; Memon et al., 2022). Researchers determined that student satisfaction arises when real performance surpasses expectations and is affected by various factors, including the learning experience (Elliott and Shin, 2002). Furthermore, student satisfaction is acknowledged as a crucial determinant affecting students' reactions to the integration of digital technology in education (Chester et al., 2011).

Although prior research recognizes the potential impact of digital technology on student satisfaction, a gap persists in understanding the precise mechanisms via learning experience and learning engagement. Learning experience and learning engagement are the two elements associated with academic outcomes (Nkomo et al., 2021). Learning experience is recognized as a vital factor influencing student satisfaction. Students are more likely to participate in practical assignments when they have extensive learning experience (Sharpe and Benfield, 2005). The learning experience generally refers to the subjective emotions and sentiments of students in educational settings (Yang, 2016). It is assessed using several evaluations that analyze students' learning processes, encompassing the learning environment, activities, and support services (Peng and Zhao, 2022). Moreover, those with substantial educational experience frequently invest considerable effort in their academic pursuits. Learning engagement correlates

positively with learning satisfaction. Learning engagement is a complex concept that includes deep learning (O'Flaherty and Phillips, 2015), the time and effort invested in learning, interaction, and involvement (Pye et al., 2015). Engaged students are more likely to participate in classroom discussions, problem-solving activities, and other duties. They are also more predisposed to employ effective learning methodologies, such as reflection, elaboration, and critical analysis (Wang and Eccles, 2013). Furthermore, students demonstrating heightened learning engagement may have a sense of autonomy in their educational pursuits during active participation, perhaps resulting in enhanced satisfaction (Gray and DiLoreto, 2016). The findings highlight the necessity of evaluating both learning experience and learning engagement to understand student satisfaction. Nevertheless, scant attention has been devoted to the impact of digital technology usage on the student satisfaction of Chinese higher vocational students. This investigation reveals a lack of comprehension satisfaction the specific methods by which digital technology usage influences student satisfaction through learning experiences and learning engagement, as delineated in pertinent theoretical frameworks.

The Social Cognitive Theory (SCT) functions as a conceptual framework to guide the creation of a model for chain mediation in this study. Social Cognitive Theory asserts that human behavior, cognitive and personal characteristics, and environmental influences are interconnected variables that may clarify learning results. Bandura posits that individuals can convert behavioral and environmental data into symbolic representations to facilitate learning (Bandura, 1986). Thus, learning behavior (learning engagement and learning experience) related to learning outcome expectations (student satisfaction) may be modified by the learning environment (digital technology usage).

This study employs a comprehensive approach by analyzing the interconnections and mediating influences of digital technology usage, learning experiences, learner engagement, and student happiness. The research examines the cumulative impacts of several factors on student satisfaction, in contrast to prior studies that typically concentrated on individual influences. The importance resides in addressing current research deficiencies and improving our comprehension of the elements influencing the satisfaction of Chinese vocational students.

This study aims to evaluate the efficacy of digital technology usage, facilitated by learning experience and learning engagement based on SCT, in enhancing student satisfaction among 424 vocational students across four colleges in Hubei Province, Central China. The subsequent thesis questions constituted the foundation of the study: 1. Is digital technology usage positively correlated with student satisfaction? 2. Does the learning experience mediate the relationship between digital technology usage and student satisfaction? 3. Does learner engagement serve as a mediator in the relationship between digital technology usage and student satisfaction? 4. Do learning experiences and engagement serve as mediators in the relationship between digital technology usage and student satisfaction?

Literature review

Digital technology usage and student satisfaction

In the field of higher vocational education, the application of digital technology covers the monitoring of big data, teaching

assistance and assessment, the construction of digital resource libraries, the use of immersive virtual simulation teaching systems and the construction of virtual simulation training bases. Researchers showed that digital technology usage is a vital determinant of student satisfaction (Pandita and Kiran, 2023). Studies indicate that digital technologies, such as video annotation tools, employed in vocational education establish a collaborative electronic environment (Bloom and Hough, 2003; Wheeler et al., 2002), clarify learning objectives, and boost teaching quality, hence promoting student satisfaction (Rahyasih et al., 2023; Colasante and Leedham, 2013). Furthermore, it has been noted that in digital learning environments, students can cultivate learning and coping mechanisms, demonstrate sensitivity to educational experiences, and achieve satisfaction with relative ease (Arbaugh, 2014; Calvert, 2014). Consequently, it can be argued that students who consistently utilize digital technology in their studies are more likely to experience satisfaction.

Nevertheless, some researches have revealed that digital technology usage adversely influences learning outcomes. Some scholars propose that the shortcomings of digital technology in education may not meet students' needs, leading to stress and ultimately impacting student satisfaction (Kearney and Maakrun, 2020; Abd Aziz et al., 2021; Vermisli et al., 2022). Lam et al. found that with higher frequency of Instagram use by younger students there is low user engagement (Lam et al., 2022). Simultaneously, the deployment of digital technology may limit instructor aid and peer collaboration (Giray, 2021) and create digital distractions in the learning process (Flanigan and Babchuk, 2020), consequently diminishing students' pleasure. After reviewing the information provided, we have formulated a hypothesis, outlined below.

> H1: Vocational students' digital technology usage relates positively to student satisfaction.

Learning experience as a mediator

According to SCT, Bandura asserted that the learning environment (digital technology usage) can affect learning behavior (such as the learning experience) and therefore influence learning outcome expectations (student satisfaction) (Bandura, 1986). Despite facing academic challenges, individuals maintain a commitment to study and have an optimistic disposition in the digital learning environment (Akcil and Bastas, 2020; Ferrer et al., 2022).

Research shows that learning experience is a key variable that is closely associated with digital technology usage (Henderson et al., 2015; Awidi and Paynter, 2019). Digital technology usage in education enables students to engage actively in the learning process, hence augmenting the enjoyment and perceived value of the experience from their perspective (Baabdullah et al., 2022). For instance, when students encounter a digital learning environment, favorable educational experience facilitates their engagement in learning and encourages them to undertake more hard activities (Awidi and Paynter, 2019).

Learning experience is also believed to be one of the important factors influencing student satisfaction (Elliott and Shin, 2002). Students possessing advanced learning experience can enhance their confidence in education, enabling them to fully commit to their studies, inclined to engage in classroom activities and attain learning satisfaction. Conversely, students with adverse learning experiences may incur stress and diminish student satisfaction (Conrad et al., 2022). Consequently, comprehending the correlation between learning experience and student satisfaction is crucial for enhancing academic success. Casey et al. assert that the learning experience alleviates their discontent by mitigating pressure and enhancing satisfaction (Casey et al., 2016).

Based on the aforementioned perspectives, digital technology usage may affect student satisfaction of higher vocational students through the indirect role of the learning experience. The subsequent hypothesis is proposed based on these factors:

> H2: Learning experience mediates the relationship between digital technology usage and students' satisfaction.

