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Leveraging digital skills to reduce cognitive strain: Implications for academic self-efficacy in medical education

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A R T I C L E I N F O

Keywords:
Digital literacy
Academic self-efficacy
Cognitive load
Medical students

A B S T R A C T

Background: Digital literacy influences academic behaviors, especially in medical education, where students encounter considerable academic challenges. However, the effects of this phenomenon on academic self-efficacy and cognitive load remain inadequately understood.
Objectives: This research explores the relationships between digital literacy and academic self-efficacy, emphasizing the mediating role of cognitive load and its various dimensions among medical students in Islamabad, Pakistan.
Methods: A descriptive cross-sectional survey was conducted from seven medical colleges in Islamabad, Pakistan, from October to December 2023. The research employed meticulously validated measurement tools encompassing a digital literacy scale, academic self-efficacy scale, and cognitive load scale and collected data on 633 medical students. Descriptive statistics and inferential testing (mediation analysis) were performed to investigate the direct and indirect relationships of the study variables.
Results: The empirical results revealed that digital literacy significantly enhances academic self-efficacy both directly and indirectly. First, the total cognitive load score showed partial mediation ($\beta = 0.165$, $p < 0.001$). Then, individual subscale analysis revealed that intrinsic cognitive load ($\beta = 0.147$, $p < 0.001$) and extraneous cognitive load ($\beta = 0.144$, $p < 0.001$) were significant mediators. However, the mediation effect through self-perceived learning ($\beta = 0.105$, $p = 0.361$) was not supported, suggesting variability in how students perceive their learning gains or other influencing factors influencing this relationship, which warrants further investigation.
Conclusion: The research finding underscores the crucial integration of digital literacy instruction into medical curriculums to bolster students' academic self-efficacy by adeptly managing cognitive load. While digital literacy notably reduces intrinsic and extraneous cognitive loads, its impact on perceived learning appears context-dependent and requires further exploration. Additional studies are needed to understand these relationships across educational settings and identify other potential influencing factors.

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1. Introduction

In recent years, information and communication technologies (ICT) have profoundly influenced various aspects of human life. The digitalization trend has accelerated, prompting citizens to adopt new strategies. The educational sector has had a notable impact as we navigate an era of consistent technological innovations (Urakova et al., 2023). Learning in this digital era extends across study, work, and leisure pursuits. Advancements in educational technologies allow students to acquire knowledge over the Internet (del C. Pegalajar Palomino & Torres, 2023; Fuentes et al., 2019; Van de Oudeweetering & Voogt, 2018). In higher education, particularly in medical training, digital literacy is critical to student success and goes beyond basic technical skills. Digital literacy is the ability to locate, evaluate, and effectively utilize digital information, tools, and resources (Eshet, 2012). For medical students, it encompasses the ability to navigate and assess digital resources, critically engage with online medical literature, and integrate digital tools into patient care and clinical decision-making processes. In the context of medical education, where information overload and the need for accurate data are common, digital literacy becomes crucial for developing clinical competencies and adapting to evolving medical technologies (Amaral et al., 2019; Shopova, 2014). Without strong digital literacy skills, students may face increased cognitive load, hindering their ability to process complex information and impacting their academic self-efficacy. Digital transformation embodies rapid and deep-seated changes in activities, processes, competencies, and business models (UNESCO, 2022). It is about strategically leveraging digital technologies' changes and opportunities (Demirkan et al., 2016). This transformation in education involves teaching and learning in digital contexts, where elements like interactivity, engagement, pedagogy, digital tools, practical learning, applications, digital services, and portable devices come into play (Fernández-Enguita et al., 2023) (Sánchez et al., 2020).

Academic self-efficacy, a student's confidence in their academic abilities, influences their effort and persistence (Schunk & Pajares, 2002). This confidence is developed through academic successes and is crucial for overcoming challenges (Alzig, 2009; Pampaka et al., 2018). Self-regulated learning (SRL) plays a vital role in higher education success. Learning analytics can enhance SRL by aiding students in planning, organizing, and assessing their learning processes (Alexander et al., 2011; Wolters et al., 2005). However, integrating SRL techniques with technology can be complex (Valentín et al., 2013; Winters et al., 2008). Prior empirical investigations have demonstrated that students' academic self-efficacy positively influences their engagement in studies, serving as a critical determinant of academic success (Ahmed et al., 2018; Kuh et al., 2006). Moreover, researchers have observed that students with high academic self-efficacy exhibit greater resilience and persist longer when confronted with challenges, leading to improved academic performance through sustained effort (Klassen & Usher, 2010). Additionally, evidence suggests a reciprocal relationship between academic self-efficacy and educational achievement, where increased self-efficacy enhances academic success, further strengthening students' self-efficacy (Shea & Howell, 2000; Talsma et al., 2018). Although the direct impact of digital literacy on academic self-efficacy is conceivable, it is imperative to examine the cognitive mechanisms that mediate this relationship (Getenet et al., 2024; Ibrahim & Aldawsari, 2023).

Cognitive load, defined as the mental effort necessary for processing information, presents a robust framework for examining the influence of digital literacy on academic self-efficacy (Sweller, 1988).

Since its comprehensive elucidation in the late 1980s, Cognitive Load Theory has emerged as a significant and influential framework within the field of instructional psychology (Paas et al., 2004; Paas & Sweller, 2014). The theoretical foundations of this framework are employed to develop educational materials and instructional methodologies that are optimally conducive to the learning process. The theory posits that the cognitive system has limited capacity, and learning is most effective when cognitive load is optimized (Sweller, 1988). In digital literacy, students with higher proficiency in digital tools may experience lower extraneous cognitive load, allowing them to manage intrinsic and germane loads better, thereby enhancing their academic self-efficacy (Paas et al., 2004; Seufert et al., 2024).

The relationship between cognitive load and academic self-efficacy is multifaceted. While the intrinsic cognitive load is driven by task complexity, its impact on self-efficacy varies depending on the student's prior knowledge and expertise. For novice learners, high intrinsic load can overwhelm and reduce self-efficacy, whereas more advanced learners may find it builds confidence (Sweller et al., 2011). On the other hand, extraneous cognitive load negatively impacts self-efficacy by demanding unnecessary cognitive effort (Van Merriënboer & Kirschner, 2017). Digital literacy mitigates this by enabling learners to organize better and process information, thus freeing up resources for learning (Paas & Sweller, 2014). Germane cognitive load has a more positive effect on self-efficacy as learners engage with content meaningfully. Digital literacy enhances germane load management, contributing to self-efficacy (Kalyuga, 2011; Van Merriënboer & Kirschner, 2017). Therefore, there is a pressing need to explore how digital literacy can balance these cognitive loads, particularly in medical education contexts, where students face a high degree of complexity.

1.1. Theoretical background

Cognitive Load Theory (CLT) (Sweller, 1988) and Social Cognitive Theory (SCT) (Bandura, 1977) provide the basis for the proposed hypotheses. CLT emphasizes the importance of managing cognitive load to optimize learning outcomes, particularly in environments where information complexity is high, such as medical education (Sweller, 1988). SCT, developed by Bandura (1977), focuses on the role of self-efficacy in shaping behavior and motivation, stating that individuals who believe in their capabilities are more likely to succeed in academic and professional tasks (Bandura, 1977).

According to SCT, students with higher self-efficacy are more likely to engage in academic challenges and persist despite difficulties (Bandura, 1986) (Bandura, 1977). Digital literacy plays a crucial role in shaping this self-efficacy by providing students with the tools necessary to manage the digital aspects of their learning environments (Hatlevik et al., 2018). With strong digital literacy skills, students can navigate online medical resources and tools more effectively, which increases their confidence in their academic abilities (Aesaert & van Braak, 2014). Therefore, we propose:

Hypothesis 1. ***(H1):*** There exists a positive relationship between digital literacy and academic self-efficacy among medical students. Higher digital literacy leads to increased self-confidence in performing academic tasks.

In addition, CLT posits that reducing extraneous and intrinsic cognitive load enhances learning outcomes (Paas & Sweller, 2012). For medical students, managing the cognitive load inherent in complex learning materials is critical for academic success. Digital literacy reduces extraneous cognitive load by enabling students to process information more efficiently, leaving more cognitive resources available for understanding the material (intrinsic load) (Kirschner & van Merriënboer, 2013; Paas & Sweller, 2012). This improved cognitive management is hypothesized to lead to higher academic self-efficacy. Hence, we propose:

Hypothesis 2. ***(H2):*** The relationship between digital literacy and academic self-efficacy is mediated by cognitive load, with digital literacy reducing cognitive demands and improving self-efficacy indirectly.

