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Digital literacy as a catalyst for academic confidence: exploring the interplay between academic self-efficacy and academic procrastination among medical students

Xianting Yuan¹, Shazia Rehman^{2,3*}, Ali Altalbe^{4,5}, Erum Rehman⁶ and Muhammad Ali Shahiman⁷

Abstract

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 procrastination remain inadequately understood.

Objectives This research explores the relationships between digital literacy and academic self-efficacy, emphasizing the mediating role of academic procrastination and its various dimensions among medical students.

Methods A descriptive cross-sectional survey was conducted from seven medical colleges from October to December 2023. The research employed meticulously validated measurement tools encompassing a digital literacy scale, academic self-efficacy scale, and academic procrastination scale and collected data on 659 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 confirmed that digital literacy positively influenced academic self-efficacy and negatively correlated with academic procrastination. Among the five dimensions of procrastination assessed, self-efficacy emerged as the most potent mediator, significantly reducing procrastination and enhancing academic self-efficacy, followed by affective procrastination, time management, task avoidance, and behavioral procrastination.

Conclusion The findings underscore the critical role of digital literacy in fostering academic self-efficacy and reducing procrastination among medical students. Educators can develop more effective interventions to support medical students in their academic journey by targeting specific dimensions of procrastination, particularly self-efficacy-related procrastination. Future research should consider longitudinal studies to confirm causality and explore these dynamics in diverse educational settings.

Keywords Digital literacy, Academic self-efficacy, Academic procrastination, Medical students

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Introduction

In recent years, digital technologies have profoundly influenced various aspects of human life, especially in education. 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 [1]. Access to a boundless and constantly evolving pool of information through digital technologies has led to an overload of information, or “intoxication.” these technological tools have become vital for both training activities and the development of educational strategies [2–4]. Learning in this digital era extends across study, work, and leisure pursuits. Advancements in educational technologies allow students to acquire knowledge over the Internet. Younger generations demonstrate a natural affinity for digital devices like computers, laptops, and smartphones, which their predecessors used less commonly, enhancing their inherent technological competencies [1, 5]. The need for digital literacy among citizens is paramount to maximize the benefits of emerging technologies and actively engage in economic, social, and cultural arenas [6]. Such skills enable full participation in digital transformation, promote lifelong learning, improve job prospects, and are vital to tackling global challenges [7]. The extensive use of tech gadgets has cultivated digital literacy in the modern populace and encouraged continual education [8]. Digital transformation embodies rapid and deep-seated changes in activities, processes, competencies, and business models. It is about leveraging digital technologies’ changes and opportunities strategically [9]. 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 [10].

In medical education, digital literacy has shown to be particularly crucial due to the integration of online medical databases, electronic health records (EHRs), telemedicine, and digital simulation platforms used for clinical skills development [11]. Several studies indicated that medical students who demonstrate higher levels of digital literacy perform better in these digital environments, which are essential for theoretical learning and practical application [12, 13]. For instance, a study by Masters et al. (2016) [14], Jeffries et al. (2016) [15], and Steinert et al. (2017) [11] showed that medical students with high digital proficiency were more adept at navigating online research databases and clinical simulations, improving both their academic performance and clinical decision-making skills. Furthermore, Estrela et al. (2023) [16] found that digital literacy enhanced the ability to access patient information through EHRs, directly improving student efficiency and patient care quality in simulated

environments. Moreover, digital literacy in medical education aids time management and reduces cognitive overload by helping students streamline their research, efficiently access study materials, and organize academic tasks through digital platforms [17]. For instance, medical students can benefit from technology such as digital simulations, which enhance clinical decision-making, or mobile apps that track study progress and provide real-time feedback, allowing students to organize their time better and reduce stress [11, 14, 15].

Academic self-efficacy, a student’s confidence in their academic abilities, influences their effort and persistence [18]. This confidence is developed through academic success and is crucial for overcoming challenges [19, 20]. 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 [21, 22]. However, integrating SRL techniques with technology can be complex [23, 24]. Prior empirical investigations have demonstrated that students’ academic self-efficacy positively influences their engagement in studies, serving as a critical determinant of academic success [25, 26]. 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 [27]. 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 [28, 29].

Academic procrastination is a pervasive issue among students, characterized by the voluntary delay in completing academic tasks despite knowing the potential negative consequences. This behavior has been linked to decreased academic performance, higher stress levels, and poor well-being [30]. While procrastination is often viewed as a uniform behavior, recent research has identified its multifaceted nature, including decisional, avoidant, and arousal procrastination [31–33]. This varied manifestation suggests that the relationship between academic procrastination and other educational variables may be more complex than previously understood. However, less attention has been paid to the potential mediating role of academic procrastination in the relationship between digital literacy and academic self-efficacy. Theoretical frameworks suggest that digital literacy could, directly and indirectly, influence academic self-efficacy through its impact on academic procrastination [34]. For instance, highly digitally literate students may be less prone to procrastination due to better time management and organizational skills facilitated by digital tools, which could enhance their academic self-efficacy [35]. Conversely, those with lower digital literacy might struggle

with digital task management, leading to increased procrastination and reduced self-efficacy.