Learning engagement as a mediator

Learning engagement is influenced by digital technology usage (Kearney and Maakrun, 2020; Khlaif et al., 2021; Hanaysha et al., 2023). Research suggests that the integration of digital technology in student education can augment student engagement (Nkomo et al., 2021), as heightened exposure to digital learning environments among higher vocational students is associated with increased participation in class discussions and inquiries (Pandita and Kiran, 2023). Chiu et al. found that digital technology in education is positively correlated with student engagement, as it is more attuned to students' needs than teacher support, based on a comparative study of student engagement in traditional classrooms versus digital learning environments (Chiu et al., 2021). Furthermore, digital technology usage in education transforms learning methodologies, augments interactive engagement, and fosters student participation in the learning process. Researchers found that the help students receive in online learning does not directly influence their academic achievement, unless it is entirely mediated by their intrinsic drive and academic engagement (García-Machado et al., 2024). Consequently, the aforementioned research substantiates the assertion that digital technology usage may augment the learning engagement of higher vocational students (AlArabi and Alsalhi, 2023). Learning engagement is seen as a crucial factor affecting student satisfaction (Pye et al., 2015; Fisher et al., 2018). It is found that learning behavior is a subjective phenomenon governed by the individual, with the learner's engagement influenced by internal factors such as motivation, beliefs, and attributes, resulting in a conscious desire to learn, substantial energy, and an enhanced state of learning, thereby elevating the level of engagement (An et al., 2024). Students demonstrating high levels of learning engagement are expected to enroll in courses and collaborate with peers, hence increasing student satisfaction (Gray and DiLoreto, 2016). This study demonstrates a strong correlation between vocational students' digital technology usage and learning engagement.

Learning experience is believed to influence students' engagement (Li and Xue, 2023; Elshami et al., 2022). Students who have positive learning experiences are more likely to collaborate with peers and educators and commit their time to academic endeavors (Poon, 2012; Miller et al., 2011; Veluvali and Surisetti, 2022). SCT posits that an individual's behavior is a manifestation of prior learning experiences, hence shaping their actions and influencing personal cognition, including student satisfaction. Students engaging in a digital

environment can construct their own learning experiences, leading to active involvement and fulfillment in the educational process.

Based on the above, the research asserts that digital technology usage can improve student satisfaction by enriching learning experiences and learning engagement. Consequently, the following hypotheses:

> H3: Learning engagement mediates the link between digital technology usage and students' satisfaction.
>
> H4: Learning experience and learning engagement mediates the relationship between digital technology usage and students' satisfaction.

Figure 1 depicts a study model based on SCT and the assumptions listed above.

Materials and methods

Research design

We utilized quantitative research, a data-driven methodology that quantitatively delineates and examines events to uncover their inherent principles and attributes (Bloomfield and Fisher, 2019). In social sciences, quantitative research primarily gathers data via surveys, experiments, and observations, employing analytical methods like statistics and sociology for data analysis and interpretation. This study assessed the efficacy of digital technology usage on student satisfaction.

Population and sampling

The sole criterion for the study's sample goal is students enrolled in higher vocational colleges. In June and July 2023, a total of $N = 424$ participants were selected from public vocational institutions in Hubei Province, Central China. This population will serve as the exclusive sample for this investigation.

In order to extract samples from the total population, the study will employ a simple random sampling method to recruit Chinese vocational students who voluntarily participated in the questionnaire collection, which is a very simple type of sampling method that gives each individual in the total population a fair and equal chance to be selected in the research (Frost, 2023). Vocational students were encouraged to respond honestly, with the assurance of confidentiality regarding their responses. A proper sample size, at least 10 times the total number of observed variables, was required based on the recommendations for Structural Equation Modeling (SEM) (Zhang et al., 2020). A total of 424 students, encompassing freshmen to juniors, were randomly selected from the vocational colleges to participate in the survey. Of the overall student population, 30 surveys (7.0%) are rejected due to incomplete records and missing answers. A total of 394 valid samples were acquired for data analysis, with a response rate of 93.0%.

Research ethic

Before beginning the study, ethical considerations were prioritized. The Institutional Review Board (IRB) at Xiangyang Polytechnic carefully reviewed and approved the research procedures, ensuring that the rights and welfare of all participants were upheld. Informed consent was obtained from vocational students in the survey.

Research technique and instrument

The questionnaire included in the study was based on established tools that have demonstrated reliability and validity. It comprised two main portions. The initial part gathered demographic information, such as gender, grade level, and major. This information was essential for characterizing the sample and contextualizing the analysis. The second segment of 20 items, meticulously chosen from proven and established measures assessing digital technology usage, learning experience, learner engagement, and student satisfaction. Each item was selected according to its pertinence to the study's aims and its shown efficacy
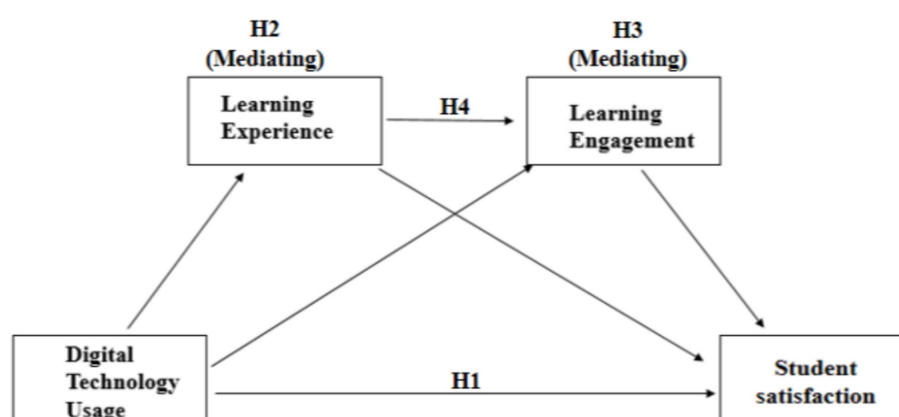

FIGURE 1
The research model.

in prior research. The segment concerning digital technology usage comprised four items (Li et al., 2015). The learning experience part included three items derived from Li et al. (2015). The learning engagement part comprises seven items derived from Dunn and Kennedy (2019), whereas the students' satisfaction component encompasses six items adapted from Sayaf et al. (2021). All 20 items were evaluated using a 5-point Likert scale, with 1 indicating severe disagreement and 5 indicating strong agreement. This scale enabled participants to evaluate their concurrence with each statement. Detailed information regarding the measurement items is available in Table 1.

To assess the reliability and validity of the variables in the measures, we used Cronbach's α to test for internal consistency and conducted a confirmatory factor analysis to demonstrate convergent validity. As shown in Table 1, all measures were found to be reliable as Cronbach's α was greater than 0.7. Furthermore, as shown, the factor loadings of digital technology usage, learning experience, learning engagement, and student satisfaction were all greater than 0.5.

Before beginning the study, ethical considerations were prioritized. The Institutional Review Board (IRB) at Xiangyang polytechnic carefully reviewed and approved the research procedures, ensuring that the rights and welfare of all participants were upheld. Informed consent was obtained from students in the survey. The study employed a simple random sampling method to recruit Chinese vocational students who voluntarily participated in the questionnaire collection. The study participants were aged 19–22 and were enrolled in public vocational institutions located in Wuhan and Xiangyang, Hubei Province, Central China. The study was conducted from June to July 2023. A total of 424 students, encompassing freshmen to juniors, were randomly selected from the vocational colleges to participate in the survey.