Likewise, intrinsic cognitive load refers to the complexity of the task itself (Plass et al., 2010). According to CLT, students with higher digital literacy can better manage complex academic tasks by focusing their cognitive efforts more efficiently (De Jong, 2010). This allows them to deal with the inherent complexity of their studies, improving their confidence in handling such tasks (Choi et al., 2014). Therefore, we hypothesize:

Hypothesis 2a. ***(H2a):*** Intrinsic cognitive load significantly mediates the relationship between digital literacy and academic self-efficacy. Higher digital literacy reduces the difficulty of complex tasks, enhancing students' academic self-efficacy.

Furthermore, extraneous cognitive load relates to how information is presented. Poorly designed materials or digital interfaces can increase this load, reducing learning effectiveness (Sweller et al., 2011). Students with higher digital literacy can better manage the extraneous cognitive load by efficiently navigating and organizing information, thus freeing cognitive resources for understanding the core material (Kalyuga, 2007). Consequently, this contributes to higher academic self-efficacy:

Hypothesis 2b. ***(H2b):*** Extraneous cognitive load significantly mediates the relationship between digital literacy and academic self-efficacy. By reducing unnecessary cognitive effort, digital literacy allows students to focus more on learning, improving their self-efficacy.

While CLT emphasizes the impact of intrinsic and extraneous cognitive loads, the perception of learning gains—self-perceived learning—is another factor that might influence students' confidence (Carpenter et al., 2020). Even with high digital literacy, students may experience variability in how they perceive their learning outcomes due to individual differences in assessment of progress, which could affect their academic self-efficacy (de Bruin et al., 2020). However, this relationship may not be as strong as those involving intrinsic or extraneous cognitive load:

Hypothesis 2c. ***(H2c):*** Self-perceived learning significantly mediates the relationship between digital literacy and academic self-efficacy, though this effect may vary depending on individual differences.

1.2. Study contribution

This study aims to bridge the knowledge gap in the existing literature by exploring the nuanced relationship between digital literacy, cognitive load, and academic self-efficacy, particularly within the context of medical education in Islamabad, Pakistan. While previous research has examined the impact of digital literacy on academic outcomes, there is a lack of understanding of how cognitive load, both as a unified construct and through its distinct dimensions (intrinsic, extraneous, and self-perceived learning), mediates this relationship. Given the high cognitive demands on medical students, understanding these dynamics is crucial for improving educational strategies. By focusing on medical students in Islamabad, this study not only adds to the limited body of research in this geographical context but also provides insights that are directly applicable to a region where the integration of digital tools in education is still evolving. This research contributes to the broader educational discourse by examining the cognitive mechanisms through which digital literacy influences academic self-efficacy, thereby informing targeted interventions that could enhance academic performance and reduce cognitive overload in high-stakes learning environments like medical colleges. The conceptual study model is presented in Fig. 1.

2. Methods

2.1. Study design and setting

The present study employed a descriptive and cross-sectional survey design to gather data from medical students enrolled in all five years of their academic program at medical colleges in Islamabad, Pakistan, from October to December 2023. Seven of the twelve colleges in the capital city permitted data collection. The selected colleges encompassed a wide array of medical education settings, thereby enhancing the generalizability of the findings to the broader population of medical students within the region.

2.2. Participation selection and approach

Participants were selected from all five years of the medical programs at the seven participating colleges. The selection process was based on convenience sampling, where all students present during the

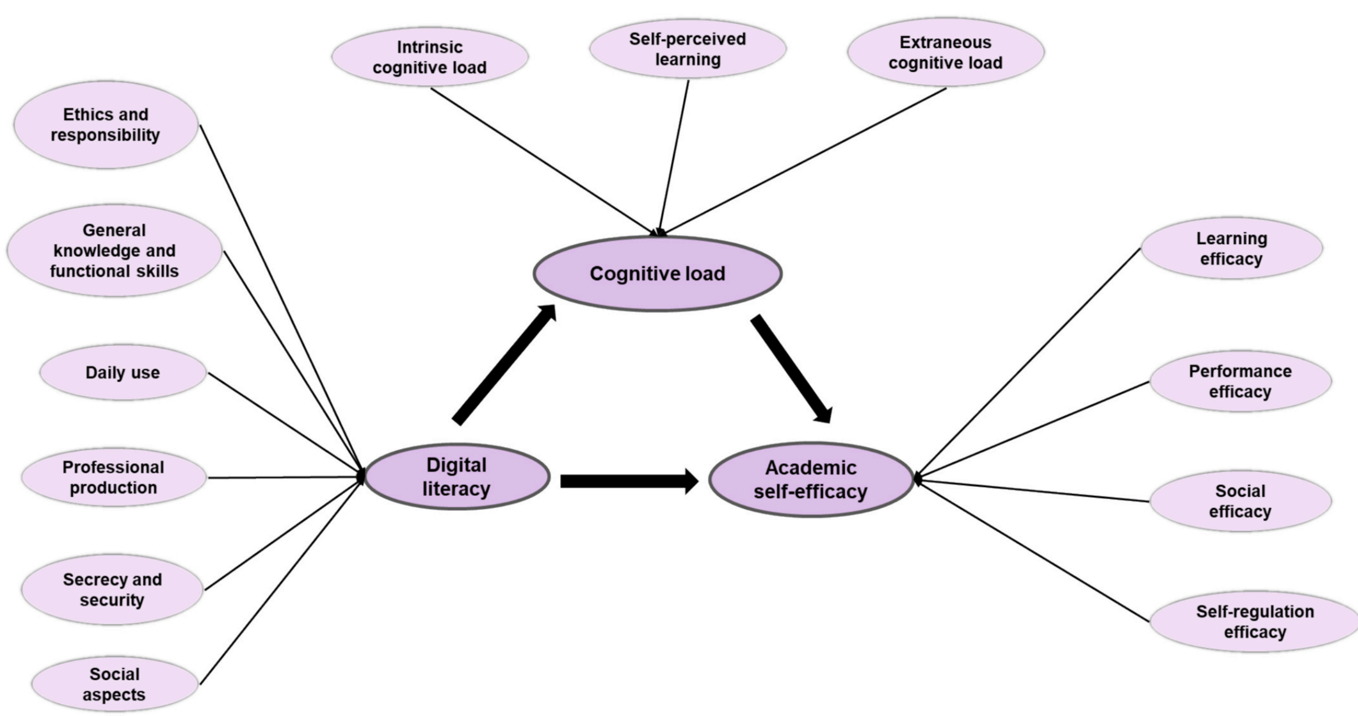

Fig. 1. Conceptual study model showing theoretical dimensions of digital literacy, academic self-efficacy, and cognitive load.

data collection period were invited to participate. This approach ensured that a wide range of students across different years and academic standings were included in the study. Data was collected through a self-administered questionnaire distributed to the students during regular academic sessions. Students were approached during their free periods or after classes to minimize disruption to their academic schedule. The questionnaire included validated scales for digital literacy, academic self-efficacy, and cognitive load. Participation was voluntary, and students were assured of the confidentiality of their responses. The eligibility criteria for the participants are as follows:

2.2.1. Inclusion

Participants enrolled in any of the five years of the MBBS program at the participating colleges were present at the time of data collection, willing to participate in the study, and completed the questionnaire without any missing data.

2.2.2. Exclusion

Participants diagnosed with any mental illness or currently undergoing treatment for a mental health condition, not willing to participate, incomplete or incorrectly filled questionnaire, and transfer students who may have had different academic experiences.

2.3. Sample size determination

The sample size for this study was calculated to ensure a representative and statistically adequate cohort of medical students across multiple institutions. We used G*Power 3.1, a widely accepted tool for power analysis, to determine the necessary sample size. The calculation was based on the following parameters: a desired statistical power of 0.80, an alpha level of 0.05, and an effect size (f^2) of 0.15, which reflects a medium effect size commonly used in social and behavioral sciences. These parameters were chosen based on previous studies examining similar relationships among variables in social and behavioral sciences (Cohen, 2016; Delaney, 2003; Fritz et al., 2012). Considering the population of medical students across all five academic years from seven institutions in Islamabad, the sample size was adjusted to account for potential non-responses or incomplete data. A larger initial sample size was targeted to ensure that the final sample was robust enough to detect smaller effect sizes. After removing incomplete and invalid responses, we obtained 633 valid responses, which exceeded the minimum requirement determined by the power analysis. This sample size ensures adequate statistical power, enabling the detection of significant effects, if present, and ensuring the findings are reliable and generalizable to the broader population of medical students. The larger sample size enhances the study's ability to explore intricate relationships among the study variables.

2.4. Measurement scales

2.4.1. Sociodemographic variables

The demographic questions include variables such as age, gender, residence, marital status, socioeconomic status, and medical years of the study participants.

