

Original Article

Digital Health Knowledge, Attitudes, and Practices Among Undergraduate Nursing Students: A Comparative Study of Public and Private Colleges in Mirpurkhas, Sindh, Pakistan

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ABSTRACT

Background: Digital health technologies are increasingly transforming healthcare delivery, requiring healthcare professionals to possess adequate digital competencies. Nursing students, as future healthcare providers, must develop sufficient knowledge, positive attitudes, and effective practices related to digital health technologies to ensure safe and efficient patient care in technology-driven healthcare systems. However, limited evidence exists regarding digital health readiness among nursing students in developing regions such as Pakistan. **Objective:** This study aimed to evaluate the levels of digital health knowledge, attitudes, and practices among undergraduate nursing students and to examine differences between public and private institutions as well as across academic years. **Methods:** A comparative cross-sectional study was conducted among 254 undergraduate nursing students enrolled in selected public and private nursing colleges in Mirpurkhas, Sindh, Pakistan. Data were collected using a structured self-administered questionnaire based on a five-point Likert scale and analyzed using IBM SPSS version 27. Descriptive statistics were used to summarize variables, while independent samples t-tests and one-way ANOVA were used to compare group differences. Pearson correlation analysis was performed to assess relationships among knowledge, attitudes, and practices. **Results:** The mean scores for knowledge (3.30 ± 0.75), attitudes (3.26 ± 0.56), and practices (3.46 ± 0.86) indicated moderate levels across all domains. Significant differences were observed between public and private institutions in knowledge ($p = 0.031$) and attitudes ($p = 0.024$), while practices showed no significant difference ($p = 0.189$). Significant variations were also found across academic years for knowledge ($p = 0.028$) and attitudes ($p = 0.003$). Strong positive correlations were identified between knowledge and attitudes ($r = 0.754$), knowledge and practices ($r = 0.688$), and attitudes and practices ($r = 0.698$), all statistically significant ($p < 0.001$). **Conclusion:** Undergraduate nursing students demonstrated moderate digital health knowledge, attitudes, and practices. Strengthening digital health literacy and informatics education within nursing curricula may enhance students' preparedness for technology-driven healthcare systems. **Keywords:** Digital health; digital health literacy; nursing students; knowledge attitude practices; telemedicine; health informatics.

"Cite this Article" | Received: 13 July 2025; Accepted: 16 December 2025; Published: 31 December 2025.

Author Contributions: Inshal Anwar, Areeba & Nimra conceptualized the study and developed the research framework. Irfan Ali Chandio, Areeba & Inshal designed the study methodology, Inshal Anwar, Areeba & Nimra conducted data collection at participating colleges. Irfan Ali Chandio performed statistical analysis and interpreted the results. Inshal Anwar, Areeba, Nimra & Irfan Ali prepared the initial manuscript draft & Sheela Davi Malhi, Dileep Kumar Malhi revised the manuscript critically for intellectual content. **Ethical Approval:** Ethical approval for the study was obtained from the Institutional Review Board of the College of Nursing Female Mirpurkhas (IRB/CONF/05/25-11-25). **Informed Consent:** Written informed consent was obtained from all participants; **Conflict of Interest:** The authors declare no conflict of interest; **Funding:** No external funding; **Data Availability:** Available from the corresponding author on reasonable request; **Acknowledgments:** The authors would like to express their sincere gratitude to the administration of the public and private nursing colleges in Mirpurkhas, Sindh, Pakistan, for granting permission to conduct this study. The authors also extend their gratitude to the undergraduate nursing students for their participation, as well as to the faculty and colleagues whose guidance and support were invaluable in completing this research.

INTRODUCTION

Digital health technologies have rapidly transformed healthcare delivery by enabling new approaches to patient management, communication, and data-driven clinical decision-making. Tools such as telemedicine platforms, electronic health records, mobile health applications, wearable monitoring devices, and artificial intelligence assisted systems are increasingly integrated into modern health

systems to enhance accessibility, efficiency, and quality of care. The adoption of these technologies has expanded globally as health systems seek to improve coordination of services, facilitate remote care, and manage large volumes of clinical data more effectively (1). Digital health is launched by different countries, for example, the Saudi Vision 2030 and the National Transformation Program (NTP) were launched in 2015 to modernize healthcare systems through technology and innovation (2). Digital therapeutics can be defined as any type of app, software or digital device that can support the treatment of disease through patient Practices modification and remote monitoring to improve chronic disease outcomes (3).