Statistical analysis

The data were analyzed using SPSS 26.0 and Amos 24.0. The Harman one-factor test was initially employed to evaluate common technique bias. Subsequent descriptive statistical analysis was employed to assess sample characteristics. Subsequently, structural equation modeling (SEM) was employed to evaluate measurement and structural models. Confirmatory factor analysis was employed to assess the validity and reliability of the data by indicating factor loadings, composite reliability (CR), and average variance extracted (AVE). The goodness of fit index and path analysis coefficients were employed to ascertain a suitable level for the structural equation model. Finally, bootstrapping was performed to examine the statistical significance of the offered hypotheses.

Results

Common method variance

To minimize common technique variance and ascertain the study's validity and reliability, we employed the Harman single factor test utilizing SPSS 26.0 (Podsakoff et al., 2012). The test findings indicated that four variables possessed a characteristic root exceeding one. The variance explanation rate of the first component (39.057%)

TABLE 1 Variables and item description.

Variables	Items	References
Digital technology usage (DTU)	1. I use a computer or other digital device to complete my assignments.	Li et al. (2015)
	2. I use a computer or other digital device to submit my assignments to my teacher.	
	3. I use a computer or other digital device to access information related to my studies.	
	4. I read my teacher's class notes on a computer or mobile phone.	
Learning experience (LEP)	1. I am stimulated by the digital learning content in learning.	Li et al. (2015)
	2. The digital equipment and software are easy to use during lessons.	
	3. The digital equipment and software allow me to have contextualized experiences with the objects or learning resources.	
Learning engagement (LEG)	1. I find learning using digital technology very rewarding.	Dunn and Kennedy (2019)
	2. I find learning about topics using digital technology very interesting.	
	3. I can interact meaningfully with other students while using digital technology for learning.	
	4. I feel that I can use digital technology to improve my learning.	
	5. The content and issues in learning using digital technology challenge me.	
	6. Using digital technology helps me to understand the content more easily.	
	7. When using digital technology in learning, I often review what I learned on previous occasions.	
Student satisfaction (SS)	1. The digital tools used for learning are efficient in analyzing knowledge.	Sayaf et al. (2021)
	2. I am excited to employ digital tools for learning.	
	3. Digital learning tools are effective for acquiring knowledge.	
	4. Digital technologies for learning are effective tools for exchanging knowledge.	
	5. Digital tools for learning are highly effective in facilitating the construction of knowledge.	
	6. I am generally content with the utilization of digital technology for educational purposes.	

did not meet the minimum threshold of 50% (Hair et al., 2010). Our research demonstrates that common procedure variance was not a substantial concern.

Descriptive analysis

As demonstrated in Table 2, the distribution between males and females are practically equal. The sample was evenly divided by gender, comprising 33.76% of vocational students in Grade 1, 44.67% in Grade 2, and 21.57% in Grade 3. Regarding major, 41.88% were enrolled in engineering, 26.14% in business, and 31.98% in arts and humanities.

Measurement model

The measurement model employs Confirmatory Factor Analysis (CFA) to generate a report on the model's reliability and validity. The Cronbach's α score, ranging from 0.80 to 0.89, indicates that the model is credible and trustworthy (Yockey, 2010). Convergent validity is evaluated by factor loadings, composite reliability (CR), and average variance extracted (AVE) (Guerrero et al., 2020). Demonstrating the convergence of this model, all indicators are at least 0.5. The constructs exhibit discriminant validity if the square root of the Average Variance Extracted (AVE) exceeds the correlation coefficient value (Fornell and Larcker, 1981).

According to Table 3, the standardized factor loadings were all significant, ranging from 0.699 to 0.764 ($p < 0.001$).

As shown in Table 4, The CR values ranged from 0.770 to 0.879, and the AVE ranged from 0.511 to 0.527.

In Table 5, it was observed that the square root of the AVE in each construct was greater than any other correlation coefficient value. The total values were higher than the standardized value, showing that the model had acceptable reliability and validity.

Structural model

The investigators utilized two measures-the goodness of fit index and the path coefficient. A well-fitting structural model should have a value of χ^2/df between 0 and 3, and values of GFI, AGFI, CFI, IFI, and TLI greater than 0.9. Additionally, the RMSEA and SRMR values should be less than 0.08 (Zhang et al., 2020). Table 6 shows the following goodness of fit index values: (χ^2)/df = 1.223, GFI = 0.952, AGFI = 0.939, CFI = 0.989, IFI = 0.989, TLI = 0.987, RMSEA = 0.024, SRMR = 0.030.

The structural model's explanatory variance and path coefficient are shown in Figure 2. The standardized regression value of 0.599 for the digital technology usage construct explains 36% of the variance in the learning experience construct. The study found that digital technology usage and the learning experience contribute to 46% of the variation in learning engagement. The standardized regression coefficients for digital technology usage and learning experience were 0.297 and 0.455, respectively. Also, digital technology usage, learning experience, and learning engagement explain 52% of the variation in student satisfaction. The path coefficients for the three constructs were

TABLE 2 Variables descriptive analysis.

Demographic	Sample (N = 394)	Frequency	Percentage
Gender	Male	175	44.42
	Female	219	55.58
Grade	Grade 1	133	33.76
	Grade 2	176	44.67
	Grade 3	85	21.57
Major	Engineering	165	41.88
	Business	103	26.14
	Art and Humanity	126	31.98
Affiliated college	Xiangyang Polytechnic	138	32.5
	Wuhan Polytechnic	76	17.9
	Wuhan Railway Vocational College of Technology	102	24.0
	Hubei Polytechnic Institute	108	25.5

TABLE 3 Factor loading.

Variables	Items	Mean	Factor loading
Digital technology usage (DTU)	DTU1	3.551	0.731
	DTU2	3.584	0.718
	DTU3	3.574	0.694
	DTU4	3.642	0.745
Learning experience (LEP)	LEP1	3.629	0.74
	LEP2	3.556	0.72
	LEP3	3.528	0.719
Learning engagement (LEG)	LEG1	3.612	0.764
	LEG2	3.604	0.702
	LEG3	3.594	0.699
	LEG4	3.627	0.714
	LEG5	3.627	0.707
	LEG6	3.67	0.709
	LEG7	3.665	0.703
Student satisfaction (SS)	SS1	3.563	0.698
	SS2	3.569	0.715
	SS3	3.614	0.723
	SS4	3.599	0.722
	SS5	3.584	0.709
	SS6	3.614	0.716

0.231, 0.389, and 0.211, respectively, with all being statistically significant in the bootstrap test ($p < 0.001$). In conclusion, these findings support the structural model.

Analyzing the hypothesis

As shown in Table 7, the hypotheses all paths are valid ($p < 0.005$) and their paths were supported by the empirical data. Specifically, digital technology usage significantly and positively predicted learning experience ($\beta = 0.599$, $p < 0.001$), hence the path DTU → LEP was verified; learning experience and learning engagement established significant and positive relationships ($\beta = 0.455$, $p < 0.001$), therefore the path LEP → LEG was supported; digital technology usage was significant and positively related to learning engagement ($\beta = 0.297$, $p < 0.001$), therefore the path DTU → LEG was verified; learning engagement was significantly and positively associated with student satisfaction ($\beta = 0.211$, $p < 0.003$), therefore the path LEG → SS was supported; digital technology usage was significantly and positively correlated with students satisfaction ($\beta = 0.231$, $p < 0.001$) therefore the path DTU → SS was verified; learning experience significantly and positively predicted student satisfaction ($\beta = 0.389$, $p < 0.001$) therefore the path LEP → SS was verified.