2.4.2. Academic self-efficacy

Academic self-efficacy was assessed utilizing the Academic Self-efficacy Scale (ASE) developed by Joo et al. (2000) (Joo et al., 2000), which comprises nine items that cover different aspects of academic performance (learning efficacy, performance efficacy, social efficacy, self-regulation efficacy) derived from the self-efficacy subscale of the Motivation Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1991). This scale is specifically designed to address the context of higher education and is employed to evaluate self-efficacy within university or college environments. Participants responded to a series of questions utilizing a 5-point Likert scale, whereby a score of 1 indicated strong disagreement and a score of 5 indicated strong agreement. These responses were based on the participants' expectations and beliefs concerning learning and research. Sample questions include "I am confident in my ability to prepare for and do well on exams" and "I feel capable of completing all my assignments on time." This scale has been validated by prior research that showed excellent internal consistency and validity (Joo et al., 2000; Pintrich & De Groot, 1990; Yao et al., 2023; Zhu et al., 2011).

2.4.3. Digital literacy

The Digital Literacy Scale developed by Bayrakcı and Narmanlıoğlu (2021) was utilized to assess the digital literacy levels of the participating students. The scale consists of 29 items categorized into six dimensions: Ethics and responsibility, General Knowledge and Functional Skills, Everyday Applications, Professional Productivity, Confidentiality and Security, and Social Considerations. The internal consistency of this scale has been reported to be high, exhibiting values ranging from good to excellent across various contexts (Park, 2023; Yeşilyurt & Vezne, 2023; Yoleri & Anadolu, 2022). Sample items include "I am aware that my personal or legal rights (privacy, copyright, freedom of speech, etc.) continue in digital media as well as in daily life." And "I can install software or programs on my computer or other electronic devices." Participants responded to a series of questions utilizing a 4-point Likert scale, whereby a score of 1 indicated not relevant and a score of 4 indicated highly relevant. A higher value signifies an elevated level of digital literacy.

2.5. Cognitive load

In our study, we employed the Cognitive Load Scale (CLS), as validated by Hadie and Yusoff (2016), to assess cognitive load in the context of a problem-based learning environment. The CLS has been developed to evaluate the cognitive load encountered by students during educational activities, thereby rendering it particularly pertinent for assessing cognitive load within the framework of digital learning environments. The scale comprises ten items categorized into three dimensions: intrinsic cognitive load, which pertains to the complexity of the material; extraneous cognitive load, which relates to the clarity and presentation of instructions; and self-perceived learning. Each item is evaluated using a 10-point semantic differential scale, which ranges from "1: not at all the case" to "10: completely the case." Minor adjustments were implemented to ensure the cognitive load scale was appropriately aligned with the digital learning context pertinent to our study. For instance, the item 'The instructions and explanations during the problem-based learning were very unclear' was adjusted to 'The instructions and explanations provided through digital tools during the session were very unclear' to precisely capture the clarity of digital content. The modified CLS was administered immediately after a digital learning session, with participants reflecting on their recent experiences. They were asked to rate each item based on their perceived cognitive load during the session. The scale has demonstrated strong construct validity and internal consistency in a problem-based learning setting (Hadie & Yusoff, 2016). In this study, we employed the total score from the CLS for overall mediation analysis, followed by an individual examination of each subscale (intrinsic, extraneous, and self-perceived learning) to assess their separate mediation effects. The overall reliability of the CLS in this study was 0.88, with the reliability for the individual dimensions as follows: intrinsic cognitive load (0.89), extraneous cognitive load (0.90), and self-perceived learning (0.87).

2.6. Statistical analysis

Descriptive analyses were performed on the variables under consideration. Continuous variables were presented as means accompanied by standard deviations, whereas categorical variables were expressed in terms of frequency counts and percentages. Harman's one-way factor analysis approach was adopted to identify the common method bias (CMB) issue, and multicollinearity diagnostics were assessed using the tolerance and variance inflation factor (VIF). The data analysis for reliability and validity assessments and descriptive statistics, correlation analyses, regression analyses, and mediation analyses was conducted using SPSS statistical software version 26.0 and the SPSS macros PROCESS (Model 4) and AMOS version 23, developed by Hayes (2012). The mediation model was tested first using the overall measure of cognitive load and then using the three dimensions of cognitive load separately: intrinsic cognitive load, extraneous cognitive load, and self-perceived learning. The mediators were entered into the model independently to evaluate their individual mediation effects.

3. Results

The CMB assessment utilized the Harman one-way analysis approach. The findings from the exploratory factor analysis revealed that the variance accounted for by the first common factor was 23.59 %, a value that does not meet the established critical threshold of 40 % (Zhou & Long, 2004), suggesting no significant issue of CMB in the data. Furthermore, a diagnostic analysis of multicollinearity was conducted for both predictor variables to assess the model's validity (Kock, 2015). The results indicated the absence of significant multicollinearity issues among the predictor variables (Tolerance = 0.83 for digital literacy, 0.89 for cognitive load, VIF = 1.20 for digital literacy, and 1.12 for cognitive load).

The univariate analysis of the demographic variables of 633 participants indicated a mean age of 21.0 years (SD = 0.89) (Table 1). The sample comprised 47.24 % male and 52.76 % female medical students, indicating no statistically significant gender distribution ($p < 0.101$). The residence patterns of individuals living on-campus (51.34 %) and off-campus (48.66 %) were found to be broadly comparable, with no statistically significant difference observed ($p = 0.116$). Most participants, 94.47 %, identified as single, whereas only 5.53 % reported marriage or divorce. The socioeconomic status demonstrated significant variability ($p < 0.001$), with individuals classified into low (25.75 %), middle (40.44 %), and high (33.81 %) categories. The participants were distributed across all years of medical study, and statistical analysis revealed no significant differences in this distribution ($p = 0.562$). Notably, the highest % of participants was found in the fourth year, comprising 35.55 % of the total sample. The results highlighted significant disparities in age, gender, and socioeconomic status among the participants. In contrast, variables such as place of residence, marital status, and year of medical education exhibited a more homogeneous distribution (Table 1).

Table 1
Univariate analysis of the demographic characteristics of the study participants with academic self-efficacy ($n = 633$).

	F (%)/ mean ± SD	t/χ^2	Significance
Age (years) (Mean ± SD)	21.0 ± 0.89	8.14	<0.001
Gender		10.63	0.101
Male	299 (47.24 %)		
Female	334 (52.76 %)		
Place of residence		72.11	0.116
On-campus	325 (51.34 %)		
Off-campus	308 (48.66 %)		
Marital status		105.71	0.436
Single	598 (94.47 %)		
Married/divorced	35 (5.53 %)		
Socioeconomic status		39.22	<0.001
Low	163 (25.75 %)		
Middle	256 (40.44 %)		
High	214 (33.81 %)		
Medical year		7.58	0.562
Year 1	107 (16.90 %)		
Year 2	142 (22.43 %)		
Year 3	88 (13.90 %)		
Year 4	225 (35.55 %)		
Year 5	71 (11.22 %)		

Table 2 summarizes the study constructs' descriptive metrics, reliability and validity indices, and model fit statistics. The descriptive statistics revealed that digital literacy has a mean of 2.26 (SD = 0.51), academic self-efficacy has a mean of 2.05 (SD = 0.51), and cognitive load has a higher mean of 6.54 (SD = 1.19), indicating varying levels of these constructs among the participants. The internal consistency of the scales, as assessed through Cronbach's alpha (α), demonstrated high reliability for all constructs, demonstrating a high level of reliability across the various constructs.

In terms of validity, the Composite Reliability (CR) values demonstrated robust internal consistency (DL: 0.912, ASE: 0.892, and CL (overall): 0.952, ICL:0.961, ECL: 0.951, SPL:0.944). All values exceed the recommended threshold of 0.7, indicating that the constructs are reliable. The Average Variance Extracted (AVE) values, which represent the proportion of variance attributable to the construct with the variance attributed to measurement error, demonstrate satisfactory results. Specifically, the AVE for DL was 0.613, for ASE was 0.583, and for CL was 0.672 (ICL: 0.680, ECL: 0.670, SPL: 0.666). All values exceeded the recommended threshold of 0.5, indicating a robust convergent validity level.

Moreover, the model fit statistics served as indicators of the adequacy of the measurement model. The ratio of the Chi-square statistic to the degrees of freedom (χ^2/df) varied from 1.18 to 2.16 across the constructs examined. These values fell within acceptable thresholds, indicating an adequate model fit. The Root Mean Square Error of Approximation (RMSEA) values ranged from 0.036 to 0.047, while the Standardized Root Mean Square Residual (SRMR) values ranged from 0.041 to 0.052. Both indices suggested a favorable model fit. The Comparative Fit Index (CFI) values recorded in this study exceeded the threshold of 0.95, showing a range from 0.961 to 0.995, and the Tucker-Lewis Index (TLI) values were similarly high, ranging from 0.974 to 0.989. These findings provided compelling evidence that the model demonstrates an excellent fit (Table 2).