Theoretical background

The intersection of digital literacy, academic procrastination, and academic self-efficacy is rooted in several psychological and educational theories. Bandura's (1977) [36] social cognitive theory (SCT) provides a foundational perspective on academic self-efficacy, suggesting that individuals' belief in their capabilities to organize and execute actions required for attaining outcomes strongly influences their academic performance. This theory posits that self-efficacy is not a fixed trait but can be developed through experiences of mastery, vicarious learning, verbal persuasion, and physiological states [36, 37]. Digital literacy, as conceptualized by scholars, encompasses a range of skills, from basic operational abilities to advanced information processing and critical thinking in digital contexts [10, 34]. However, digital literacy goes beyond technical proficiency in using digital devices. It also encompasses cognitive skills that allow individuals to critically evaluate the credibility of information, ethically use digital resources, and communicate effectively in digital environments [Reference]. Author et al. (Year) expanded the definition of digital literacy to include the ability to curate and assess digital information, adapt to new digital tools, and employ these tools for problem-solving and collaborative learning [Reference]. In medical education, this becomes especially important as students must evaluate the credibility of research articles, use digital platforms to collaborate with peers and mentors, and integrate technology into clinical practice [Reference]. This broader understanding of digital literacy emphasizes the role of information literacy, communication skills, and critical thinking in fostering an effective learning environment. It is closely tied to self-regulated learning, which suggests that students proficient in using digital tools are better equipped to manage their learning processes effectively [38, 39]. SRL includes strategies such as goal setting, time management, and self-reflection, all of which can be facilitated by digital technologies when used appropriately. However, the role of academic procrastination—defined as the voluntary delay in studying despite knowing the potential adverse outcomes [40, 41]—in this equation remains less explored. While procrastination is often viewed negatively, it is a complex behavior influenced by task aversion, perfectionism, and self-regulation failure [42]. The proliferation of digital devices may exacerbate procrastination tendencies, as immediate access to entertainment and communication tools can distract students from their academic tasks [43].

Existing literature has primarily focused on direct relationships: digital literacy's impact on academic

self-efficacy [44, 45] and the influence of procrastination on academic performance [30, 46]. However, the pathway through which digital literacy might influence academic self-efficacy via academic procrastination remains under-explored. This represents a significant gap, as understanding this mechanism could inform interventions to mitigate procrastination's adverse effects and enhance the benefits of digital literacy on academic self-efficacy. Furthermore, most studies have treated procrastination as a unidimensional construct, overlooking its multifaceted nature. Recent research suggests that procrastination can manifest in various forms, including decisional procrastination [31], avoidant procrastination [32], and arousal procrastination [33]. These different types of procrastination may have distinct relationships with digital literacy and academic self-efficacy [47].

In recent years, the role of digital literacy in shaping academic outcomes has been well-documented, with much focus on how it can empower students by improving their access to information and enhancing self-regulation. However, recent theoretical advancements suggested that digital literacy may also contribute to the epistemology of ignorance when not fully understood or appropriately applied in educational contexts. Bhatt & MacKenzie (2019) [48] explored how digital literacy, while intended to foster critical engagement, may instead lead to superficial learning and the reinforcement of ignorance when students rely too heavily on easily accessible digital tools without deeper engagement. This concept introduced a paradox where digital literacy simultaneously opens doors to knowledge but also creates barriers by promoting passive learning behaviors. Moreover, Bhatt's work on post-digital literacies (2023) [49] further emphasized how digital tools can complicate learning environments, especially in educational settings. He argued that in the post-digital era, the omnipresence of technology could obscure the boundaries between learning and distraction, leading to procrastination and reduced academic self-efficacy [49, 50]. These insights highlighted the importance of critically assessing how students use digital tools, not just as enablers of learning but also as potential contributors to procrastination and cognitive overload. In medical education, where digital resources are increasingly relied upon, the misuse of digital literacy could exacerbate procrastination and undermine self-efficacy. This perspective broadens digital literacy's scope from merely a set of technical skills to understanding its complex role in shaping students' academic behaviors [49, 50]. By incorporating these contemporary insights, this study aims to provide a more nuanced understanding of digital literacy's dual role as a tool for academic empowerment and a potential source of distraction, procrastination, and ignorance in the learning process.

The present study

The existing literature provides a solid foundation regarding the independent effects of digital literacy and academic procrastination on academic self-efficacy. However, the interplay between these variables remains underexplored. Scholars have focused on how digital tools can aid in developing self-regulated learning (SRL) skills, which are closely linked to academic self-efficacy [51–53]. Nevertheless, the mediating pathways through which digital literacy influences self-efficacy—specifically through academic procrastination—have been largely neglected. To bridge this gap, the current study investigates the mediating role of academic procrastination in the relationship between digital literacy and academic self-efficacy among medical students in Islamabad, Pakistan. By doing so, we seek to provide a nuanced understanding of how digital literacy might indirectly shape students’ confidence in their academic capabilities through their tendencies to procrastinate. Moreover, this research delves into the diverse dimensions of academic procrastination, offering a comprehensive assessment of how different facets of procrastination might mediate the influence of digital literacy on academic self-efficacy.