To achieve high standards of quality nursing care, all nurses are supposed to follow the principle of developing and maintaining clear and understandable documentation so that everyone can read and understand patients' status and progress (4). The use of technology in healthcare settings has been identified as a crucial priority in many countries to provide quality healthcare services, more especially in many developed countries where they invested a lot in the e-health system (5). In this connection, the digital health technologies are an integral part of the healthcare environment associated with considerable benefits including the storage and management of vast amounts of health data, coordinated patient care, improved access and quality of patient data and improved interdisciplinary health team communication (6).

A growing body of literature depicts that one of the contributory factors to the failure of eHealth is the fact that most healthcare cadres have low levels of computer literacy and skills to use the information and communication technologies (ICTs) required for the implementation of eHealth (7). However, nursing students in different countries perceive the use of the internet to be useful (8). Digital competencies are essential for nurses to actively participate in the digitization of healthcare systems. Therefore, it is important to assess their skill levels to identify strengths and areas for improvement (9). The adoption of eHealth in healthcare services is one of the steps for opening doors towards the implementation of digital technologies (10). WHO developed a framework that includes a wide range of digital tools and interventions, such as computers and smart mobile phones to intangible products such as software, web-based platforms, telemonitoring, and algorithms, e.g., artificial intelligence (AI). Despite its potential effectiveness, digitalization is not fully implemented in clinical practice (WHO, 2018; and Elsayed & Sleem, 2020) (11).

Hence, digital health literacy appears as a new concept, which can be implicit as "an extension of health literacy within the context of technology or electronic sources of information to understand and address any health problem" (11). Nurses are playing an important role as care providers in every sphere of healthcare systems, globally. With the recent digital health revolution, nurses are forced or pushed to adapt to innovative technological devices, machinery, and equipment and also exchange knowledge, skills, and education in nursing care by the health industry market forces (12). Digital tools, incorporated by the term health information technology, seem indispensable for today's patient management and professional communication. "Digital Health" implies a lot more (13) in providing quality healthcare services to health systems and better patient outcomes.

The use of technology in healthcare settings has been identified as a crucial priority in many countries to provide quality healthcare services, more especially in many developed countries where they invested a lot in the e-health system (5). Although eHealth encourages communication between healthcare providers and the clients and sharing of information and knowledge between healthcare providers, the lack of a clear eHealth strategy remains the major barrier that contributes to poor healthcare quality (14). Various international examples have already reported on courses and electives in undergraduate healthcare academia, usually with a focus on a defined field of the digital health sector (13).

In a study conducted in Uganda, the researchers identified that most of the eHealth applications and products were running in silos, not interoperable, and remained limited in sharing of information and services. A prevalent literature shows that one of the contributory factors to the failure of eHealth is the

fact that most healthcare cadres have low levels of computer literacy and skills to use the information and communication technologies (ICTs) required for the implementation of eHealth (7, 14). The literature also suggests that there is an increasing need for the implementation of eHealth. Both eHealth and mHealth contribute to healthcare services by ensuring that healthcare services are provided in a cost-effective and secure manner. The adoption of eHealth in healthcare services is one of the steps for opening doors towards the implementation of digital technologies. With these highlighted potential encouraging benefits of eHealth, it has been found that eHealth poses a positive influence on improving the efficiency and quality of healthcare services. Moreover, eHealth or digital health technologies have been proven to provide opportunities to strengthen health systems (15).

The global health care sector is also placing great importance on the adoption and utilization of health information technology, making it a top priority in healthcare transformation plans. To successfully implement and utilize these technologies, healthcare professionals and students need to be educated in health informatics and computer literacy (16).

PROBLEM STATEMENT

With the increasing use of digital health technology in healthcare settings, nursing students need to possess adequate knowledge, positive attitudes, and effective practice to provide sufficient and advanced patient care. Therefore, assessing these elements among undergraduate nursing students in public and private colleges of Mirpurkhas will help in identifying the gaps in digital health competencies, guiding in curriculum development, and enhancing preparedness of the future healthcare providers for modern healthcare delivery with positive outcomes.

PURPOSE OF THE STUDY

The present study aimed to evaluate the level of knowledge, attitudes, and practices related to digital health among undergraduate nursing students in public and private nursing colleges in Mirpurkhas, Sindh, Pakistan.

OBJECTIVES OF THE STUDY

To determine the level of knowledge regarding digital health among undergraduate nursing students in selected public and private colleges of Mirpurkhas, Sindh, Pakistan.