Analyzing the mediation effect

MacKinnon suggested that the mediation effects could be tested if the results met the following conditions: The Z-value is greater than 1.96, while the 95% bias-corrected confidence interval value excludes 0 (MacKinnon, 2008). Based on Table 5, it has been found that digital technology usage has a positive impact on students' satisfaction. The overall effect was 0.539 [95% bias-corrected CI (0.411, 0.676), $p < 0.01$]. The direct effect of digital technology usage on students' satisfaction was 0.213 [95% bias-corrected CI (0.068, 0.381), $p < 0.01$]. This means that both the overall and direct effects were statistically significant. Moreover, the indirect effects were also significant. The value was 0.053 [95% bias-corrected CI (0.016, 0.117), $p < 0.01$] for the pathway of digital technology usage—learning experience—learning engagement—students' satisfaction, 0.215 [95% bias-corrected CI (0.107, 0.381), $p < 0.01$] for the pathway of digital technology usage—learning experience—students' satisfaction, and 0.058 [95% bias-corrected CI (0.009, 0.148), $p < 0.01$] for the pathway of digital technology usage—learning engagement—students' satisfaction. This is an indication that all mediation effects were significant.

To further explore the potential mediating roles played by learning experience and learning engagement in the association between digital technology usage and student satisfaction, the alternative model was tested. As shown in Table, the model was found to be adequate with fit indices. Data analysis indicated that the mediating effect that of digital technology usage on student satisfaction of Chinese vocational student satisfaction was associated with learning experience and learning engagement, which significantly and positively played a partial mediating role in the association between digital technology usage and student satisfaction. And H2, H3, and H4 were also confirmed. The indirect effect percentages of learning experience and learning engagement were examined as partial mediators. The direct effect of digital technology usage on student satisfaction was 21.3%. However, the total indirect effect of digital technology usage on student satisfaction was 78.7 percent, which was larger than the direct effect. Among the three indirect effects, the indirect effect of learning experience is the highest accounting for 39.9% of the total indirect effect. Table 8 shows the details.

Discussion

In China, there is a significant demand for digital technology in the high-quality growth of higher vocational education, although there is limited research on the specific mechanisms related to learning experience and learning engagement. This study aims to assess the relationship between digital technology usage, learning experience, learning engagement, and student satisfaction among vocational college students in China. Simultaneously, the study aims to elucidate the research hypothesis grounded in Social Cognitive Theory (SCT). Research demonstrates that SCT helps elucidate the determinants influencing student satisfaction in digital technology learning settings in Chinese vocational colleges. The study's findings indicate that digital technology usage directly improves the satisfaction levels of vocational college students. The results correspond with the forecasts made by Kakada et al. (2019) and Jinglin (2020).

Digital technology usage toward student satisfaction

The findings indicated a positive and significant correlation between digital technology usage and student satisfaction among Chinese vocational students, demonstrating that digital technology usage affects student satisfaction. Multiple plausible reasons exist for this outcome. One reason is the integration of digital technology in vocational education may diminish the gap between the classroom and the workplace by enabling continuous interaction with industry experts, hence improving student satisfaction (Wang et al., 2019). Vocational students in China are aware of their responsibilities and seek to learn from technologically proficient instructors who desire feedback to improve their engagement with learners through digital technology. The other one is the incorporation of digital technology in vocational education modifies the learning modality, enabling seamless interactions with industry professionals and instructors, which subsequently encourages vocational students to engage in their studies, thereby improving student satisfaction in vocational colleges (Rahyasih et al., 2023). The vocational students aspired to a rich learning environment with well-structured courses and clearly defined outcomes and assessment strategies used. This study further demonstrates that digital technology usage is a predictive driver of students' satisfaction. The digital technologies utilized in our research mostly encompass online teaching platforms (e.g., MOOC, NetEase Cloud Classroom), Virtual simulation training system, intelligent tutoring systems, virtual laboratories, and digital instructional materials.

The indirect effects of learning experience

The research findings indicated that the learning experience of Chinese vocational college students serves as a significant partial mediator between digital technology usage and student satisfaction. The discovery corroborates prior study by Ghaderizefreh and Hoover (2018), since it further elucidates the mediation function of learning experience between online and mixed learning environments and college student satisfaction. The research findings corroborate the SCT, which asserts that digital technology provides an efficient,

TABLE 4 Reliability and validity.

Variable	Items	UC	SE	Z-value	p-value	SC	Cronbach's a	CR	AVE
	DTU1	1				0.731	0.813	0.813	0.521
Digital technology usage	DTU2	0.947	0.075	12.688	***	0.718			
	DTU3	0.907	0.074	12.312	***	0.694			
	DTU4	0.989	0.076	13.095	***	0.745			
Learning experience	LEP1	1				0.740	0.769	0.770	0.527
	LEP2	1.023	0.083	12.341	***	0.720			
	LEP3	0.939	0.076	12.335	***	0.719			
Learning Engagement	LEG1	1				0.764	0.879	0.879	0.51
	LEG2	0.874	0.063	13.863	***	0.702			
	LEG3	0.898	0.065	13.814	***	0.699			
	LEG4	0.94	0.066	14.136	***	0.714			
	LEG5	0.944	0.068	13.978	***	0.707			
	LEG6	0.886	0.063	14.023	***	0.709			
	LEG7	0.933	0.067	13.884	***	0.703			
	SS1	1				0.698	0.862	0.862	0.51
Student satisfaction	SS2	1.011	0.079	12.797	***	0.715			
	SS3	1.031	0.08	12.923	***	0.723			
	SS4	1.037	0.08	12.916	***	0.722			
	SS5	1.009	0.079	12.703	***	0.709			
	SS6	1.036	0.081	12.807	***	0.716			

UC, unstandardized coefficients; SE, standard error; SC, standardized coefficients.
***$p < 0.001$.

TABLE 5 Discriminant validity analysis.

	Digital technology usage	Learning experience	Learning engagement	Student satisfaction
Digital technology usage	**0.722**			
Learning experience	0.599***	**0.726**		
Learning engagement	0.570***	0.633***	**0.714**	
Student satisfaction	0.584***	0.661***	0.589***	**0.714**

The diagonal contains the square root of the AVE value for each latent construct, while the correlation coefficients are located below the diagonal.
The bold values represent the square root of AVE.
***$p < 0.001$.

TABLE 6 The goodness of fit index of the structural model.