The selection of medical students was because this demographic represents a group that is not only challenged by the complexity and volume of their academic work but also faces increasing digitalization of educational resources and clinical practices. Understanding how digital literacy influences their academic self-efficacy through procrastination tendencies can provide

valuable insights into improving their learning outcomes and future professional performance. Secondly, Pakistan, with a particular emphasis on its capital city, Islamabad, provides a compelling contextual framework for this research. This is attributable to the region’s rapidly expanding higher education sector, which exists alongside disparate levels of digital infrastructure and accessibility. The nation is undergoing a transitional phase characterized by the convergence of traditional educational methodologies and contemporary technological advancements. This context presents a valuable opportunity to investigate the intricate relationships among digital literacy, procrastination, and self-efficacy. Furthermore, concentrating on Pakistani medical students is timely, given that global health issues have highlighted the need for a competently trained healthcare labor force. By examining the elements that affect these demographics’ confidence in their academic abilities, this research seeks to add to the broader initiative of improving medical training and, in turn, providing healthcare services in the area. The conceptual study model is presented in Fig. 1.

Study hypotheses

Drawing upon the theoretical framework established in the existing literature, the current study posits the following hypotheses:

Hypothesis 1 A significant positive relationship is expected between digital literacy and academic self-efficacy.

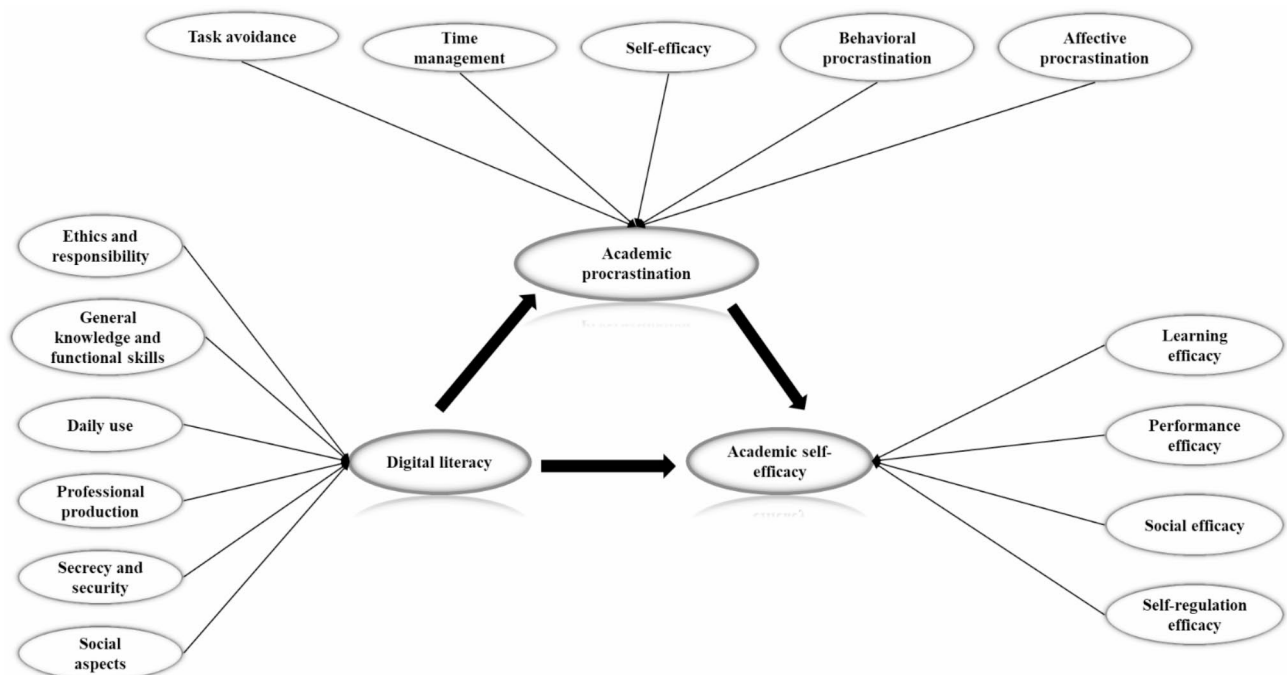


Fig. 1 Conceptual model

cacy, such that higher levels of digital literacy are associated with increased academic self-efficacy among medical students.

Hypothesis 2 It is further hypothesized that academic procrastination mediates the relationship between digital literacy and academic self-efficacy among medical students.

Hypothesis 2a Higher digital literacy is expected to lead to decreased task avoidance procrastination, enhancing academic self-efficacy among medical students.

Hypothesis 2b Better digital literacy is anticipated to improve time management skills, thereby reducing time management-related procrastination and fostering academic self-efficacy among medical students.

Hypothesis 2c Digital literacy is hypothesized to positively influence self-efficacy related to academic tasks, leading to reduced self-efficacy procrastination and higher overall academic self-efficacy among medical students.

Hypothesis 2d Greater digital literacy is predicted to diminish behavioral procrastination tendencies, facilitating increased academic self-efficacy among medical students.

Hypothesis 2e Enhanced digital literacy is expected to mitigate affective procrastination, contributing to higher academic self-efficacy among medical students.

Materials and methods

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.

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 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 academic procrastination. Participation was voluntary, and students were assured of the confidentiality of their responses. The eligibility criteria for the participants are as follows:

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.

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.