Table 3 demonstrates the bivariate correlations among the study constructs under investigation. DL was positively correlated with ASE ($r = 0.59$, $p < 0.001$), ICL ($r = 0.47$, p < 0.001), and SPL ($r = 0.49$, p < 0.001). However, it showed a negative correlation with ECL ($r = -0.60$, p < 0.001) and overall CL ($r = -0.46$, p < 0.001). ASE was strongly positively correlated with ICL ($r = 0.62$, p < 0.001) and CL ($r = 0.51$, p < 0.001), but negatively correlated with ECL ($r = -0.58$, p < 0.001) and SPL ($r = -0.43$, $p < 0.01$). ICL was positively correlated with ASE (r = 0.62, p < 0.001) and CL ($r = 0.74$, $p < 0.05$) and showed a negative correlation with ECL ($r = -0.22$, p < 0.05), with a non-significant positive relationship with SPL ($r = 0.17$). ECL showed negative correlations with DL, ASE, and ICL, with a weaker, non-significant negative relationship with SPL ($r = -0.13$). SPL had positive correlations with DL (r = 0.49, $p < 0.001$) and CL ($r = 0.70$, $p < 0.01$) but was negatively associated with ASE (r = −0.43, p < 0.01). CL showed significant positive correlations with ICL (r = 0.74, p < 0.05) and SPL (r = 0.70, p < 0.01) while being negatively correlated with ECL ($r = -0.61$, p < 0.01).

The path mediation analysis in our study revealed several significant findings regarding the relationships between digital literacy, academic self-efficacy, and cognitive load, as shown in Table 4. The direct path from digital literacy to academic self-efficacy is strongly supported, showing a significant positive effect (β = 0.42, $p < 0.001$), indicating that higher digital literacy directly leads to greater academic self-efficacy, with the effect size suggesting a meaningful impact on student's confidence in their academic abilities. When cognitive load is considered a unified construct, it significantly mediates the relationship between digital literacy and academic self-efficacy (β = 0.165, $p < 0.001$). This mediation suggests that cognitive load plays a crucial role in how digital literacy influences academic self-efficacy, with better digital skills likely reducing the overall cognitive burden and thereby boosting self-efficacy.

Table 2
Summary of descriptive metrics, reliability and validity indices, and model fit statistics.

	Mean ± SD	α	CR	AVE	χ^2/df	RMSEA	SRMR	CFI	TLI
DL	2.26 ± 0.51	0.90	0.912	0.613	2.16	0.047	0.052	0.961	0.974
ASE	2.05 ± 0.42	0.89	0.892	0.583	1.45	0.043	0.049	0.975	0.981
CL	6.54 ± 1.19	0.88	0.952	0.672	1.18	0.036	0.041	0.995	0.989

Note: DL: Digital literacy, ASE: Academic self-efficacy, CL: Cognitive load, RMSEA: Root mean square error of approximation, SRMR: Standardized root mean square residual, CFI: Comparative fit index, TLI: Tucker-Lewis index, α: Cronbach's alpha for reliability statistics, CR: Composite reliability, AVE: average variance extracted.

Table 3
Bivariate correlation analysis of the study constructs.

	DL	ASE	ICL	ECL	SPL	CL
DL	1					
ASE	0.59***	1				
ICL	0.47***	0.62***	1			
ECL	−0.60***	−0.58***	−0.22*	1		
SPL	0.49***	−0.43**	0.17	−0.13	1	
CL	−0.46***	0.51***	0.74*	−0.61**	0.70**	1

Note: DL: Digital literacy, ASE: Academic self-efficacy, CL: Cognitive load, ICL: Intrinsic cognitive load, ECL: Extraneous cognitive load, SPL: Self-perceived learning.

*** $p < 0.001$.

** $p < 0.01$.

* $p < 0.05$.

Breaking down cognitive load into its distinct dimensions, both intrinsic and extraneous cognitive loads are found to be significant mediators. For mediation analysis, we used bootstrapped confidence intervals to determine the significance of the indirect effects. The mediation effect is accepted as significant if the bootstrapped confidence interval does not contain zero. Higher digital literacy reduces intrinsic cognitive load (β = 0.147, $p < 0.001$), enhancing academic self-efficacy. Similarly, reducing extraneous cognitive load (β = 0.144, $p < 0.001$) also leads to greater self-efficacy as students can focus more effectively on learning tasks. However, the mediation effect through self-perceived learning (β = 0.105, $p = 0.361$), which relates to the student's perceptions of their learning and understanding of the material, is not supported, indicating that self-perceived learning does not significantly influence the relationship between digital literacy and academic self-efficacy in this study. The direct effect of digital literacy on academic self-efficacy was significant in the initial model. After introducing the cognitive load dimensions as mediators, the direct effect of digital literacy on academic self-efficacy decreased, indicating a partial mediation effect. This demonstrates that cognitive load explains part of the relationship between digital literacy and academic self-efficacy but does not fully account for it, leaving room for other contributing factors. The schematic illustration of the individual paths and the mediation model is presented in Figs. 2a and 2b.

Holistically, the R^2 values provide insights into the variance explained by these relationships. The direct effect of digital literacy on academic self-efficacy explains 35 % of the variance, indicating a substantial impact. When cognitive load as a unified construct is included as a mediator, the explained variance slightly decreases to 28 %, suggesting that cognitive load partially mediates the relationship. This reduction in explained variance suggests that while cognitive load contributes to explaining ASE, other unaccounted factors may also influence the relationship between digital literacy and academic self-efficacy. The explained variance decreases further when examining the distinct dimensions of cognitive load, with intrinsic and extraneous cognitive loads accounting for 22 % and 18 % of the variance, respectively. Self-perceived learning shows minimal influence, with an R^2 value of 7 %. These R^2 values collectively highlight the importance of considering the overall and specific cognitive processes that influence the relationship between digital literacy and academic self-efficacy.

4. Discussion

The current study aimed to investigate the impact of digital literacy on academic self-efficacy among medical students in Islamabad, with a

Table 4
Path mediation analysis.

	R^2 (F-statistics)	β (SE)	t	Bootstrap 95 % CI	Decision
Path a (IV → Mediator)					
DL → CL		0.35 (0.062)	5.65***		
DL → ICL		0.32 (0.068)	4.71***		
DL → ECL		−0.36 (0.055)	6.55***		
DL → SPL		0.30 (0.085)	3.53***		
Path b (Mediator → DV)					
CL → ASE		0.47 (0.051)	9.22***		
ICL → ASE		0.46 (0.063)	7.03***		
ECL → ASE		−0.40 (0.071)	5.63***		
SPL → ASE		0.35 (0.072)	4.86***		
Path c' (IV → DV)					
DL → ASE	0.35 (179.05***)	0.42 (0.043)	9.67***	0.322–0.513	Supported
Mediating paths					
DL → CL → ASE	0.28 (132.19***)	0.165 (0.034)	4.82***	0.112–0.189	Supported
DL → ICL → ASE	0.22 (91.56***)	0.147 (0.063)	2.35***	0.096–0.165	Supported
DL → ECL → ASE	0.18 (67.28***)	−0.144 (0.068)	2.12***	0.101–0.159	Supported
DL → SPL → ASE	0.07 (39.92***)	0.105 (0.102)	1.03	0.000–0.117	Not supported

Note: IV: Independent variable, DV: Dependent variable, DL: Digital literacy, ASE: Academic self-efficacy, CL: Cognitive load. ICL: Intrinsic cognitive load, ECL: Extraneous cognitive load, SPL: Self-perceived learning.

