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Digital Literacy in Medical Education: Strengths, Gaps, and the Way Forward

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ABSTRACT

Digital transformation of healthcare has transformed clinical practice, medical education, and professional competencies around the world. Digital literacy includes technological skills, ethical use, artificial intelligence (AI), and cybersecurity. It is now regarded as a safe, effective, and future-ready healthcare practice. Despite increased exposure to digital tools, evidence reveals that healthcare students may lack structured capabilities in new digital domains. **Objectives:** To evaluate the level of digital literacy among undergraduate medical and dental students and identify domain-specific strengths and gaps, particularly in emerging areas such as artificial intelligence and cybersecurity. **Methods:** An analytical cross-sectional study was conducted using a validated 24-item self-report instrument. The survey measured seven domains of digital literacy using a 5-point Likert scale. A total of 304 MBBS and BDS students participated. Data were analyzed using SPSS v26, applying descriptive statistics, t-tests, and Spearman's correlation. **Results:** Among the participants, 77.6% were MBBS students and 22.4% were from BDS, with 60.9% females and 39.1% males. No significant gender-based differences were found in any digital literacy domain. First-year students scored significantly higher in the digital security domain than second-year students (p=0.002). Overall, students demonstrated moderate digital literacy, with comparatively lower scores in AI and cybersecurity domains. **Conclusions:** While digital literacy is generally consistent across gender and academic levels, low competency in AI and cybersecurity signals an urgent need for targeted curricular interventions. Integrating digital literacy, especially AI and data security, into undergraduate curricula is essential for preparing future-ready healthcare professionals.

INTRODUCTION

The rapid digitalization of the health sector has led to significant advances across medical training, diagnostic accuracy, disease surveillance, and treatment regimens [1]. This development has tremendously contributed to the quality of patient care as it has enhanced medical infrastructure, improved the quality of diagnosis, treatment outcome, and automation of follow-ups. It is also transforming clinical practice systems [2]. The implications of this transformation are the most poignant in the sphere of education and training of medical students. Digital possibly has upended the knowledge acquisition process, collaboration, and outreach to the up-and-coming technologies by medical students [3]. This evolution highlights the significance of digital literacy and training the future healthcare providers to manage the needs of clinical practice. The development of digital healthcare has brought significant changes in methods of teaching, the learning process, diagnostic quality, and

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management of patients [2]. These evolutions have not only optimized clinical workflows but have also resulted in more accurate diagnoses, treatments, and patient follow-ups [4]. Online platforms are recently becoming a good source of learning that allows students to use resources, perform in virtual simulations, and be involved in the most advanced types of medical equipment [4]. This digital transition will require that students have good digital capabilities to stay motivated and useful in a system that is increasingly becoming more tech-oriented [5]. Integrating digital literacy into medical education is becoming a reality in Pakistan. An example is the introduction by the National University of Medical Science (NUMS) of special computer skills as part of its current undergraduate MBBS curriculum. Such an initiative also provides students with the crucial competencies that will be useful in their future profession, such as the utilization of medical software, which makes them ready to succeed in a digitalized healthcare space [6]. Nevertheless, a study carried out reveals that even at the time, much can still be done to enhance digital literacy among healthcare students. De La HOZ *et al.* underlined the necessity to conduct undergraduate programs to train digital and scientific skills, dedicated to e-Health literacy [7]. Although there is increased application of digital tools in learning and in social life, most of the students do not tune into some of the basic competencies that they need to utilize these tools properly [1]. To illustrate, there is research done in Canada, which found that even first-year university students who owned their personal computers and smartphones were not very familiar with them, but only operated basic operations [6]. This underscores a very important disparity between the current and actualized need in digital proficiency. ChatGPT and other tools that are artificial intelligence (AI) based are highly useful in medical education as they can aid cognitive skills that include recalling, interpreting, applying, analyzing, evaluating, and creating [8].

Nevertheless, the idea of AI integration should be approached with precautions to prevent any threats to sensitive patient information and ethical and legal issues related to this practice. This study aims to assess the level of digital literacy among health professions students at our institution and to identify gaps requiring curricular improvement. The findings will inform targeted curriculum development to enhance digital competence and support the effective integration of digital tools into contemporary clinical practice.