To assess nursing students' attitudes toward the use of digital health technologies in selected public and private colleges of Mirpurkhas.

To evaluate the Practices and utilization of digital health tools among nursing students in selected public and private colleges of Mirpurkhas.

To determine the relationship between knowledge, attitude, and Practices regarding digital health among nursing students in selected public and private colleges of Mirpurkhas.

MATERIAL AND METHODS

A comparative cross-sectional observational study was conducted to assess knowledge, attitudes, and practices related to digital health technologies among undergraduate nursing students enrolled in selected public and private nursing colleges in Mirpurkhas, Sindh, Pakistan. The cross-sectional design was chosen because it allows the simultaneous measurement of exposure variables and outcome variables within a defined population at a single point in time and is widely used in educational and health-behavior research to examine associations between knowledge, attitudes, and practices (25). The study setting included accredited nursing institutions in Mirpurkhas offering the Bachelor of Science in Nursing (BSN) Generic program. Both public and private sector colleges were included in order to

enable comparison between institutional contexts and to examine potential variations in digital health exposure across different academic environments.

The study population comprised undergraduate BSN students enrolled from first year to final year in the selected institutions. Eligibility criteria included currently registered BSN Generic students who were present during the data collection period and willing to participate voluntarily. Students enrolled in other nursing programs, those absent during the survey period, or those who declined participation were not included in the study. Participants were recruited using a non-probability convenience sampling approach because it allowed access to a large number of students across multiple academic years within the available timeframe. Recruitment was conducted through coordination with institutional administrators and faculty members. An invitation explaining the study purpose, voluntary nature of participation, and confidentiality protections was shared with students through official academic WhatsApp groups used for educational communication. Interested students accessed the survey through a secure online questionnaire link and were able to complete the survey electronically using personal mobile devices or computers. Participation was voluntary, and digital informed consent was obtained before respondents could proceed to the questionnaire.

The required sample size was determined using the RaoSoft sample size calculator based on an estimated population of undergraduate nursing students within the selected institutions, a 95% confidence level, and a 5% margin of error. The calculation yielded a minimum required sample size of 254 participants. This sample size was considered adequate to estimate the prevalence of knowledge, attitudes, and practices related to digital health technologies with acceptable precision and to permit subgroup comparisons between public and private institutions as well as across academic years. A total of 254 completed responses were obtained and included in the final analysis.

Data were collected using a structured self-administered questionnaire adapted from previously validated instruments designed to assess digital health knowledge, attitudes, and practices among healthcare professionals and nursing students (9,26). The questionnaire was developed based on frameworks outlined in the World Health Organization Global Strategy on Digital Health and existing digital health literacy measurement tools (11). The instrument consisted of two main sections. The first section collected demographic and academic information including age, gender, marital status, academic year of study, and type of institution (public or private). The second section assessed digital health knowledge, attitudes, and practices using a series of items rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Knowledge items evaluated respondents' awareness and understanding of digital health technologies such as telemedicine, electronic health records, mobile health applications, and online health information systems. Attitude items measured perceptions regarding the usefulness, importance, and willingness to use digital health technologies in healthcare practice. Practice items assessed the frequency with which students engaged in activities such as searching for health information online, using digital platforms for academic learning, or interacting with digital health tools.

Composite scores for knowledge, attitude, and practice domains were calculated by averaging the item responses within each domain. Domain scores therefore ranged from 1 to 5, with higher scores indicating greater knowledge, more positive attitudes, or more frequent digital health practices. For interpretive purposes, mean scores were categorized into three levels: low (1.00–2.33), moderate (2.34–3.66), and high (3.67–5.00). The questionnaire was reviewed by academic experts in nursing education and health informatics to ensure content validity and clarity of wording. The online format prevented submission of incomplete questionnaires, thereby minimizing missing data. Data were automatically recorded in a secure spreadsheet through the Google Forms platform and exported for statistical analysis.

Several procedural steps were implemented to minimize potential sources of bias. Standardized instructions were provided to all participants, and the questionnaire was self-administered to reduce

interviewer bias. The survey was anonymous to decrease social desirability bias and encourage honest responses. Participation was voluntary, and students were informed that declining participation would not affect their academic standing. Restricting survey access to institutional groups helped ensure that only eligible nursing students could participate. Data were screened for duplicate entries and inconsistencies before analysis to maintain data integrity. Potential confounding variables such as age, gender, academic year, and type of institution were recorded and considered in the statistical analysis to evaluate group differences.