Sample size determination

The sample size was determined by obtaining a representative and statistically adequate cohort of medical students from various institutions. Considering the aggregate population of medical students spanning all five years of their academic program, the appropriate sample size was determined to ensure sufficient statistical power for the subsequent analyses. The final sample consisted of 659 valid responses, attained following the exclusion of incomplete and incorrect responses. This sample size was deemed adequate based on statistical power, population representation, and effect size considerations. The sample size was determined to ensure a minimum statistical power of 0.80, thereby enhancing the likelihood of identifying significant effects, should they be present. Furthermore, the sample size of 659 constitutes a substantial representation of the student population across the seven participating colleges, thereby enhancing

the reliability of the findings and suggesting that they may be extrapolated to the larger cohort of medical students in Islamabad. Anticipated effect sizes derived from previous research were considered, with the larger sample size facilitating the detection of smaller effect sizes [54–56]. This consideration is particularly pertinent in studies investigating intricate relationships among variables such as digital literacy, academic self-efficacy, and academic procrastination. By integrating these considerations, a final sample size of 659 participants was established, ensuring that the study possessed adequate statistical power to produce reliable and valid findings

while also sufficiently representing the target population. The study flow chart is presented in Fig. 2.

Data collection tools

Sociodemographic variables

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

Academic self-efficacy

Academic self-efficacy was assessed utilizing the Academic Self-efficacy Scale (ASE) developed by Joo et al. (2000) [57], 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) [58]. 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 [57, 59–61].

Digital literacy

The Digital Literacy Scale developed by Bayrakci et al. (2021) [62] 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 [63–65]. 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.

Academic procrastination

The Academic Procrastination Scale (APS) consisted of 25 items with five distinct dimensions (Task avoidance, Time management, Self-efficacy, Behavioral procrastination, and Affective procrastination) developed by McCloskey and Scielzo (2015) [66] was used to identify the procrastination behaviors of the study participants. The participants are requested to rate their response on a 5-point Likert-type response pattern ranging from 1 (strongly disagree) – 2 (disagree) – 3 (neutral) – 4 (agree)

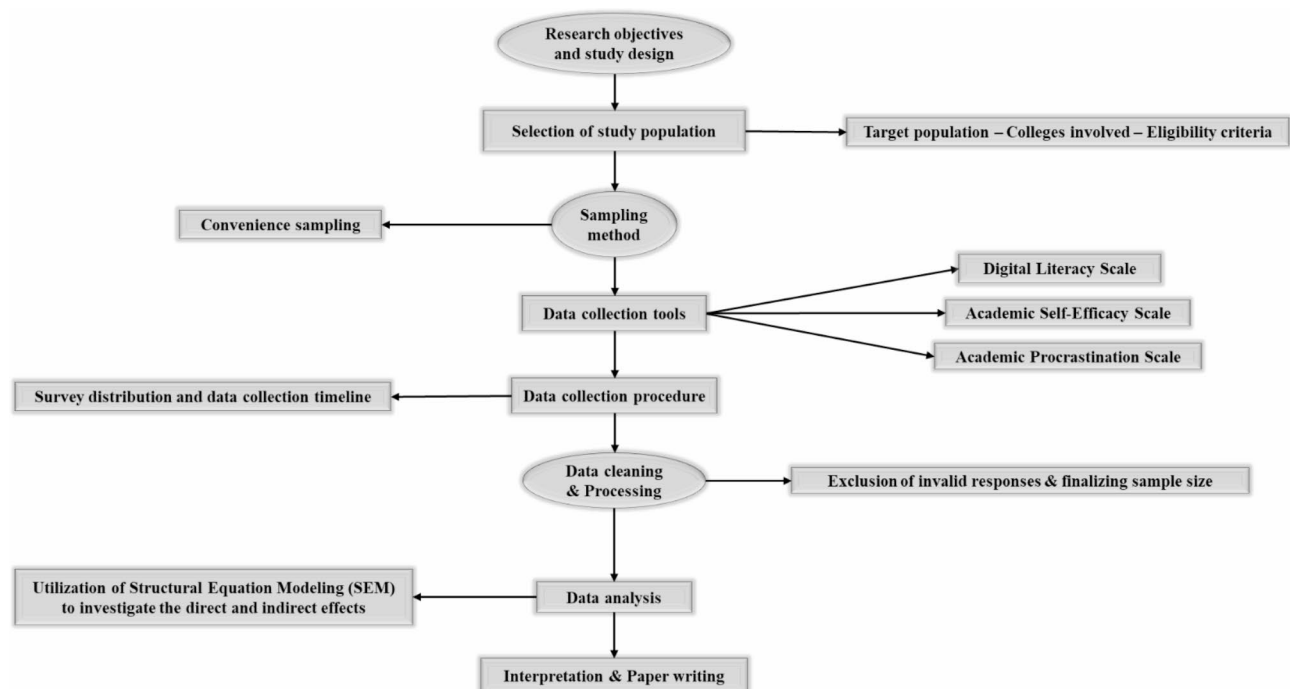


Fig. 2 Study flow chart

–5 (strongly agree). Sample items include “I have found myself waiting until the day before to start a big project” and “When given an assignment, I usually put it away and forget it until it is almost due.” Scores rated lower signify a reduced level of academic procrastination, whereas higher scores reflect an elevated level of academic procrastination. The scale scores range from a minimum of 25 to a maximum of 125. The scale has been adopted in various settings and disciplines with good to excellent reliability and validity [67–69], along with the Pakistani population [70].

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 SPSS 26.0 statistical software with SPSS macros PROCESS, Amos (v23), prepared by Hayes, was used to process the data analysis for reliability and validity tests, descriptive statistics, correlation analyses, regression analyses, and mediation analyses.