*** $p < 0.001$.

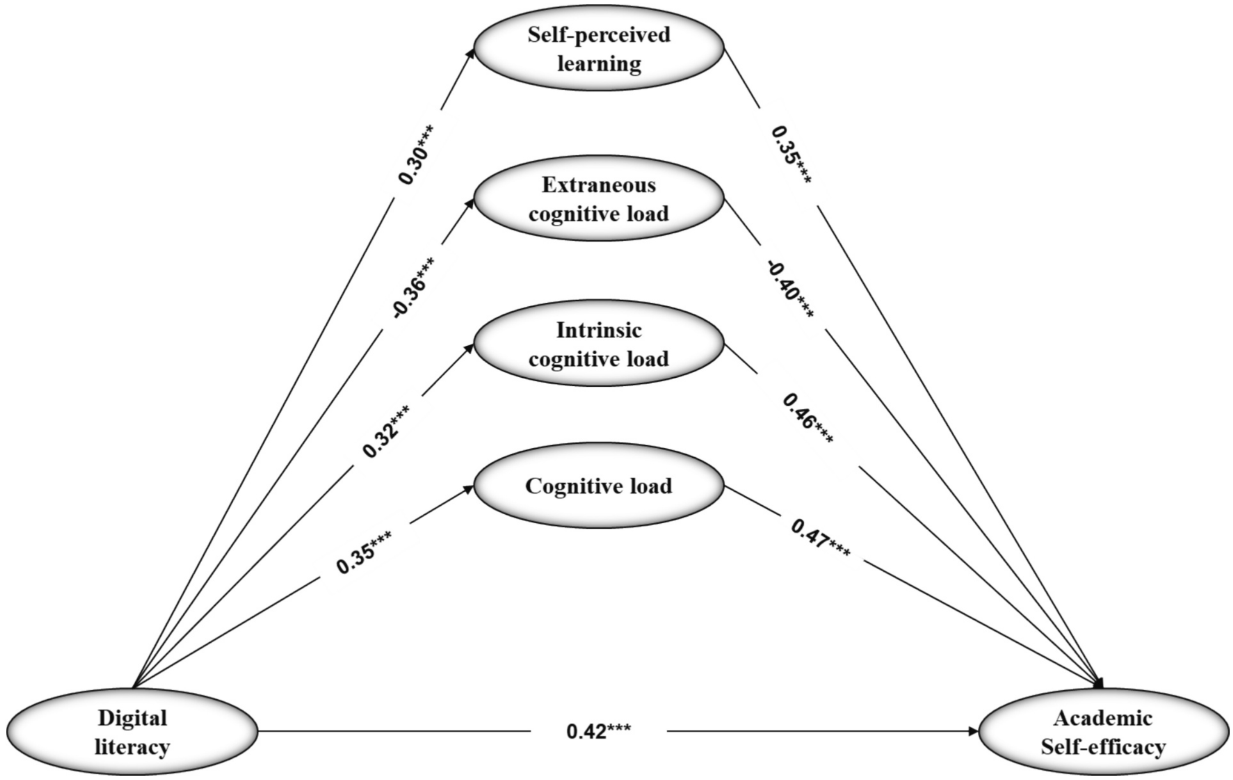

Fig. 2a. The individual direct paths (with standardized β coefficients).

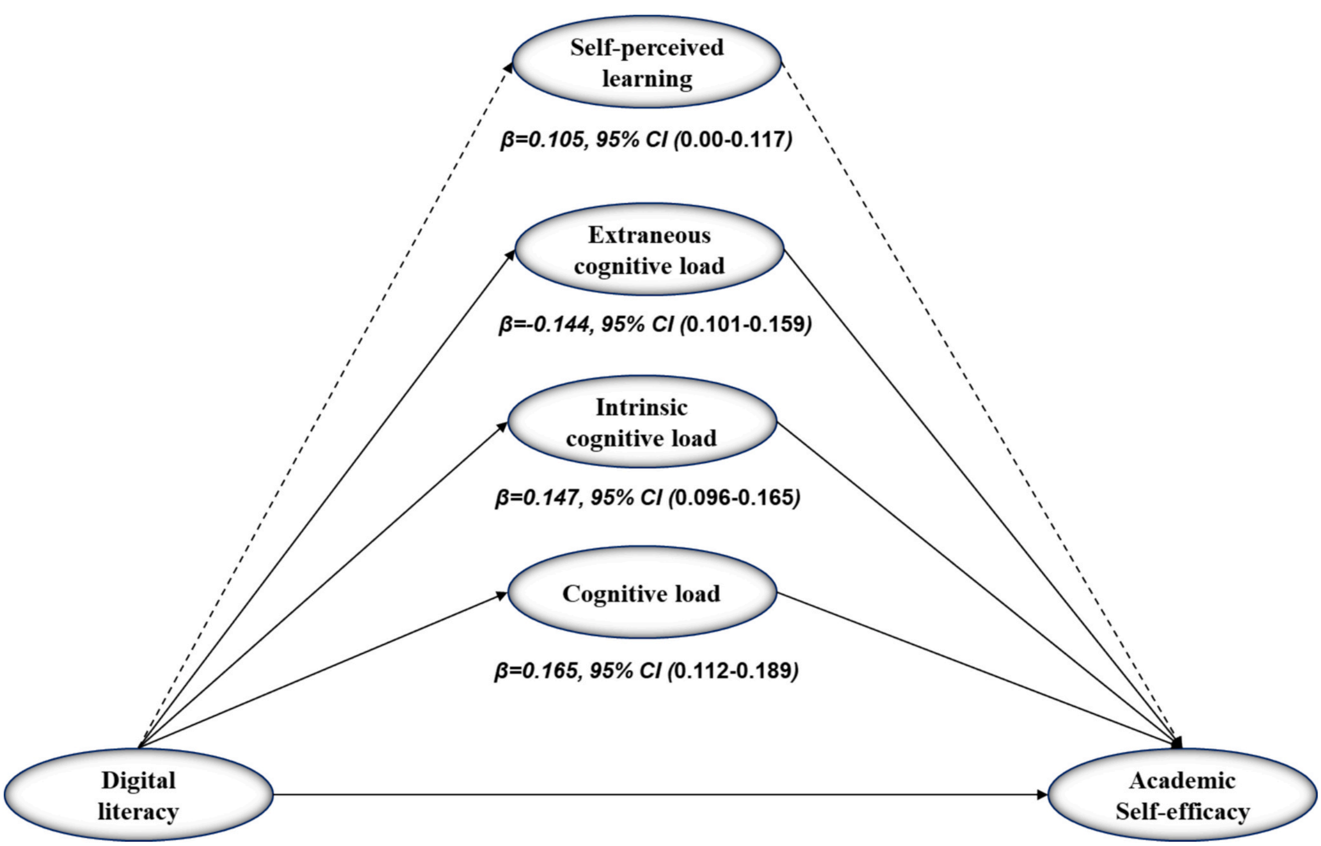

Fig. 2b. The indirect (mediating) paths.

specific focus on the mediating role of cognitive load within this relationship. In contrast to previous empirical studies that have typically addressed these constraints in isolation, the present research provides a unique investigation of cognitive load as an integrated construct. This study concurrently considers intrinsic load, extraneous load, and self-perceived learning. This research seeks to offer new perspectives on the impact of digital competencies on academic performance within medical education, specifically within a delineated geographic area characterized by an evolving state of digital literacy. The findings of the study indicate that digital literacy significantly influences academic self-efficacy. Moreover, cognitive load serves as a crucial mediator in this relationship, predominantly affecting it through intrinsic and extraneous cognitive load dimensions. The results of this study suggest that improvements in digital literacy can alleviate cognitive load, thereby facilitating students' capacity to manage their academic obligations with increased effectiveness and confidence. The implications of this study are substantial for educators and policymakers, highlighting the importance of integrating digital literacy training into medical curricula. Integrating such approaches is imperative for improving academic performance and enhancing student confidence within demanding educational contexts.

The findings indicated a direct relationship, thereby corroborating the study's first hypothesis, which posits that digital literacy positively influences academic self-efficacy among medical students. This aligns with preceding research conducted across diverse educational contexts (Joo et al., 2000; Prior et al., 2016; Rohatgi et al., 2016). Research conducted in developed nations has consistently indicated that students possessing heightened levels of digital literacy exhibit increased confidence in their capacity to undertake academic tasks, contributing to enhanced academic self-efficacy (Hatlevik et al., 2018; Van Deursen & Van Dijk, 2014). This evidence is further substantiated by research in Asia, which indicates that digital tools play a crucial role in the educational process (Jeon & Kim, 2022; Yong, 2022). While research on digital literacy remains nascent within the Pakistani context, analogous patterns have been identified. Research conducted at universities in Pakistan has demonstrated a correlation between digital literacy and academic confidence among students (Hassan et al., 2022; Naveed & Mahmood, 2022; Naz et al., 2022). Specifically, findings indicate that students exhibiting higher levels of digital literacy are more proficient in utilizing online resources for educational purposes, subsequently enhancing their academic self-efficacy. This relationship can be elucidated through the theoretical framework of SCT (Bandura, 1977), which asserts that mastery experiences—such as successfully engaging with digital platforms and tools—enhance individuals' perceptions of their capabilities. The positive correlation identified between digital literacy and academic self-efficacy in this study can be further elucidated by the observation that medical students in Islamabad, akin to students in other regions, are progressively compelled to utilize digital resources as part of their educational framework. As individuals enhance their proficiency in utilizing these tools, their self-efficacy regarding academic capabilities correspondingly increases. This enhancement in self-efficacy subsequently diminishes anxiety levels and positively influences overall performance. This finding highlights the critical need to promote digital literacy within educational environments, particularly in areas where digital competencies are still maturing. The enhancement of digital literacy is shown to have a direct and substantial influence on students' academic self-efficacy.