Statistical analysis was performed using IBM Statistical Package for the Social Sciences (SPSS) version 27. Descriptive statistics were used to summarize participant characteristics and digital health knowledge, attitude, and practice scores. Continuous variables were reported as means and standard deviations, while categorical variables were presented as frequencies and percentages. Independent samples t-tests were conducted to compare mean knowledge, attitude, and practice scores between students from public and private institutions.

One-way analysis of variance (ANOVA) was used to examine differences in these scores across academic years. Post-hoc pairwise comparisons were conducted to identify specific group differences where significant ANOVA results were observed. Pearson correlation analysis was performed to evaluate the strength and direction of relationships among knowledge, attitude, and practice scores. Statistical significance was determined using a two-tailed p-value threshold of less than 0.05. Prior to analysis, data were assessed for completeness and plausibility, and descriptive screening was conducted to detect potential outliers.

Ethical approval for the study was obtained from the Institutional Review Board of the College of Nursing Female Mirpurkhas (IRB/CONF/05/25-11-25). Permission to conduct the study was also obtained from the administrations of participating institutions.

All participants received an explanation of the study purpose, confidentiality measures, and their right to withdraw at any time without consequences. No identifying personal information was collected, and all data were analyzed in aggregate form to protect participant anonymity. The study was conducted in accordance with recognized ethical principles for research involving human participants.

To ensure reproducibility and data integrity, standardized data collection procedures were applied across all participating institutions. The questionnaire items, scoring procedures, and statistical analysis approach were documented in advance to maintain methodological transparency. Data were stored securely and analyzed using validated statistical software. The structured methodology and clearly defined operational definitions allow replication of the study in other educational settings to evaluate digital health competencies among nursing students in comparable contexts.

RESULTS

A total of 254 undergraduate nursing students were included in the analysis. As shown in Table 1, female students constituted the majority of the sample, accounting for 180 participants (70.9%), whereas 74 participants (29.1%) were male. Most respondents were aged 21-23 years, comprising 165 students (65.0%), followed by 49 students (19.3%) aged 24-30 years and 40 students (15.7%) aged 17-20 years. With respect to academic level, third-year students represented the largest proportion of the sample, with 80 participants (31.5%), followed by fourth-year students with 75 participants (29.5%), second-year students with 50 participants (19.7%), and first-year students with 49 participants (19.3%).

The vast majority of respondents were unmarried, comprising 238 students (93.7%), while only 16 students (6.3%) were married. In terms of institutional distribution, 149 students (58.7%) were enrolled in public colleges and 105 students (41.3%) in private colleges.

Table 2 presents the descriptive statistics for the three main study domains. The mean knowledge score was 3.30 with a standard deviation of 0.75, indicating a moderate level of digital health knowledge among the participants. The mean attitude score was 3.26 ± 0.56 , also falling within the moderate range, suggesting that students generally held moderately positive attitudes toward digital health technologies. Among the three domains, practices yielded the highest mean score at 3.46 ± 0.86 , although this too remained within the moderate category.

Overall, these findings suggest that while undergraduate nursing students demonstrated some familiarity with digital health concepts and reported a generally favorable orientation toward digital technologies, the levels were not high, indicating room for further academic strengthening.

As shown in Table 3, statistically significant differences were observed between students from public and private institutions in both knowledge and attitude scores. Public college students demonstrated a higher mean knowledge score of 3.39 ± 0.60 compared with 3.17 ± 0.89 among private college students. This difference of 0.22 points was statistically significant ($t = -2.178, p = 0.031$), with a 95% confidence interval ranging from -0.418 to -0.021. Likewise, the mean attitude score was higher among public college students (3.32 ± 0.50) than among private college students (3.15 ± 0.62), with a mean difference of 0.17 points. This difference was also statistically significant ($t = -2.274, p = 0.024$), and the 95% confidence interval ranged from -0.312 to -0.022.

In contrast, the mean practices score was 3.52 ± 0.70 for public college students and 3.37 ± 1.03 for private college students, yielding a smaller mean difference of 0.15 points that was not statistically significant ($t = -1.319, p = 0.189$), with a 95% confidence interval from -0.384 to 0.076. These findings indicate that students from public institutions had modestly higher knowledge and more favorable attitudes toward digital health technologies, whereas actual practices did not differ significantly by institutional type.