METHODS

An analytical cross-sectional study design was used to determine the level of digital literacy among undergraduate students at Lahore Medical College and Institute of Dentistry, Lahore, Pakistan. The population of interest was all the registered students of the MBBS and BDS programs at Lahore Medical College and the Institute of Dentistry. The study was conducted from March to June 2024 after receiving ethical clearance from the institutional review board (Case#901/ERC/CMH/LMC; dated 15th March 2023). Taking part in the study was voluntary, and informed consent was received digitally from all participants. Anonymity and confidentiality of information were assured. Students who were enrolled in the MBBS or BDS courses and used the internet were included in the study. Those students who didn't use the internet, academically detained or repeating a year, and those who declined participation were excluded. The sample size was calculated using the standard formula for estimating a proportion in a cross-sectional study: $n = Z^2 \times p \times (1 - p) / d^2$ and found to be a required minimum of 278 participants. The study was completed by a total of 304 students, more than required. A non-probability convenience sampling approach was utilized to have a representative sample from various academic years and programs. The data were gathered via a self-report, pre-tested, reliable, and validated instrument consisting of 24 items [2]. Before the main study, a pilot testing phase was carried out to evaluate the questionnaire's validity and reliability. Thirty undergraduate medical and dentistry students (15 from each group) took part in the validation procedure; however, they were excluded from the final sample. Cronbach's alpha was used to assess internal consistency reliability (α-value is 0.785). The tool was meant to evaluate digital literacy over seven different dimensions, like Software and multimedia, Hardware, Network and communication/ collaboration, Ethics, Security, Artificial intelligence, Interest, and knowledge. Part A aimed to obtain demographic information such as gender, academic program, and level of study. Part B: Each of the items had a rating over a 5-point Likert scale from "Strongly Disagree" (1) through "Strongly Agree"(5). The participants self-administered the questionnaire. Quantitative data were analyzed with SPSS version 26. Descriptive statistics such as means, standard deviations (SD), medians, interquartile ranges (IQR), frequencies, and percentages were utilized to describe demographic attributes and digital literacy scores. Each of the domain scores was calculated by averaging the responses to corresponding items, and a total digital literacy score was calculated by taking the mean of all the domain scores. A 95% confidence level was used for statistical analysis, and results were considered statistically significant at a p-value of less than 0.05, in accordance with standard biomedical research conventions. Along with p-values, effect sizes were calculated using Cohen's d to assess the practical

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significance of differences between gender and academic-year groups. The comparisons were conducted across predefined digital literacy domains; no formal adjustment for multiple comparisons was applied. The analyses were exploratory in nature and guided by prior literature. To support meaningful interpretation, effect sizes (Cohen's d) were reported alongside p-values. In addition to p-values, effect sizes were calculated using Cohen's d to assess the magnitude and practical significance of differences between groups. Effect sizes were interpreted as small (d=0.2), moderate (d=0.5), and large (d=0.8), in accordance with standard conventions. Before performing independent samples t-tests, assumptions of normality and homogeneity of variances were assessed. Normality of digital literacy scores was evaluated using the Shapiro–Wilk test, while equality of variances was examined using Levene's test. As assumptions were met, parametric independent samples t-tests were applied for gender- and academic-year comparisons.

RESULTS

Data screening demonstrated that the assumptions required for parametric testing were satisfied. The data analysis showed that the overall digital literacy scores were approximately normally distributed (p>0.05). Minor deviations observed in some subdomains were acceptable given the sample size, supporting the use of parametric tests for group comparisons. A total of 345 students participated in the study; 249 (72.1%) were enrolled in the MBBS program, while 96 (27.8%) were from the BDS program. 149 (43.18%) of the participants were female, and 196 (56.8%) were male. Assumption testing confirmed that digital literacy scores were approximately normally distributed and that homogeneity of variances was satisfied across comparison groups (Shapiro–Wilk and Levene's tests, all p>0.05), supporting the use of independent samples t-tests (Table 1).

Table 1: Distribution of Participants by Academic Year (n=345)

Academic Years	Programs	Frequency (%)
1st Year	MBBS	55 (15.9%)
2nd Year	MBBS	62 (18.9%)
3rd Year	MBBS	48 (13.9%)
4th Year	MBBS	45 (13.0%)
Final Year	MBBS	39 (11.3%)
1st Year	BDS	24 (7.0%)
2nd Year	BDS	21 (6.1%)
3rd Year	BDS	28 (8.1%)
Final Year	BDS	23 (6.6%)
Total	BDS	345 (100%)

Assessment of data distribution showed that the overall digital literacy score was approximately normally distributed. Shapiro–Wilk tests conducted for each digital literacy domain revealed no significant deviation from normality (all p-values>0.05). Visual inspection of histograms and Q–Q plots further supported the assumption of normal distribution. Therefore, parametric statistical tests were considered appropriate for subsequent analyses. The descriptive statistics (mean ± SD) of digital literacy components among male and female students indicate no statistically significant differences between genders (p>0.05) (Table 2).