Fit index	χ^2/df	GFI	AGFI	RMSEA	SRMR	CFI	IFI	TLI
	<3	>0.900	>0.900	<0.080	<0.080	>0.900	>0.900	>0.900
	1.223	0.952	0.939	0.024	0.030	0.989	0.989	0.987

interactive, and immediate learning environment that amalgamates work and education. This enables vocational students to develop a customized learning experience that improves their satisfaction levels. In China, as firms undergo digital transformation, heightened standards are set for the quality of workers developed through higher vocational education (Luo, 2024). The cultivation of skilled technical professionals with digital literacy is currently the foremost aim of higher vocational education. One unanticipated result was that the mediating effect of learning experience is the greatest among the three indirect effects. This may be ascribed to the incorporation of

technology into classroom instruction may improve the digital learning experience for higher vocational students. Furthermore, the incorporation of digital technology in higher vocational education can augment the diverse interactive experiences among instructors, students, and educational materials. For instance, the immediate sensations of voting and competing on the smart whiteboard, along with the intuitive and quick experiences provided by sketching tools (Dong and Ma, 2024). Personalized learning experience improves classroom engagement, hence increasing student satisfaction (Pérez-López et al., 2020). This outcome further substantiates the considerable
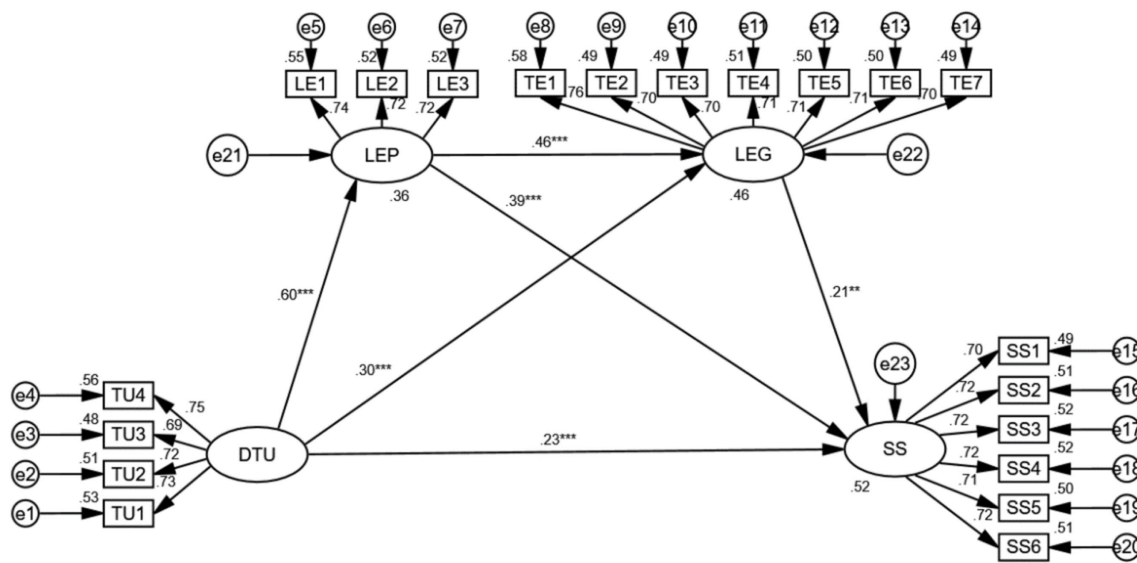
FIGURE 2
The structure modeling diagram.

TABLE 7 The path analysis.

Path	Estimate	S.E.	Z	p	STD
LEP ← DTU	0.577	0.067	8.657	***	0.599
LEG ← LEP	0.476	0.079	5.991	***	0.455
LEG ← DTU	0.3	0.071	4.203	***	0.297
SS ← LEG	0.193	0.064	3.017	0.003	0.211
SS ← DTU	0.213	0.065	3.292	***	0.231
SS ← LEP	0.373	0.079	4.719	***	0.389

effect that learning experiences have on the correlation between digital technology usage and vocational college student satisfaction.

The indirect effects of learning engagement

Also, we tried to measure the DTU-LEG-SS with the mediating effect of LEG. The related question was "Does the digital technology usage can enhance student satisfaction of Chinese vocational students through the mediation of learning engagement"? The research findings revealed that learning engagement acts as a notable partial mediating variable, corroborating Pandita and Kiran's hypothesis (Pandita and Kiran, 2023). This demonstrates that digital technology, absent its use for learning engagement in vocational education, will not significantly contribute to the high-quality development of Chinese higher vocational education. There are several possible explanations for this result. Students with high learning engagement can display adaptability and perseverance when faced with problems, along with enhanced effort in overcoming hurdles, resulting in active participation in the learning process (Bećirović, 2023). In China, industry-teaching integration and college-enterprise co-operation are the most obvious features of vocational education. The cultivation of technical and skilled competencies is a crucial aspect of

learning engagement, profoundly impacted by the utilization of digital technologies. Digital technology usage can augment the dynamism of the learning process and promote students' concentration and engagement (Haleem et al., 2022; Penprase, 2018). The findings highlighted the importance of learning engagement as a crucial link between digital technology usage and student satisfaction of Chinese vocational students.

The chain effect of learning experience and learning engagement

The most notable aspect was the significant disparity in which the learning experience and learning engagement acted as a mediating chain in the relationship between digital technology usage and student satisfaction. This signifies that both the learning experience and engagement are crucial in connecting digital technology utilization with student satisfaction. There are several possible explanations for this result. First, the integration of digital technology can provide more engaging and interactive teaching tools that increase students' interest in learning, so facilitating a robust educational experience that promotes better student involvement and practical interaction with the subject matter (Wang, 2024). For example, the use of cloud classrooms in higher vocational education has led to the creation of DGclass, a digital skills learning platform that enables the online acquisition and practice of digital competencies (Luo, 2024). This platform accurately replicates real-world learning experiences in firms, successfully bridging the gap between instruction and practical application in online education, thus enhancing the motivation of higher vocational students to participate in their studies. Second, the employment of digital technology empowers vocational educators to design and execute training more efficiently, fostering a more individualized and adaptive learning environment for vocational students. Such environments can accommodate the diverse learning requirements of pupils, hence enhancing their engagement (Li et al., 2024). For instance, by employing the online teaching platform, vocational educators can independently

TABLE 8 Direct, indirect, and total effect analysis.

Path relationship	Parameter	Estimate	Bias-corrected 95% CI		Percentile 95% CI	
			Lower	Upper	Lower	Upper
Total effect	DTU → SS	0.539	0.411	0.676	0.409	0.674
Direct effect	DTU → SS	0.213	0.068	0.381	0.056	0.371
Indirect effect 1	DTU → LEP → SS	0.215	0.107	0.381	0.105	0.38
Indirect effect 2	DTU → LEG→SS	0.058	0.009	0.148	0.004	0.135
Indirect effect 3	DTU → LEP → LEG→SS	0.053	0.016	0.117	0.006	0.102
Comparison of indirect effects	1–3	0.162	0.036	0.349	0.037	0.353
	2–3	0.005	−0.041	0.075	−0.043	0.072
	1–2	0.157	−0.01	0.359	−0.006	0.363
Percentage of indirect effects	1	0.399	0.191	0.706	0.194	0.716
	2	0.107	0.017	0.275	0.007	0.246
	3	0.098	0.028	0.223	0.011	0.197

create students' learning pathways and conduct thorough analyses of behavioral data, clickstream data (encompassing hesitation, duration of hesitation, and error repetition), and expression data, thus promptly updating students on their evolving learning status, enhancing their educational experience, and enabling rapid modifications to their engaged studies. Our findings also indicated that in comparison to digital technology usage ($\beta = 0.30$, $p < 0.01$), the learning experience significantly influenced learning engagement ($\beta = 0.46$, $p < 0.01$). This suggests that learning engagement mostly stems from the vocational education experience during the utilization of digital technology, since a positive and intrinsically engaging learning experience is an effective method for enhancing student learning engagement (Miller et al., 2011). These findings deepen our comprehension of the complex relationships between digital technology usage, learning experiences, learner engagement, and student satisfaction.