In addition, the second hypothesis, which postulated that cognitive load mediates the relationship between digital literacy and academic self-efficacy, received empirical support from the findings of this study. This finding aligns with the established literature indicating that cognitive load is pivotal in influencing students' ability to effectively employ digital skills to improve their academic performance (Kirschner & van Merriënboer, 2013; Leppink et al., 2013). International research has revealed that students possessing higher levels of digital literacy generally encounter reduced cognitive load, specifically extraneous cognitive load. This reduction in cognitive load is associated with enhanced academic self-efficacy among these students. For example, investigations in technologically advanced educational environments have demonstrated that students proficient in digital tools can navigate academic tasks more efficiently (Chen et al., 2014; Kalyuga, 2008; Leppink et al., 2014). This proficiency minimizes extraneous cognitive load, enabling students to concentrate more effectively on comprehending and mastering the subject matter. Despite the relatively limited scope of research on cognitive load in Pakistan, emerging studies have begun investigating its mediating role in the relationship between digital literacy and academic outcomes. Consistent with findings observed in various other countries, Pakistani students exhibiting higher levels of digital literacy tend to experience diminished cognitive strain while interacting with academic material (Mughari et al., 2023; Nawaz & Kundi, 2010; Shoaib & Hussain, 2023). This reduction in cognitive load appears to enhance their self-confidence regarding their academic competencies. This relationship can be elucidated through the CLT framework (Bandura, 1977), which posits that reducing extraneous cognitive load allocates cognitive resources to self-perceived learning, thereby facilitating improved learning outcomes and performance.

The present research emphasizes the mediating role of cognitive load, underscoring the significance of enhancing students' digital literacy and creating educational environments that effectively reduce extraneous cognitive load. In the context of medical education in Islamabad, students frequently encounter complex and information-dense content. In this environment, digital literacy is crucial in facilitating their study processes. By enhancing students' ability to navigate digital platforms and comprehend academic materials, digital literacy effectively mitigates the cognitive burden associated with these tasks. This reduction in cognitive load subsequently enhances academic self-efficacy among students, as individuals perceive themselves to be more competent and experience a diminished sense of being overwhelmed by the rigorous demands of their academic pursuits. The findings underscore that enhancing digital literacy encompasses acquiring technical skills and optimizing cognitive processes, collectively contributing to improved academic outcomes.

To facilitate a more comprehensive understanding, the present research examined the various dimensions of cognitive load, indicating that intrinsic and extraneous cognitive loads significantly mediate the relationship between digital literacy and academic self-efficacy. These findings supported our hypotheses concerning the dimensions of intrinsic cognitive load and extraneous cognitive load. Nevertheless, the hypothesis regarding the mediating role of self-perceived learning did not receive robust support. One key difference between intrinsic and extraneous cognitive load and self-perceived learning is that intrinsic and extraneous cognitive load are more directly related to the cognitive demands placed on students during academic tasks, making them more responsive to interventions targeting digital literacy. On the other hand, self-perceived learning might be more subjective and less affected by external interventions such as digital literacy. This could explain why intrinsic and extraneous cognitive load were robust mediators while self-perceived learning was not. Future research might explore whether other factors, such as motivation or emotional regulation, contribute to variability in self-perceived learning. These results are consistent with previous research that underscores the significant influence of intrinsic and extraneous cognitive loads within educational settings. Intrinsic cognitive load is significantly influenced by an individual's level of digital literacy (Novak et al., 2018; Sweller et al., 2011). Students exhibiting higher proficiency in digital skills are better equipped to navigate complex academic tasks, thereby mitigating the cognitive burden associated with such endeavors. Comparably, extraneous cognitive load tends to be diminished when students possess digital literacy skills (De Jong, 2010; Skulmowski & Xu, 2022; Sweller et al., 2011). This proficiency enables them to navigate and process academic materials more efficiently, allocating additional cognitive resources to the learning process. On the other hand, the role of self-perceived learning, while present, may not have shown significant mediation in this study because medical students, despite being digitally literate, might still experience variability in how they perceive their learning gains, particularly in a high-pressure environment like medical education (Cook & Artino Jr, 2016; Zimmerman, 2000). It is also possible that self-perceived learning is influenced by subjective factors, such as individual motivation or emotional states, which are less likely to be directly affected by digital literacy (Artino, 2012). This contrasts with the more tangible cognitive processes involved in intrinsic and extraneous cognitive loads, which are more directly linked to task performance and instructional design. Therefore, self-perceived learning may require further exploration, particularly in terms of how it interacts with other psychological factors or contextual variables in learning environments.

4.1. Theoretical implications

This study offers several theoretical contributions by deepening the understanding of how digital literacy, cognitive load, and academic self-efficacy interact within medical education. By examining cognitive load as a unified construct and through its distinct dimensions—intrinsic load, extraneous load, and self-perceived learning—this research extends CLT by providing empirical evidence on how digital literacy influences these specific cognitive processes. The finding that intrinsic and extraneous cognitive loads significantly mediate the relationship between digital literacy and academic self-efficacy underscores the critical necessity of optimizing cognitive resources to improve learning outcomes. The findings of this study indicated that self-perceived learning plays a significant role, as students' subjective perceptions of their learning experiences may be influenced by various factors such as instructional design and task complexity. This variability in perceptions suggests a need for further investigation into the underlying mechanisms that contribute to these differences. Furthermore, this study synthesizes SCT with CLT, illustrating that digital literacy directly facilitates academic self-efficacy while concurrently mitigating cognitive burdens indirectly. This integrated approach fosters a more nuanced understanding of the cognitive and psychological mechanisms that underlie academic success, especially within high-stakes educational settings such as medical colleges.

4.2. Practical implications

This study provides valuable insights for educators, curriculum developers, and policymakers in medical education. The positive correlation between digital literacy and academic self-efficacy highlights the importance of integrating comprehensive digital literacy training into the medical curriculum. This would equip students with the necessary skills to manage academic tasks efficiently, boosting their confidence and academic performance. Institutions should offer personalized learning programs and digital literacy workshops tailored to varying proficiency levels to enhance student success, especially among weaker students. Peer-assisted learning and mentoring could support those struggling with cognitive load, helping them better manage complex academic tasks and reduce unnecessary cognitive burdens.

Additionally, the findings related to cognitive load suggest that minimizing extraneous cognitive load through well-structured digital learning environments can significantly improve academic self-efficacy. Educators should focus on streamlining digital interfaces, providing clear instructional resources, and fostering environments that promote active engagement and deep comprehension of material, particularly for complex subjects in medical education. For future cohorts of medical students, adopting a proactive approach by embedding digital literacy training early in their academic journey is critical. Furthermore, utilizing adaptive learning technologies can help monitor students' progress, offering tailored interventions, such as study skills workshops, to help students manage cognitive demands more effectively. By addressing these considerations, educational institutions can create supportive learning environments that cater to current and future students, enhancing their cognitive and psychological well-being and better preparing them for the challenges of medical practice.

4.3. Limitations

This study acknowledges several limitations that warrant consideration. The cross-sectional design employed in this research limits the capacity to draw causal inferences regarding the relationships among digital literacy, cognitive load, and academic self-efficacy. Consequently, it underscores the necessity for future research utilizing longitudinal methodologies to elucidate these dynamics better. Secondly, the dependence on self-reported data may introduce various biases, including social desirability bias and recall bias, which could potentially undermine the accuracy of the findings. Thirdly, future research could benefit from including control variables such as age, gender, and socioeconomic status to further examine how these demographic factors influence the relationships between digital literacy, cognitive load, and academic self-efficacy. Furthermore, the emphasis of this study on medical students in Islamabad may restrict the generalizability of its findings to other populations or educational contexts. This limitation arises from the potential impact of cultural and technological factors on the relationships observed within the study. Besides, the variability in self-perceived learning may be context-dependent, shaped by the specific instructional design employed within the medical curriculum. In conclusion, the study did not consider potential confounding variables, including prior digital literacy training and external stressors, which may have influenced the outcomes. This limitation underscores the necessity for further research to investigate the impact of these factors on the results.