Results

The CMB assessment utilized the Harman one-way analysis approach. The results of the exploratory factor analysis indicated that the variance explained by the first common factor was 23.59%, which fell below the critical threshold of 40% [71], 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 [72]. The results indicated the absence of significant multicollinearity issues among the predictor variables (Tolerance=0.89 for digital literacy and 0.91 for academic procrastination, VIF=1.12 for digital literacy, and 1.10 for academic procrastination).

The univariate analysis of the demographic variables of 659 participants indicated a mean age of 21.0 years (SD=0.91) (Table 1). The sample comprised 46.59% male and 53.41% female medical students, indicating a statistically significant gender distribution ($p<0.001$). The residence patterns of individuals living on-campus (50.23%) and off-campus (49.77%) were found to be broadly comparable, with no statistically significant difference observed ($p=0.103$). Most participants, 91.20%, identified as single, whereas only 8.80% reported marriage or divorce. The socioeconomic status demonstrated significant variability ($p<0.001$), with individuals classified into low (25.04%), middle (45.83%), and high (29.14%) categories. The participants were distributed across all years of medical study, and statistical analysis revealed no significant differences in this distribution ($p=0.632$). Notably, the highest % of participants was found in the fourth year, comprising 32.32% 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 2 demonstrates the summary of the descriptive metrics, reliability and validity indices, model fit statistics, and constructs correlations of the independent variable (digital literacy), dependent variable (academic self-efficacy), and mediator (academic procrastination). The descriptive statistics revealed that Digital Literacy has a mean of 2.36 (SD=0.49), academic self-efficacy has a mean of 2.13 (SD=0.39), and academic procrastination has a higher mean of 6.21 (SD=1.24), 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 values demonstrated robust internal consistency (digital literacy: 0.934, academic self-efficacy: 0.912, and academic procrastination: 0.987). 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.

Table 1 Univariate analysis of the demographic characteristics of the study participants ($n=659$)

	f (%) / mean \pm SD	t / χ^2	Significance
Age (years) (Mean \pm SD)	21.0 \pm 0.91	7.46	<0.001
Gender		12.84	<0.001
Male	307 (46.59%)		
Female	352 (53.41%)		
Residence		98.51	0.103
On-campus	331 (50.23%)		
Off-campus	328 (49.77%)		
Socioeconomic status		43.09	<0.001
Low	165 (25.04%)		
Middle	302 (45.83%)		
High	192 (29.14%)		
Medical year		9.18	0.632
1st	104 (15.78%)		
2nd	143 (21.70%)		
3rd	85 (12.90%)		
4th	213 (32.32%)		
5th	114 (17.30%)		

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

	Mean ± SD	α	CR	AVE	DL	ASE	AP
DL	2.36 ± 0.49	0.89	0.934	0.623	1		
ASE	2.13 ± 0.39	0.89	0.912	0.601	0.62***	1	
AP	4.01 ± 0.64	0.91	0.987	0.662	-0.53***	-0.57***	1
χ^2/df					2.01	1.65	1.31
RMSEA					0.048	0.043	0.035
SRMR					0.051	0.052	0.044
CFI					0.952	0.973	0.992
TLI					0.966	0.982	0.985

Note: DL: Digital literacy, ASE: Academic self-efficacy, AP: Academic procrastination, 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 A path mediation analysis

	R ² (F-statistics)	β (SE)	t	Bootstrap 95% CI	Decision
Direct path					
DL → ASE	0.38 (232.56***)	0.55 (0.043)	12.68***	0.341–0.632	Supported
Indirect paths					
DL → Academic procrastination → ASE	0.30 (187.35***)	0.156 (0.020)	7.82***	0.783–0.204	Supported
Indirect paths via Academic Procrastination dimensions					
DL → TA → ASE	0.14 (65.19***)	0.074 (0.041)	1.82***	0.054–0.095	Supported
DL → TM → ASE	0.18 (98.11***)	0.084 (0.034)	2.48***	0.601–0.099	Supported
DL → SE → ASE	0.28 (153.06***)	0.125 (0.024)	5.24***	0.983–0.189	Supported
DL → BP → ASE	0.11 (35.17***)	0.068 (0.055)	1.23***	0.055–0.078	Supported
DL → AP → ASE	0.21 (115.81***)	0.097 (0.036)	2.69***	0.085–0.126	Supported

Note: DL: Digital literacy, ASE: academic self-efficacy, Task avoidance, TM: Time management, SE: Self-efficacy, BP: behavioral procrastination, AP: affective procrastination

Specifically, the AVE for digital literacy was 0.623, for academic self-efficacy was 0.601, and for academic self-efficacy was 0.662. All values exceed the recommended threshold of 0.5, indicating a robust convergent validity level.

The analysis of the bivariate correlations among the constructs demonstrates the presence of significant relationships. Digital literacy significantly correlated with academic self-efficacy ($r=0.62, p<0.001$). This finding suggests that increased levels of digital literacy are associated with elevated academic self-efficacy. Also, the results indicated a significant negative correlation between digital literacy and academic procrastination ($r = -0.53, p<0.001$). This finding suggests that individuals exhibiting higher levels of digital literacy are less inclined to engage in academic procrastination. Likewise, academic self-efficacy demonstrated a significant negative correlation with academic procrastination ($r = -0.57, p<0.001$), suggesting that individuals with higher academic self-efficacy are likely to engage in lower procrastination.