Implications of the study

Research possesses relevance if it yields academic and practical ramifications. Likewise, the present research possesses both theoretical and practical relevance. This study's theoretical contribution enhances satisfaction among Chinese higher vocational students, improves the quality of Chinese vocational education, and increases employability. Particularly in China during the Industry 4.0 era, the extent of digital technology-enhanced learning has expanded. Consequently, a significant significance of our study is that Chinese higher vocational institutions should prioritize the enhancement of digital technology usage.

This research expands the current DTU–SS interaction by proposing the DTU–LEP–SS and DTU–LEG–SS relationships, and further verifies that the influence of DTU on SS has intensified with LEP and LEG acting as chain mediators. This enhances understanding of the essential mechanisms linking these variables. Significant study has concentrated on the heightened interest of Chinese higher vocational colleges in integrating digital technology into the educational process; however, insufficient attention has been directed into the chain effect of LEP-LEG on SS. Our research addresses the gap by correlating digital technology utilization with student satisfaction via the mediating factors of learning experience and learning

engagement. Therefore, it is recommended that Chinese higher vocational colleges prioritize the enhancement of learning experiences and engagement over mere investment in digital technology infrastructure, as this will significantly improve student satisfaction.

It enhances the understanding of the role of Chinese higher vocational colleges within the framework of developing nations. Chinese higher vocational institutions must concentrate on the learning experience and engagement to effectively connect digital technology usage with student satisfaction. Meanwhile it offers empirical evidence for the SCT, revealing that digital technology usage as an environmental variable indirectly affects student satisfaction through the mediating functions of learning experience and learning engagement. This highlights the importance of environmental factors in shaping vocational students' subjective cognitive evaluations (student satisfaction) via behavioral dimensions (learning experience and engagement).

It implores administrators to acknowledge the importance of learning experience and learning engagement in digital technology usage, promotes a supportive educational atmosphere through digital resources, enables significant transformations in teaching and learning within higher vocational education, and bridges the divide between academia and industry. Educators must understand how to enhance student satisfaction by analyzing elements related to the learning environment, such as digital technology usage, as well as learner characteristics, including prior learning experiences and levels of engagement. Students in higher vocational education must participate in crucial training, seminars, and symposiums to deepen their understanding of the importance of information acquisition in digital technology and to hone their practical skills in its application.

Conclusion

This research aims to analyze the effect of digital technology utilization on student happiness in higher vocational colleges in China. We utilized structural equation modeling to examine the relationship between digital technology utilization and student happiness among higher vocational students. Our findings demonstrate that digital technology usage is positively correlated with student satisfaction among higher vocational students, indicating that digital technology

usage is a significant factor influencing student satisfaction. Further studies indicate that the mediating effect of learning experience is the most significant among the three indirect effects, demonstrating that learning experience is a crucial factor in student satisfaction, providing authentic simulations and virtual experiences, enabling vocational students to implement their acquired knowledge in practical settings. Moreover, we have established that learning experience and learning engagement function as advantageous mediators between digital technology usage and student satisfaction.

The study's findings indicate that initiatives must be implemented to aid higher vocational students in cultivating effective learning experiences. Creating a digital, immersive educational environment such as MOOC, NetEase Cloud Classroom, Virtual simulation training system, enables vocational students to view themselves in an authentic situation, hence improving engagement and understanding of the subject, which can contribute to student satisfaction by providing digital practice programs to ensure their full commitment to their studies (Dong and Ma, 2024). Educators can assist higher vocational students in developing digital technology competency by utilizing digital techniques, for instance intelligent tutoring systems, that enhance their emotional engagement during practical training.

Overall, according to SCT, digital technology usage in vocational education provides an important learning environment for students' learning behaviors by examining the intricate relationship among digital technology usage, learning experience, learning engagement, and student satisfaction. It is essential to utilize digital technology in a manner that enhances students' learning experience and engagement, rather than serving as a replacement for quality instruction as well as individual involvement.

Limitations and further research

The research has some significant implications that warrant consideration. The theoretical model proposed in the study may have limited generalizability, as it was exclusively assessed using samples from higher vocational colleges in Hubei Province. To enhance the model's validity, subsequent research should include supplementary samples from diverse colleges and institutions across China. Secondly, it is essential to acknowledge that employing a cross-sectional design in the research implies the inability to demonstrate causal links between variables. To investigate the correlation between digital technology usage and student satisfaction, doing longitudinal study in the future would be advantageous.

Digital technology is perpetually advancing, with new innovations consistently being implemented in vocational education environments. Future research may examine the impact of developing digital technologies, including augmented reality, virtual reality, and artificial intelligence, on the learning experience, learning engagement, and student satisfaction. Comprehending the impact of these technologies on learning experience helps guide the creation of efficient technological connections that improve learning engagement and student satisfaction.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

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

Author contributions

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Conflict of interest

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

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

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References

Abd Aziz, N. N., Awang Kader, M. A. R., and Ab, H. R. (2021). The impact of technostress on student satisfaction and performance expectancy. *Asian J. Univ. Educ.* 17:538. doi: 10.24191/ajue.v17i4.16466

Achtenhagen, C., and Achtenhagen, L. (2019). The impact of digital technologies on vocational education and training needs. *Educ. Train.* 61, 222–233. doi: 10.1108/et-05-2018-0119

Akcil, U., and Bastas, M. (2020). Examination of university students' attitudes towards e-learning during the COVID-19 pandemic process and the relationship of digital citizenship. *Contemp. Educ. Technol.* 13:ep291. doi: 10.30935/cedtech/9341

AlArabi, K., and Alsalhi, N. (2023). The role of computer simulations (CSs) and artificial intelligence on student learning: moderating the impact of the learning environment. *Przestrzeń Społeczna (Social Space)* 23, 103–122.

An, D., Ye, C., and Liu, S. (2024). The influence of metacognition on learning engagement the mediating effect of learning strategy and learning behavior. *Curr. Psychol.* 43, 31241–31253. doi: 10.1007/s12144-024-06400-y

Arbaugh, J. B. (2014). System, scholar or students? Which most influences online MBA course effectiveness? *J. Comput. Assist. Learn.* 30, 349–362. doi: 10.1111/jcal.12048

Athiyaman, A. (1997). Linking student satisfaction and service quality perceptions: the case of university education. *Eur. J. Mark.* 31, 528–540. doi: 10.1108/03090569710176655

Awidi, I. T., and Paynter, M. (2019). The impact of a flipped classroom approach on student learning experience. *Comput. Educ.* 128, 269–283. doi: 10.1016/j.compedu.2018.09.013

Baabdullah, A. M., Alsulaimani, A. A., Allamnakhrah, A., Alalwan, A. A., Dwivedi, Y. K., and Rana, N. P. (2022). Usage of augmented reality (AR) and development of e-learning outcomes: an empirical evaluation of students' e-learning experience. *Comput. Educ.* 177:104383. doi: 10.1016/j.compedu.2021.104383

Bandura, A. (1986). Social foundations of thought and action: a social cognitive theory. Englewood Cliffs, NJ: Prentice-Hall.