5. Conclusion

This study illustrates the crucial significance of digital literacy in enhancing the academic self-efficacy of medical students through the modulation of cognitive load. The study's findings indicated a direct correlation between digital literacy and increased confidence in managing academic tasks. Furthermore, these results suggest that digital literacy also confers indirect benefits by reducing intrinsic and extraneous cognitive loads. Nevertheless, the mediating role of self-perceived learning appears limited, indicating that the complexities inherent in this relationship may be context-dependent. These insights emphasize the necessity of incorporating digital literacy training into medical education to enhance cognitive resources and improve academic performance. Although the study provides significant contributions to the field, its limitations, including the cross-sectional design and context-specific emphasis, underscore the need for further investigation in varied educational contexts and the incorporation of additional influencing variables. This research emphasizes the essential support medical students require to cultivate technical competencies and effectively navigate the cognitive challenges inherent in their demanding academic milieu.

Institutional review board statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Review Committee of the Benazir Bhutto Hospital, Rawalpindi (Approval No. MOH/2023-KT4381).

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

Consent to publish declaration

Not applicable.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used ChatGPT in order to improve the language clarity and coherence of the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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CRediT authorship contribution statement

SR: Conceptualization, Formal analysis, Methodology, Visualization, Validation, Supervision, Writing – original draft, Writing – review & editing. ***AA:*** Conceptualization, Formal analysis, Methodology, Visualization, Funding acquisition, Writing – original draft, Writing – review & editing, Funding. ***ER:*** Conceptualization, Formal analysis, Methodology, Visualization, Validation, Supervision, Writing – original draft, Writing – review & editing. ***MNK:*** Conceptualization, Formal analysis, Methodology, Visualization, Validation, Supervision, Writing – original draft, Writing – review & editing. ***MAS:*** Conceptualization, Formal analysis, Methodology, Visualization, Validation, Supervision, Writing – original draft, Writing – review & editing. ***MAR:*** Conceptualization, Data Curation, Formal analysis, Methodology, Visualization, Validation, Supervision, Writing – original draft, Writing – review & editing. ***MW:*** Formal analysis, Methodology, Visualization, Validation, Supervision, Writing – original draft, Writing – review & editing. All authors read and approved the final version of the manuscript for publication.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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None.

Data availability

Data will be made available on request.

References

Aesaert, K., & van Braak, J. (2014). Exploring factors related to primary school pupils' ICT self-efficacy: A multilevel approach. *Comput. Human Behav., 41*, 327–341.

Ahmed, U., Umrani, W. A., Qureshi, M. A., & Samad, A. (2018). Examining the links between teachers support, academic efficacy, academic resilience, and student engagement in Bahrain. *Int. J. Adv. Appl. Sci., 5*(9), 39–46.

Alexander, P. A., Dinsmore, D. L., Parkinson, M. M., & Winters, F. I. (2011). Self-regulated learning in academic domains: University of Maryland. In *Handbook of self-regulation of learning and performance* (pp. 407–421). Routledge.

A. Y. Alzig, "Academic perceived self-efficacy among undergraduate students at the University of Jordan and its relation to gender, college and academic level," *J. Educ. Psychol. Sci.*, vol. 10, no. 02, 2009.

Amaral, N., Novella, R., & Rucci, G. (2019). Las tendencias:¿ Qué dicen los datos. *El Futur. ya está aquí*, 60–81.

Artino, A. R. (2012). Academic self-efficacy: From educational theory to instructional practice. *Perspect. Med. Educ., 1*, 76–85.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191.

Bandura, A. (1986). Social foundations of thought and action. *Englewood Cliffs, NJ, 1986* (23–28), 2.

Bayrakcı, S., & Narmanlıoğlu, H. (2021). Digital literacy as whole of digital competences: Scale development study. *Düşünce ve Toplum Sos. Bilim. Derg., 4*, 1–30.

Carpenter, S. K., Endres, T., & Hui, L. (2020). Students' use of retrieval in self-regulated learning: Implications for monitoring and regulating effortful learning experiences. *Educational Psychology Review, 32*(4), 1029–1054.

Chen, M.-P., Wong, Y.-T., & Wang, L.-C. (2014). Effects of type of exploratory strategy and prior knowledge on middle school students' learning of chemical formulas from a 3D role-playing game. *Educational Technology Research and Development, 62*, 163–185.

Choi, H.-H., Van Merriënboer, J. J. G., & Paas, F. (2014). Effects of the physical environment on cognitive load and learning: Towards a new model of cognitive load. *Educational Psychology Review, 26*, 225–244.

J. Cohen, "A power primer.," 2016.

Cook, D. A., & Artino, A. R., Jr. (2016). Motivation to learn: An overview of contemporary theories. *Medical Education, 50*(10), 997–1014.

A. B. H. de Bruin, J. Roelle, S. K. Carpenter, M. Baars, and Efg-Mre, "Synthesizing cognitive load and self-regulation theory: A theoretical framework and research agenda," Educational Psychology Review, vol. 32, no. 4, pp. 903–915, 2020.

De Jong, T. (2010). Cognitive load theory, educational research, and instructional design: Some food for thought. *Instructional Science, 38*(2), 105–134.

M. del C. Pegalajar Palomino and Á. F. Rodríguez Torres, "Digital literacy in university students of education degrees in Ecuador," in *Frontiers in* Education, 2023, vol. 8, p. 1299059.

Delaney, H. D. (2003). *Designing experiments and analyzing data: A model comparison perspective*. Routledge.

Demirkan, H., Spohrer, J. C., & Welser, J. J. (2016). Digital innovation and strategic transformation. *IT Professional, 18*(6), 14–18.

Eshet, Y. (2012). Thinking in the digital era: A revised model for digital literacy. *Issues informing Sci. Inf. Technol., 9*(2), 267–276.

Fernández-Enguita, M., García, M., Vaillant, D., & Zubillaga, A. (2023). Competencia digital docente para la transformación educativa. *Organ. Estados Iberoam. para la Educ. la Cienc. y la*.

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: Current use, calculations, and interpretation. *Journal of Experimental Psychology. General, 141*(1), 2.

Fuentes, A., López, J., & Pozo, S. (2019). Análisis de la competencia digital docente: Factor clave en el desempeño de pedagogías activas con Realidad Aumentada. *REICE. Rev. Iberoam. sobre Calidad, Efic. y cambio en Educ., 17*(2), 27–40.

Getenet, S., Cantle, R., Redmond, P., & Albion, P. (2024). Students' digital technology attitude, literacy and self-efficacy and their effect on online learning engagement. *International Journal of Educational Technology in Higher Education, 21*(1), 3.

Hadie, S. N. H., & Yusoff, M. S. B. (2016). Assessing the validity of the cognitive load scale in a problem-based learning setting. *J. Taibah Univ. Med. Sci., 11*(3), 194–202.

Hassan, M., Malik, A. S., Sang, G., Rizwan, M., Mushtaque, I., & Naveed, S. (2022). Examine the parenting style effect on the academic achievement orientation of secondary school students: The moderating role of digital literacy. *Frontiers in Psychology, 13*, 1063682.

Hatlevik, O. E., Throndsen, I., Loi, M., & Gudmundsdottir, G. B. (2018). Students' ICT self-efficacy and computer and information literacy: Determinants and relationships. *Computers in Education, 118*, 107–119.

Hayes, A. F. (2012). *PROCESS: A versatile computational tool for observed variable mediation, moderation, and conditional process modeling*.

Ibrahim, R. K., & Aldawsari, A. N. (2023). Relationship between digital capabilities and academic performance: The mediating effect of self-efficacy. *BMC Nursing, 22*(1), 434. https://doi.org/10.1186/s12912-023-01593-2

Jeon, J., & Kim, S. (2022). The mediating effects of digital literacy and self-efficacy on the relationship between learning attitudes and Ehealth literacy in nursing students: A cross-sectional study. *Nurse Education Today, 113*, Article 105378.

Joo, Y.-J., Bong, M., & Choi, H.-J. (2000). Self-efficacy for self-regulated learning, academic self-efficacy, and internet self-efficacy in web-based instruction. *Educational Technology Research and Development, 48*, 5–17.

Kalyuga, S. (2007). Expertise reversal effect and its implications for learner-tailored instruction. *Educational Psychology Review, 19*, 509–539.

Kalyuga, S. (2008). *Managing cognitive load in adaptive multimedia learning*. IGI Global.

Kalyuga, S. (2011). Cognitive load theory: How many types of load does it really need? *Educational Psychology Review, 23*, 1–19.

Kirschner, P. A., & van Merriënboer, J. J. G. (2013). Do learners really know best? Urban legends in education. *Educational Psychologist, 48*(3), 169–183.

Klassen, R. M., & Usher, E. L. (2010). Self-efficacy in educational settings: Recent research and emerging directions. *Decad. ahead Theor. Perspect. Motiv. Achiev., 16*, 1–33.