Table 2: Mean Scores of the Studied Digital Variables According to Total and Academic Level

Components	Male (n=196), Mean ± SD	Female (n=149), Mean ± SD
Software & Multimedia	3.85 ± 0.58	4.02 ± 0.54
Hardware	3.72 ± 0.60	3.89 ± 0.57
Network	3.66 ± 0.64	3.78 ± 0.59
Ethics	3.94 ± 0.55	4.10 ± 0.52
Security	3.58 ± 0.63	3.80 ± 0.58
Artificial Intelligence	3.49 ± 0.69	3.70 ± 0.62
Interest & Knowledge	3.80 ± 0.61	3.95 ± 0.57

The primary inferential analysis for gender-based differences in digital literacy components, conducted using independent samples t-tests, indicated no statistically significant differences between male and female students across any domain (all p > 0.05) (Table 3).

Table 3: Analysis of Year of Gender-Based Difference in Digital Literacy Components

Component	t-value	p-value
Software & Multimedia	-0.18	0.86
Hardware	-0.47	0.64
Network	0.69	0.49
Ethics	0.68	0.50
Security	0.69	0.49
AI	0.36	0.72
Interest & Knowledge	-1.48	0.14

Although minor differences in mean scores were observed between genders (Table 2), these differences were not statistically significant based on inferential analysis (Table 3). For gender-based comparisons, effect size analysis revealed small Cohen's d values across all digital literacy domains (d<0.20), indicating negligible practical differences between male and female students despite minor variations in mean scores. These findings support the absence of meaningful gender-based differences in digital literacy competencies. Although a statistically significant difference was observed in the digital security domain between first- and second-year students (p=0.002), the associated effect size was small (Cohen's d=0.28), suggesting limited practical significance. No other academic-year comparisons demonstrated meaningful effect sizes. Students in their first and second years did not

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substantially differ in many digital literacy components, according to a follow-up t-test analysis, depending on the research year (Table 4).

Table 4: Analysis of Year of Study-Based Difference in Digital Literacy Components

Component	1st Year (n=79), Mean ± SD	2nd Year (n=83), Mean ± SD	p-value
Software & Multimedia	3.78 ± 0.60	3.89 ± 0.56	0.153
Hardware	3.71 ± 0.63	3.75 ± 0.59	0.628
Network	3.60 ± 0.67	3.68 ± 0.61	0.421
Ethics	3.96 ± 0.58	4.05 ± 0.53	0.229
Security	3.59 ± 0.66	3.67 ± 0.60	0.387
Artificial Intelligence	3.52 ± 0.72	3.60 ± 0.66	0.439
Interest & Knowledge	3.83 ± 0.64	3.91 ± 0.58	0.398

Overall, first-year students demonstrated significantly higher perceived knowledge of digital security than second-year students. These findings suggest that while digital literacy competencies are relatively consistent across demographics, certain areas, such as security, may require targeted interventions based on academic level