Bećirović, S. (2023). Fostering student engagement in implementing digital pedagogy. *Digit. Pedag.* 1, 97–111. doi: 10.1007/978-981-99-0444-0_8

Bloom, K. C., and Hough, M. C. (2003). Student satisfaction with technology-enhanced learning. *Comput. Inform. Nurs.* 21, 241–246. doi: 10.1097/00024665-200309000-00011

Bloomfield, J., and Fisher, M. J. (2019). Quantitative research design. *J. Austral. Rehabil. Nurses Assoc.* 22, 27–30. doi: 10.33235/jarna.22.2.27-30

Calvert, C. E. (2014). Developing a model and applications for probabilities of student success: a case study of predictive analytics. *Open Learn. J. Open Dist. e-Learn.* 29, 160–173. doi: 10.1080/02680513.2014.931805

Casey, A., Goodyear, V. A., and Armour, K. M. (2016). Rethinking the relationship between pedagogy, technology and learning in health and physical education. *Sport Educ. Soc.* 22, 288–304. doi: 10.1080/13573322.2016.1226792

Chen, B., Liu, Y., and Zheng, J. (2022). Using data mining approach for student satisfaction with teaching quality in high vocation education. *Front. Psychol.* 12:746558. doi: 10.3389/fpsyg.2021.746558

Chester, A., Buntine, A., Hammond, K., and Atkinson, L. (2011). Podcasting in education: student attitudes, behaviour and self-efficacy. *J. Educ. Technol. Soc.* 14, 236–247.

Chiu, T. K. F., Lin, T. J., and Lonka, K. (2021). Motivating online learning: the challenges of COVID-19 and beyond. *Asia Pac. Educ. Res.* 30, 187–190. doi: 10.1007/s40299-021-00566-w

Colasante, M., and Leedham, M. (2013). Motivation and satisfaction for vocational education students using a video annotation tool. Sydney: ASCILITE Publications, 167–177.

Conrad, C., Deng, Q., Caron, I., Shkurska, O., Skerrett, P., and Sundararajan, B. (2022). How student perceptions about online learning difficulty influenced their satisfaction during Canada's COVID-19 response. *Br. J. Educ. Technol.* 53, 534–557. doi: 10.1111/bjet.13206

Dong, X. C., and Ma, G. W. (2024). Constructive framework and practical progression of intelligent learning space in vocational education from the perspective of meta-cosmos. *Adult Educ.* 44, 80–85.

Dunn, T. J., and Kennedy, M. (2019). Technology enhanced learning in higher education; motivations, engagement and academic achievement. *Comput. Educ.* 137, 104–113. doi: 10.1016/j.compedu.2019.04.004

Elliott, K. M., and Shin, D. (2002). Student satisfaction: an alternative approach to assessing this important concept. *J. High. Educ. Policy Manag.* 24, 197–209. doi: 10.1080/1360080022000013518

Elshami, W., Taha, M. H., Abdalla, M. E., Abuzaid, M., Saravanan, C., and Al Kawas, S. (2022). Factors that affect student engagement in online learning in health professions education. *Nurse Educ. Today* 110:105261. doi: 10.1016/j.nedt.2021.105261

Ferrer, J., Ringer, A., Saville, K., Parris, M. A., and Kashi, K. (2022). Students' motivation and engagement in higher education: the importance of attitude to online learning. *High. Educ.* 83, 317–338. doi: 10.1007/s10734-020-00657-5

Fisher, R., Perényi, Á., and Birdthistle, N. (2018). The positive relationship between flipped and blended learning and student engagement, performance and satisfaction. *Act. Learn. High. Educ.* 22, 97–113. doi: 10.1177/1469787418801702

Flanigan, A. E., and Babchuk, W. A. (2020). Digital distraction in the classroom: exploring instructor perceptions and reactions. *Teach. High. Educ.* 27, 352–370. doi: 10.1080/13562517.2020.1724937

Fornell, C., and Larcker, D. F. (1981). Erratum: structural equation models with unobservable variables and measurement error: algebra and statistics. *J. Mark. Res.* 18, 39–50. doi: 10.1177/002224378101800104

Frost, J. (2023). Simple random sampling: definition & examples. Statistics by Jim. Available at: https://statisticsbyjim.com/basics/simple-random-sampling/ (Accessed September 10, 2024).

García-Machado, J. J., Martínez Ávila, M., Dospinescu, N., and Dospinescu, O. (2024). How the support that students receive during online learning influences their academic performance. *Educ. Inf. Technol.* 29, 20005–20029. doi: 10.1007/s10639-024-12639-6

Ghaderizefreh, S., and Hoover, M. L. (2018). Student satisfaction with online learning in a blended course. *Int. J. Digit. Soc.* 9, 1393–1398. doi: 10.20533/ijds.2040.2570.2018.0172

Giray, G. (2021). An assessment of student satisfaction with e-learning: an empirical study with computer and software engineering undergraduate students in Turkey under pandemic conditions. *Educ. Inf. Technol.* 26, 6651–6673. doi: 10.1007/s10639-021-10454-x

Gray, J. A., and DiLoreto, M. (2016). The effects of student engagement, student satisfaction, and perceived learning in online learning environments. *Int. J. Educ. Leaders. Prep.* 11:n1.

Guerrero, A. B., Cárdenas-Gutiérrez, A. R., and Montoro-Fernández, E. (2020). Basic business knowledge scale for secondary education students. Development and validation with Spanish teenagers. *PLoS One* 15:e0235681. doi: 10.1371/journal.pone.0235681

Hair, J., Black, W. C., Babin, B. J., and Anderson, R. E. (2010). Multivariate data analysis: a global perspective. *7th* Edn. Upper Saddle River: Pearson Education, Cop.

Haleem, A., Javaid, M., Qadri, M. A., and Suman, R. (2022). Understanding the role of digital technolo gies in education: a review. *Sustain. Oper. Comput.* 3, 275–285. doi: 10.1016/j.susoc.2022.05.004

Hanaysha, J. R., Shrideh, F. B., and In'airat, M. (2023). Impact of classroom environment, teacher competency, information and communication technology resources, and university facilities on student engagement and academic performance. *Int. J. Inf. Manag. Data Insights* 3:100188. doi: 10.1016/j.jjimei.2023.100188

He, X. (2022). The innovative development of Chinese vocational education from the perspective of the metaverse. *J. Educ. Educ. Res.* 1, 8–12. doi: 10.54097/jeer.v1i2.3046

Henderson, M., Selwyn, N., and Aston, R. (2015). What works and why? Student perceptions of "useful" digital technology in university teaching and learning. *Stud. Higher Educ.* 42, 1567–1579. doi: 10.1080/03075079.2015.1007946

Indrawati, S. M., and Kuncoro, A. (2021). Improving competitiveness through vocational and higher education: Indonesia's vision for human capital development in 2019–2024. *Bull. Indones. Econ. Stud.* 57, 29–59. doi: 10.1080/00074918.2021.1909692

Jinglin, M. (2020). Research on the application of data mining technology in educational management system. *J. Educ. Pract.* 2021, 1–7. doi: 10.1155/2021/6529174

Kakada, P., Deshpande, Y., and Bisen, S. (2019). Technology support, social support, academic support, service support, and student satisfaction. *J. Inf. Technol. Educ. Res.* 18, 549–570. doi: 10.28945/4461

Kearney, S., and Maakrun, J. (2020). Let's get engaged: the Nexus between digital technologies, engagement and learning. *Educ. Sci.* 10:357. doi: 10.3390/educsci10120357

Khlaif, Z. N., Salha, S., and Kouraichi, B. (2021). Emergency remote learning during COVID-19 crisis: students' engagement. *Educ. Inf. Technol.* 26, 7033–7055. doi: 10.1007/s10639-021-10566-4

Lam, A. H. C., Ho, K. K., and Chiu, D. K. (2022). Instagram for student learning and library promotions: a quantitative study using the 5E instructional model. *Aslib J. Inf. Manag.* 75, 112–130. doi: 10.1108/AJIM-12-2021-0389

Li, B., Kong, S. C., and Chen, G. (2015). Development and validation of the smart classroom inventory. *Smart Learn. Environ.* 2, 1–18. doi: 10.1186/s40561-015-0012-0

Li, S. S., Luo, Z. C., and Lin, X. (2024). Digital intelligence facilitates the high-quality advancement of vocational education: an analysis utilizing a two-dimensional framework of enabling modes and innovative elements study. *Adv. Eng. Educ.* 10, 1–7.