Kock, N. (2015). Common method bias in PLS-SEM: A full collinearity assessment approach. *Int. J. e-Collaboration, 11*(4), 1–10.

Kuh, G. D., Kinzie, J. L., Buckley, J. A., Bridges, B. K., & Hayek, J. C. (2006). *What matters to student success: A review of the literature* (Vol. 8). DC: National Postsecondary Education Cooperative Washington.

Leppink, J., Paas, F., Van der Vleuten, C. P. M., Van Gog, T., & Van Merriënboer, J. J. G. (2013). Development of an instrument for measuring different types of cognitive load. *Behavior Research Methods, 45*, 1058–1072.

Leppink, J., Paas, F., Van Gog, T., van Der Vleuten, C. P. M., & Van Merrienboer, J. J. G. (2014). Effects of pairs of problems and examples on task performance and different types of cognitive load. *Learning and Instruction, 30*, 32–42.

Mughari, S., Naveed, M. A., & Rafique, G. M. (2023). Effect of information literacy on academic performance of business students in Pakistan. *Libri, 73*(4), 355–368.
Naveed, M. A., & Mahmood, M. (2022). Correlatives of business students' perceived information literacy self-efficacy in the digital information environment. *Journal of Librarianship and Information Science, 54*(2), 294–305.
Nawaz, A., & Kundi, G. M. (2010). Digital literacy: An analysis of the contemporary paradigms. *J. Sci. Technol. Educ. Res., 1*(2), 19–29.
Naz, F. L., Raheem, A., Khan, F. U., & Muhammad, W. (2022). An effect of digital literacy on the academic performance of university-level students. *J. Posit. Sch. Psychol., 6*(8), 10720–10732.
Novak, E., Daday, J., & McDaniel, K. (2018). Assessing intrinsic and extraneous cognitive complexity of e-textbook learning. *Interacting with Computers, 30*(2), 150–161.
Paas, F., Renkl, A., & Sweller, J. (2004). Cognitive load theory: Instructional implications of the interaction between information structures and cognitive architecture. *Instructional Science, 32*(1/2), 1–8.
Paas, F., & Sweller, J. (2012). An evolutionary upgrade of cognitive load theory: Using the human motor system and collaboration to support the learning of complex cognitive tasks. *Educational Psychology Review, 24*, 27–45.
Paas, F., & Sweller, J. (2014). Implications of cognitive load theory for multimedia learning. *Cambridge Handb. Multimed. Learn., 27*, 27–42.
Pampaka, M., Swain, D., Jones, S., Williams, J., Edwards, M., & Wo, L. (2018). Validating constructs of learners' academic self-efficacy for measuring learning gain. *High. Educ. Pedagog., 3*(1), 118–144.
H. Park, "Exploring digital literacy in the context of remote education for Korean elementary school teachers: Challenges, efforts, and demands," *KEDI J. Educ.* Policy, vol. 20, no. 2, 2023.
Pintrich, P. R., & De Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Education & Psychology, 82*(1), 33.
P. R. Pintrich, D. A. F. Smith, T. García, and W. J. McKEACHIE, "The motivated strategies for learning questionnaire (MSLQ)," *Ann Arbor, MI NCRIPTAL,* Univ. Michigan, 1991.
Plass, J. L., Moreno, R., & Brünken, R. (2010). *Cognitive load theory*.
Prior, D. D., Mazanov, J., Meacheam, D., Heaslip, G., & Hanson, J. (2016). Attitude, digital literacy and self efficacy: Flow-on effects for online learning behavior. *The Internet and Higher Education, 29*, 91–97.
Rohatgi, A., Scherer, R., & Hatlevik, O. E. (2016). The role of ICT self-efficacy for students' ICT use and their achievement in a computer and information literacy test. *Computers in Education, 102*, 103–116.
Sánchez, S. P., Campoy, N. D., & Cabrera, A. F. (2020). El nivel de competencia digital en profesionales de la educación: el caso de los educadores físicos españoles. *Zo. Próxima, 33*, 146–165.
D. H. Schunk and F. Pajares, "The development of academic self-efficacy," in *Development of achievement motivation*, Elsevier, 2002, pp. 15–31.
Seufert, T., Hamm, V., Vogt, A., & Riemer, V. (2024). The interplay of cognitive load, Learners' resources and self-regulation. *Educational Psychology Review, 36*(2), 1–30.
Shea, C. M., & Howell, J. M. (2000). Efficacy-performance spirals: An empirical test. *J. Manage., 26*(4), 791–812.
Shoaib, M., & Hussain, K. G. (2023). Citing the empirical shreds of electronic evidence on pedagogical skills employing bibliometric analysis from 2001-2020. *Pakistan J. Soc. Res., 5*(02), 1050–1062.
Shopova, T. (2014). Digital literacy of students and its improvement at the university. *J. Effic. Responsib. Educ. Sci., 7*(2), 26–32.
Skulmowski, A., & Xu, K. M. (2022). Understanding cognitive load in digital and online learning: A new perspective on extraneous cognitive load. *Educational Psychology Review, 34*(1), 171–196.
Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*(2), 257–285.
Sweller, J., Ayres, P., Kalyuga, S., Sweller, J., Ayres, P., & Kalyuga, S. (2011). Intrinsic and extraneous cognitive load. *Cogn. load theory*, 57–69.
Talsma, K., Schüz, B., Schwarzer, R., & Norris, K. (2018). I believe, therefore I achieve (and vice versa): A meta-analytic cross-lagged panel analysis of self-efficacy and academic performance. *Learning and Individual Differences, 61*, 136–150.
UNESCO. (2022). The ICT competency framework for teachers harnessing OER project: Digital skills development for teachers. https://unesdoc.unesco.org/ark:/48223/pf0000383206?posInSet=4&queryId=a61baa4e-3719-4f51-a262-4b1863c77b6f. (Accessed 11 August 2024).
Urakova, F. K., et al. (2023). Investigating digital skills among Russian higher education students. *Contemporary Educational Technology, 15, no. 1*, ep398.
Valentín, A., Mateos, P. M., González-Tablas, M. M., Pérez, L., López, E., & García, I. (2013). Motivation and learning strategies in the use of ICTs among university students. *Computers in Education, 61*, 52–58.
Van de Oudeweetering, K., & Voogt, J. (2018). Teachers' conceptualization and enactment of twenty-first century competences: Exploring dimensions for new curricula. *Curriculum Journal, 29*(1), 116–133.
Van Deursen, A. J. A. M., & Van Dijk, J. A. G. M. (2014). The digital divide shifts to differences in usage. *New Media & Society, 16*(3), 507–526.
Van Merriënboer, J. J. G., & Kirschner, P. A. (2017). *Ten steps to complex learning: A systematic approach to four-component instructional design*. Routledge.
Winters, F. I., Greene, J. A., & Costich, C. M. (2008). Self-regulation of learning within computer-based learning environments: A critical analysis. *Educational Psychology Review, 20*, 429–444.
C. A. Wolters, P. R. Pintrich, and S. A. Karabenick, "Assessing academic self-regulated learning," *What do Child. need to flourish? Conceptualizing Meas.* Indic. Posit. Dev., pp. 251–270, 2005.
H. Yao, S. Chen, and A. Liu, "Exploring the Relationship between Academic Challenge Stress and Self-Rated Creativity of Graduate Students: Mediating Effects and Heterogeneity Analysis of Academic Self-Efficacy and Resilience," *Journal of* Intelligence, vol. 11, no. 9. 2023, doi: https://doi.org/10.3390/jintelligence11090176.
Yeşilyurt, E., & Vezne, R. (2023). Digital literacy, technological literacy, and internet literacy as predictors of attitude toward applying computer-supported education. *Education and Information Technologies, 28*(8), 9885–9911.
Yoleri, S., & Anadolu, Z. N. (2022). Examination of digital literacy skills of undergraduate students according to various variables. *Adv. Educ.*, 121–134.
E. Yong, "Influences of Academic Self-Efficacy, Academic Procrastination and Digital Literacy for Online Learning," in *Proceedings of the 6th International Conference on Education and Multimedia Technology*, 2022, pp. 190–194.
Zhou, H., & Long, L. (2004). Statistical remedies for common method biases. *Advances in Psychological Science, 12*(06), 942.
Zhu, Y.-Q., Chen, L.-Y., Chen, H.-G., & Chern, C.-C. (2011). How does internet information seeking help academic performance?–the moderating and mediating roles of academic self-efficacy. *Computers in Education, 57*(4), 2476–2484.
Zimmerman, B. J. (2000). Self-efficacy: An essential motive to learn. *Contemporary Educational Psychology, 25*(1), 82–91.