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 1.31 to 2.01 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 0.035 to 0.048, while the Standardized Root Mean Square Residual (SRMR) values ranged from 0.044 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 0.952 to 0.992, and the Tucker-Lewis Index (TLI) values were similarly high, ranging from 0.966 to 0.985. These findings provided compelling evidence that the model demonstrates an excellent fit.

Table 3 presents the findings of the path mediation analysis. The analysis reveals a statistically significant direct effect of digital literacy on academic self-efficacy ($\beta=0.55, p<0.001$), suggesting that increased levels of digital literacy are positively correlated with enhanced academic self-efficacy. This finding indicates that digital literacy significantly enhances students' confidence in their academic capabilities. Upon investigating the indirect effect of digital literacy on academic self-efficacy, with academic procrastination as a mediating variable, the analysis indicates the presence of a significant mediation effect ($\beta=0.156, p<0.001$). This indicates that digital literacy positively impacts academic self-efficacy by mitigating procrastination and enhancing individuals' confidence in their academic abilities.

The study further investigates the mediating effects of academic procrastination through various dimensions (task avoidance, time management, self-efficacy, behavioral procrastination, and affective procrastination). The results of the analysis revealed several noteworthy findings. The relationship between digital literacy and academic self-efficacy, mediated by task avoidance, demonstrated a significant mediation effect ($\beta = 0.074, p < 0.001$), suggesting that a decrease in task avoidance, attributable to enhanced digital literacy, benefits self-efficacy. The mediation effect of time management is statistically significant ($\beta = 0.084, p < 0.001$), indicating that enhanced time management competencies, which are correlated with elevated levels of digital literacy, contribute to an increase in academic self-efficacy. Out of the five, the mediation effect for self-efficacy was the most robust dimension with a substantive effect size ($\beta = 0.125, p < 0.001$), which means that improvement in digital literacy substantially decreases procrastination regarding self-efficacy and, in turn, enhances academic self-efficacy. Although the mediation effect of behavioral procrastination was weaker compared to other dimensions, it still can be considered significant ($\beta = 0.068, p < 0.001$), which means that a decrease in behavioral procrastination through increasing digital literacy explains to some

degree the increase in academic self-efficacy. Similarly, the mediation effect due to affective procrastination was also significant ($\beta = 0.097, p < 0.001$), suggesting that the diminishing nature of emotional procrastination behavior is due to increased digital literacy favoring academic self-efficacy. The graphical representation of the path mediation analysis is demonstrated in Fig. 3.

Holistically, the direct effect of digital literacy on academic self-efficacy and its indirect effect, through which it could enhance self-efficacy by reducing the different dimensions of academic procrastination, was evident. The model explains a relatively good portion of the variance in academic self-efficacy, based on R^2 values, i.e., from 0.11 to 0.38%, depending on the path and specific dimension of procrastination (Table 3). Furthermore, the 95% bootstrap confidence intervals (CIs) for all paths consistently remain within ranges excluding zero, reinforcing the reliability and significance of direct and indirect paths in the model—which emphasizes the robust relationships between digital literacy, academic procrastination, and academic self-efficacy.