Li, J., and Xue, E. (2023). Dynamic interaction between student learning behaviour and learning environment: meta-analysis of student engagement and its influencing factors. *Behav. Sci.* 13:59. doi: 10.3390/bs13010059

Luo, Y. C. (2024). Digital virtual simulation technology and the high-quality development of vocational education. *Shanxi Univ. Finance Econ.* 46, 245–247.

MacKinnon, D. P. (2008). Introduction to statistical mediation analysis. Mahwah: Erlbaum.

Memon, M. Q., Lu, Y., Memon, A. R., Memon, A., Munshi, P., and Shah, S. F. A. (2022). Does the impact of technology sustain students' satisfaction, academic and functional performance: an analysis via interactive and self-regulated learning? *Sustain. For.* 14:7226. doi: 10.3390/su14127226

Miller, R. L., Rycek, R. F., and Fritson, K. (2011). The effects of high impact learning experiences on student engagement. *Procedia Soc. Behav. Sci.* 15, 53–59. doi: 10.1016/j.sbspro.2011.03.050

Nkomo, L. M., Daniel, B. K., and Butson, R. J. (2021). Synthesis of student engagement with digital technologies: a systematic review of the literature. *Int. J. Educ. Technol. High. Educ.* 18, 1–26.

O'Flaherty, J., and Phillips, C. (2015). The use of flipped classrooms in higher education: a scoping review. *Internet Higher Educ.* 25, 85–95. doi: 10.1016/j.iheduc.2015.02.002

Pandita, A., and Kiran, R. (2023). The technology Interface and student engagement are significant stimuli in sustainable student satisfaction. *Sustain. For.* 15:7923. doi: 10.3390/su15107923

Peng, H., and Zhao, J. (2022). Has technology empowered learning? -the impact of learners' use of technology on the learning experience. *Open Educ. Res.* 28, 110–120. doi: 10.13966/j.cnki.kfjyyyj.2022.02.012

Penprase, B. E. (2018). The fourth industrial revolution and higher education. *Tạp chí Nghiên cứu dân tộc* 23, 207–229. doi: 10.1007/978-981-13-0194-0_9

Pérez-López, R., Gurrea-Sarasa, R., Herrando, C., Martín-De Hoyos, M. J., Bordonaba-Juste, V., and Utrillas-Acerete, A. (2020). The generation of student engagement as a cognition-affect-beha viour process in a twitter learning experience. *Austral. J. Educ. Technol.* 36, 132–146. doi: 10.14742/ajet.5751

Podsakoff, P. M., MacKenzie, S. B., and Podsakoff, N. P. (2012). Sources of method bias in social science research and recommendations on how to control it. *Annu. Rev. Psychol.* 63, 539–569. doi: 10.1146/annurev-psych-120710-100452

Poon, J. (2012). Use of blended learning to enhance the student learning experience and engagement in property education. *Prop. Manag.* 30, 129–156. doi: 10.1108/02637471211213398

Pye, G., Holt, D., Salzman, S., Bellucci, E., and Lombardi, L. (2015). Engaging diverse student audiences in contemporary blended learning environments in Australian higher business education: implications for design and practice. *Austral. J. Inf. Syst.* 19:19. doi: 10.3127/ajis.v19i0.1251

Rahyasih, Y., Wijaya, W. M., and Syarifah, L. S. (2023). Exploring vocational students' satisfaction with online learning. *J. Educ. e-Learn. Res.* 10, 352–357. doi: 10.20448/jeelr.v10i3.4668

Sayaf, A. M., Alamri, M. M., Alqahtani, M. A., and Al-Rahmi, W. M. (2021). Information and communications technology used in higher education: an empirical study on digital learning as sustainability. *Sustain. For.* 13:7074. doi: 10.3390/su13137074

Selwyn, N. (2021). Education and technology: key issues and debates. London: Bloomsbury Publishing.

Sharpe, R., and Benfield, G. (2005). The student experience of e-learning in higher education. *Brookes eJ. Learn. Teach.* 1, 1–9.

Veluvali, P., and Surisetti, J. (2022). Learning management system for greater learner engagement in higher education—a review. *Higher Educ. Future* 9, 107–121. doi: 10.1177/23476311211049855

Vermisli, S., Cevik, E., and Cevik, C. (2022). The effect of perceived stress and digital literacy on student satisfaction with distance education. *Rev. Esc. Enferm. U.S.P.* 56:56. doi: 10.1590/1980-220x-reeusp-2021-0488en

Wang, Q. (2024). Objectives, obstacles, and practical approaches of deep learning for vocational education students in the context of digital textbook development. *China Vocat. Techn. Educ.* 20, 70–79.

Wang, S. L., Chen, H. P., Hu, S. L., and Lee, C. D. (2019). Analyzing student satisfaction in the technical and vocational education system through collaborative teaching. *Sustain. For.* 11:4856. doi: 10.3390/su11184856

Wang, M. T., and Eccles, J. S. (2013). School context, achievement motivation, and academic engagement: a longitudinal study of school engagement using a multidimensional perspective. *Learn. Instr.* 28, 12–23. doi: 10.1016/j.learninstruc.2013.04.002

Wheeler, S., Waite, S. J., and Bromfield, C. (2002). Promoting creative thinking through the use of ICT. *J. Comput. Assist. Learn.* 18, 367–378. doi: 10.1046/j.0266-4909.2002.00247.x

Xibin, H. A. N., Chengming, Y. A. N. G., and Qian, Z. H. O. U. (2023). Digital transformation in vocational education: present situation, problems, and countermeasures. *Front. Educ. China* 18, 70–82. doi: 10.3868/s110-008-023-0005-2

Yang, J. (2016). Evaluation and optimization of classroom environments for technology for learning. *Electrochem. Educ.* 37, 99–105. doi: 10.13811/j.cnki.eer.2016.12.014

Ye, J. H., Lee, Y. S., and He, Z. (2022). The relationship among expectancy belief, course satisfaction, learning effectiveness, and continuance intention in online courses of vocational-technical teachers college students. *Front. Psychol.* 13:904319. doi: 10.3389/fpsyg.2022.904319

Yockey, R. D. (2010). "SPSS is actually very simple" in Translating. eds. C. Liu and Z. Wu (Beijing: China Renmin University Press).

Zhang, W., Xu, M., and Su, H. (2020). Dance with structural equations. Xiamen: Xiamen University Press.