DISCUSSION

The current research examined the level of digital literacy of undergraduate students who are studying health professions. Since the demand for technology in healthcare is rising, the paper provides relevant information on the combination of the preparedness of aspiring medical practitioners to work productively within a digital environment. Analyzing the results, it becomes clear that despite relatively modest and steadily distributed levels of digital literacy among students across gender and academic years, there are several areas, such as cybersecurity and artificial intelligence (AI), which require a significant amount of attention to be paid to them within the undergraduate curriculum [9]. The small effect sizes observed across gender and academic-year comparisons indicate that differences in digital literacy, while occasionally statistically significant, are unlikely to be educationally meaningful, emphasizing the need for institution-wide rather than subgroup-specific interventions. The results of the study are the absence of any statistically significant differences in the scores of digital literacies between male and female students in both categories that were checked [10]. The finding applies to similar studies conducted in other countries, such as those that found that gender bore no discernible influence on the level of digital proficiency among Turkish health care students [2]. This follows results obtained in Bangladesh, where authors highlighted the importance of curriculum adjustments to improve the weaker aspects of learning, such as ethics and AI, whilst maintaining gender equity, and observed positive results in that they were unable to detect gender disparities when measured in seven digital areas [11]. Once it can be seen as the same availability of digital devices, internet, and platforms between the two genders in the Pakistani education system of medicine, and specifically in CMH LMC and IOD [12]. In another similar study performed in King Edward Medical University utilizing the Digital Health Literacy Instrument (DHLI), there were also sufficient scores in operational skills as well as privacy protection, with inadequacies that occurred in assessing the reliability and relevance of data. These results justify why the medical students in Pakistan are required to have more organized interventions to enhance their critical digital skills [13]. Except for digital security, where first-year students scored noticeably higher than second-year students, there was no statistically significant difference in digital literacy between first- and second-year students in most categories [14]. This finding defies logic and poses significant queries. It might represent a recent focus on cybersecurity in orientation sessions or beginning computer courses taken by young professionals, which is bolstered by recent curriculum modifications implemented by organizations such as NUMS and UHS. On the other hand, it could indicate a decrease in the focus on digital ethics and safety beyond the first phases of medical education, indicating the necessity of ongoing curriculum-wide reinforcement [15]. The students reported mild proficiency in the areas of network and collaboration, hardware understanding, and software and multimedia usage. These outcomes are in line with research by Sriram *et al.* which found that junior physicians thought they were somewhat proficient in fundamental digital abilities but had trouble using them in clinical situations. This highlights a global trend: despite students' growing exposure to technology in social and academic settings, their capacity to effectively use it for academic, clinical, and collaborative objectives is still lacking [16]. In recent studies, the low to moderate results in the AI domain indicate a deficiency in structured AI teaching. Many researchers emphasized the need for foundational AI education among medical students; if students are aware of AI's presence in modern medicine, their actual understanding of AI applications, limitations, and ethical implications remains superficial [17, 18]. This area requires immediate attention due to the exponential rise of AI in diagnostics, decision support systems, and instructional tools. Institutional efforts toward equity have been successful; the lack of gender inequalities also shows that interventions can be broadly implemented without requiring gender-specific customization [19]. In the meantime, subpar results in AI and cybersecurity highlight deficiencies in teacher knowledge or structured curriculum content [20]. Integrating digital literacy into professional training is crucial for lowering inequities and enhancing healthcare

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procedures, as emphasized in a recent scoping review. Literature also suggests the effectiveness of interactive teaching strategies, gamification, and curriculum mapping in improving digital health literacy among future healthcare professionals. These innovative methods can bridge the gap between theoretical knowledge and real-world application [12, 21]. Beyond academic competence, digital literacy plays a transformative role in achieving health equity. By equipping students with digital skills, institutions can help reduce disparities in healthcare access and empower future professionals to deliver more equitable and inclusive care [22]. Modules on cybersecurity awareness, data protection regulations, and AI applications in medicine should be given top priority by curriculum writers through interactive workshops or interdisciplinary partnerships [9].

This study has certain limitations. This cross-sectional design, based on a self-administered questionnaire, precludes inferring causal and/or temporal relationships between digital literacy and the variables being assessed, and self-reported responses may be subject to social desirability bias and recall bias, thereby possibly leading participants to overestimate or underestimate their actual skills, especially in newer fields like AI and Cybersecurity; in addition, the data was collected from a single institution (Lahore Medical College and Institute of Dentistry, Lahore) using non-probability convenience sampling, which may hamper the generalizability of the findings to other institutions and areas within Pakistan where curricular exposure to digital tools or technology infrastructure might vary. Digital competency ought to be required as a fundamental undergraduate accomplishment by regulatory organizations such as PM and DC. These competencies will be further reinforced by faculty training programs that incorporate digital resources into instruction.

CONCLUSIONS

Undergraduate students have a modest level of digital literacy in most disciplines. However, significant deficiencies in cybersecurity and artificial intelligence skills point to important areas for curriculum improvement. To prepare skilled and future-ready healthcare practitioners, undergraduate programs must incorporate structured digital literacy training, with a special emphasis on AI, data security, and ethical digital practice.

Authors' Contribution

Conceptualization: HS, SI
Methodology: HS, ZA, SI
Formal analysis: ZA, HK, FA, NW
Writing and Drafting: HS, HK, NW
Review and Editing: HS, NW, ZA, HK, FA, SI

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflicts of Interest

All the authors declare no conflict of interest.

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