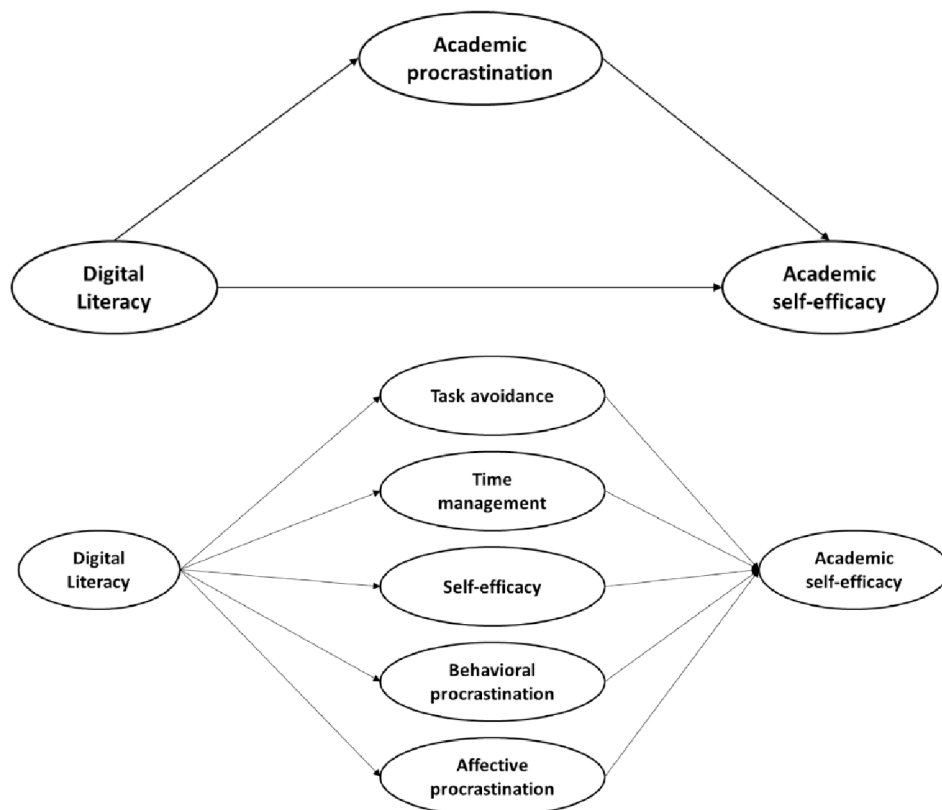


Fig. 3 The conceptual path mediation model

Discussion

This study examined the intricate relationships between digital literacy, academic self-efficacy, and the various dimensions of academic procrastination among medical students in Islamabad, Pakistan. By uniquely assessing five distinct dimensions of academic procrastination as mediators, this research offers a detailed perspective on how digital competencies and self-efficacy impact specific procrastination behaviors in this population. The research outcomes indicated that higher levels of digital literacy are positively associated with greater academic self-efficacy and are inversely related to overall academic procrastination. Of particular importance, within the various facets of academic procrastination, the self-efficacy dimension emerged as the most influential mediator in these relationships. These insights suggest that enhancing digital literacy and self-efficacy, mainly focusing on self-efficacy, could serve as effective interventions for reducing academic procrastination, ultimately benefiting the academic performance of medical students.

The significant direct impact of digital literacy on academic self-efficacy identified in the present research supports the first study hypothesis and is consistent with findings from similar investigations in educational contexts [44, 73, 74]. The findings indicated that medical students with higher digital literacy levels demonstrated significantly greater academic self-efficacy, suggesting that digital competencies are essential for fostering confidence in academic abilities. This relationship can be attributed to the increasing integration of digital tools in medical education, which requires students to be proficient in using technology for learning, research, and communication. Similar empirical investigations, such as those conducted in other higher education contexts, reported a positive correlation between digital literacy and academic self-efficacy, particularly in technologically advanced learning environments. For instance, research by Margaryan et al. (2011) [75] and Kay & Lauricella (2011) [76] reported that students who are more adept at using digital resources tend to feel more confident in their ability to manage academic tasks, likely due to their familiarity with accessing information, utilizing educational platforms, and engaging in collaborative online activities. The rationale behind this relationship may also be rooted in the sense of control and autonomy that digital literacy provides. Medical students possess advanced skills in using digital technologies can effectively traverse intricate data, interact with educational materials outside traditional classroom settings, and remain informed about recent developments in the healthcare sector. Such adeptness amplifies their confidence in their academic abilities and diminishes apprehension and doubt related to academic challenges. As a result, those with heightened digital skills are more adequately prepared to

confront academic requirements, fostering a more robust conviction in their capacities to achieve success in their academic endeavors.

Furthermore, this research explored the role of academic procrastination as a mediator between digital literacy and academic self-efficacy (hypothesis 2), offering valuable insights into the connections among these concepts. The findings indicated that academic procrastination is crucial in connecting digital literacy and self-efficacy. Specifically, students with higher digital literacy tend to show reduced levels of procrastination. This decrease in procrastination ultimately boosts their confidence in their academic abilities. The results indicated that digital literacy enhances students' ability to handle their academic duties more effectively, resulting in fewer delays in task completion and boosting their confidence in their academic skills. The mediating role of academic procrastination corresponds with earlier investigations that identify procrastination as a significant barrier to achieving academic success. Research conducted by Steel (2007) [40] and Kandemir (2014) [77] reported that procrastination frequently correlates with diminished academic self-efficacy, as it heightens stress levels and limits the time available to finish academic assignments adequately. For medical students contending with intense academic pressures, improving digital literacy can be especially advantageous in helping them overcome academic procrastination. It enables students to effectively manage their academic resources, maintain organization, and adhere to deadlines, bolstering their confidence in their academic abilities.

Expanding on this, the research explored the five unique facets of academic procrastination and found that self-efficacy (hypothesis 2c) emerged as the most potent mediator between digital literacy and academic self-efficacy. This suggests that students with higher digital literacy are significantly less likely to procrastinate due to self-doubt or lacking confidence in their skills. This conclusion aligns with Bandura's (1977) theory [36], highlighting how self-efficacy influences individuals' motivation to take action and remain resilient when confronted with difficulties. The significant impact of self-efficacy on academic procrastination can be linked to how digital literacy boosts students' confidence in their ability to accomplish academic assignments. When students are confident in their ability to utilize digital tools for finding information, managing their tasks, and working with others, they are less prone to self-doubt, which often results in procrastination. Furthermore, explorations in similar educational settings have shown that initiatives to bolster confidence in one's academic capabilities are potent in diminishing procrastinating behavior and enhancing academic outcomes [78, 79]. This implies that endeavors to elevate digital literacy

among students in medical education could substantially influence the lessening of such procrastinating behavior and the strengthening of their overall academic self-efficacy, ultimately culminating in enhanced academic achievement.

In addition to self-efficacy, the research also explored the other facets of academic procrastination—task avoidance (hypothesis 2a), time management (hypothesis 2b), behavioral procrastination (hypothesis 2d), and affective procrastination (hypothesis 2e)—as mediators between digital literacy and academic self-efficacy. While these facets were not as impactful as self-efficacy, they enhanced our comprehension of how digital literacy affects academic behaviors. This may be because these students feel more confident in managing academic tasks, leading to more effective time management and task completion. On the other hand, students with lower self-efficacy may procrastinate more frequently as they attempt to avoid tasks they perceive as challenging or beyond their capabilities. This dynamic reinforces the crucial role of self-efficacy in shaping academic behaviors and outcomes. Furthermore, task avoidance and time management are intricately connected. Students with strong digital skills are more adept at breaking tasks into smaller, manageable parts and efficiently prioritizing their responsibilities. This capability diminishes the chance of procrastination that often arises from feeling overwhelmed by large tasks or ineffective time management [80]. Behavioral procrastination, characterized by the habitual postponement of tasks, is alleviated by digital literacy [81]. Students possessing robust digital competencies can enhance their study processes, efficiently access resources, and sustain regular study practices. Affective procrastination, defined by the emotional responses that precipitate delays—such as anxiety or frustration—exhibits an analogous relationship with digital literacy. When students possess a sense of self-efficacy regarding their proficiency in utilizing digital tools, they are less prone to experiencing negative emotions that can lead to procrastination [82]. These findings align with Ferrari, Johnson, and McCown (1995) research [80], highlighting how task management and emotional regulation are critical factors in procrastination. By enhancing digital literacy, educational strategies can help students develop better time management [80], reduce task avoidance [40], and manage their emotional responses [82], leading to a comprehensive reduction in procrastination behaviors and an overall increase in academic self-efficacy.

The context of this study, conducted in Islamabad, Pakistan, is an essential consideration for interpreting the findings. Digital infrastructure in Pakistan, including access to stable internet and digital tools, can vary significantly between institutions. While generally exposed to modern digital tools, the medical students in this study

may face institutional barriers such as limited access to high-quality online resources, which could influence their digital literacy and its impact on academic behaviors. Moreover, curriculum designs may not always incorporate digital literacy into the learning process, potentially affecting how students manage procrastination and their self-efficacy in academic settings. Future research should explore how these factors vary across different educational institutions in Pakistan and internationally.

Implications

The insights drawn from this research bear multiple implications, offering substantial relevance to medical education and the overall welfare of medical students. The significant positive association between digital literacy and academic self-efficacy suggests that reinforcing digital skills among medical students could amplify their confidence in tackling academic challenges. Such an outcome may, in turn, lead to improved academic accomplishments and reduced stress, which are crucial given the intense demands of medical training. Furthermore, educators and administrative staff can devise more precise interventions by recognizing that procrastination is a multifaceted behavior influenced by self-efficacy, time management, task evasion, and emotion regulation. For example, the inclusion of digital literacy modules in the medical syllabus could equip students with the capabilities to manage their schedules effectively, dissect intricate tasks, and alleviate the emotional catalysts that induce procrastination. Significantly, the discovery that self-efficacy is the most impactful aspect of procrastination indicates that bolstering students' belief in their capabilities should be a priority. Initiatives that amalgamate digital skill advancement with self-efficacy enhancement could be especially effective in diminishing procrastination and boosting academic results. These initiatives might encompass workshops, peer mentorships, and digital platforms that nurture a sense of triumph and competency among students. In conclusion, the wide-ranging implications of this study indicate that nurturing a digitally adept and self-assured student cohort could yield long-term benefits for the medical sector. Medical students who are both digitally savvy and possess robust self-efficacy are likely to exhibit greater adaptability, resilience, and capability to meet the intricate and evolving requirements of the healthcare sector. Hence, investing in these domains elevates students' academic performance and prepares them to confront the challenges of their impending careers.

Limitations

The present research encounters certain limitations that warrant consideration. Employing a cross-sectional methodology constrains the inference of causal links

between digital literacy, academic self-efficacy, and academic procrastination, necessitating longitudinal investigations to ascertain temporal associations. Moreover, the dependence on self-reported data might introduce discrepancies like social desirability and recall inaccuracies, potentially impacting the precision of the outcomes. The adoption of convenience sampling further curtails the broad applicability of the findings, as the sampled group might not fully encapsulate the wider cohort of medical students, possibly generating selection bias. Additionally, the research was undertaken within a specific geographic context—medical institutions in Islamabad, Pakistan—which could restrict its relevance to other areas or educational frameworks. Finally, the study did not consider potential confounders such as age, gender, individual dispositions, and external academic stressors, which could affect the observed correlations. Future studies should address these limitations to offer a more holistic comprehension of the underlying mechanisms.

Conclusion

The research offers significant insights into the intricate relationships among digital literacy, academic self-efficacy, and academic procrastination within the context of medical students. The results emphasize the substantial impact of digital literacy on enhancing academic self-efficacy and reducing procrastination. Furthermore, self-efficacy emerges as the most influential mediating factor among the various dimensions of procrastination. The findings underscore the necessity of incorporating digital literacy instruction and initiatives to enhance self-efficacy within medical education. Such integration is essential for optimizing academic outcomes and adequately preparing students to face the challenges they may encounter in their future professional endeavors. However, the limitations inherent in the study, including its cross-sectional design, reliance on self-reported data, and utilization of convenience sampling—factors that warrant caution in the generalization of findings—the implications for educational practices are undeniably significant. Medical colleges have the potential to play a pivotal role in cultivating adaptable and proficient healthcare professionals by creating an educational environment that encourages the development of digital literacy and self-efficacy among students. Future research endeavors should aim to expand upon these findings by addressing the identified limitations and investigating potential targeted strategies designed to enhance the academic performance of medical students.

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Author contributions

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Data availability

The raw data supporting this study's findings are available upon reasonable request from the author (Muhammad Ali Shahiman, dr_ali2875@yahoo.com).

Declarations

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-KT4382).

Informed consent

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

Consent to publish

Not applicable.

Competing interests

The authors declare no competing interests.

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