The variation in knowledge scores across academic years is summarized in Table 4. One-way ANOVA demonstrated a statistically significant difference in knowledge across first-, second-, third-, and fourth-year students ($F = 3.084, p = 0.028$). The between-group sum of squares was 5.055 with 3 degrees of freedom, producing a mean square of 1.685, while the within-group sum of squares was 136.612 with 250 degrees of freedom and a mean square of 0.546.

This result indicates that knowledge regarding digital health technologies differed significantly across year of study, suggesting that academic progression was associated with variation in knowledge levels.

A similar pattern was observed for attitude scores in Table 5. One-way ANOVA showed a statistically significant difference in attitudes across the four academic years ($F = 4.841, p = 0.003$). The between-group sum of squares was 4.402 with 3 degrees of freedom, corresponding to a mean square of 1.467, whereas the within-group sum of squares was 75.792 with 250 degrees of freedom and a mean square of 0.303. The relatively smaller p-value for attitude compared with knowledge suggests stronger evidence of variation in attitudes by academic year, indicating that students' perceptions of digital health technologies were not uniform across the different levels of study.

In contrast, Table 6 shows that practices scores did not vary significantly across academic year ($F = 1.513, p = 0.212$). The between-group sum of squares was 3.344 with 3 degrees of freedom, and the within-group sum of squares was 184.219 with 250 degrees of freedom. The corresponding mean squares were 1.115 and 0.737, respectively. Since the p-value exceeded the 0.05 threshold, the null hypothesis was not rejected, indicating that students from different academic years reported relatively similar levels of digital health practices despite the observed differences in knowledge and attitudes.

The post-hoc LSD comparisons presented in Table 7 further clarify the academic-year differences in knowledge scores. First-year students had significantly higher scores than second-year students, with a mean difference of 0.420 (SE = 0.149, $p = 0.005$), and the 95% confidence interval ranged from 0.128 to 0.713. Similarly, fourth-year students scored significantly higher than second-year students, with a mean

difference of 0.324 (SE = 0.135, $p = 0.017$), and the 95% confidence interval ranged from 0.058 to 0.590. No statistically significant differences were found between first- and third-year students (mean difference = 0.207, $p = 0.125$), first- and fourth-year students (mean difference = 0.096, $p = 0.479$), second- and third-year students (mean difference = -0.214, $p = 0.110$), or third- and fourth-year students (mean difference = -0.110, $p = 0.353$). These pairwise findings suggest that the second-year group had comparatively lower knowledge scores than both first- and fourth-year students, while the remaining year groups did not differ significantly from one another.

Table 1. Demographic characteristics of study participants (n = 254)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	74	29.1
	Female	180	70.9
Age (years)	17–20	40	15.7
	21–23	165	65.0
	24–30	49	19.3
Academic Year	1st year	49	19.3
	2nd year	50	19.7
	3rd year	80	31.5
	4th year	75	29.5
Marital Status	Unmarried	238	93.7
	Married	16	6.3
Institution	Private	105	41.3
	Public	149	58.7

Table 2. Descriptive statistics of digital health knowledge, attitude, and practices (n = 254)

Variable	Mean	Standard Deviation (SD)	Interpretation
Knowledge	3.30	0.75	Moderate
Attitude	3.26	0.56	Moderate
Practices	3.46	0.86	Moderate

Table 3. Comparison of knowledge, attitude, and practices between public and private institutions

Variable	Public Mean ± SD	Private Mean ± SD	Mean Difference	t-value	p-value	95% CI (Lower–Upper)
Knowledge	3.39 ± 0.60	3.17 ± 0.89	0.22	-2.178	0.031	-0.418 to -0.020
Attitude	3.32 ± 0.50	3.15 ± 0.62	0.17	-2.274	0.024	-0.312 to -0.022
Practices	3.52 ± 0.70	3.37 ± 1.03	0.15	-1.319	0.189	-0.384 to 0.076

Table 4. One-way ANOVA for knowledge scores across academic years

Source	Sum of Squares	df	Mean Square	F-value	p-value
Between Groups	5.055	3	1.685	3.084	0.028
Within Groups	136.612	250	0.546		
Total	141.668	253			

Table 5. One-way ANOVA for attitude scores across academic years

Source	Sum of Squares	df	Mean Square	F-value	p-value
Between Groups	4.402	3	1.467	4.841	0.003
Within Groups	75.792	250	0.303		
Total	80.195	253			

Table 6. One-way ANOVA for practices scores across academic years

Source	Sum of Squares	df	Mean Square	F-value	p-value
Between Groups	3.344	3	1.115	1.513	0.212
Within Groups	184.219	250	0.737		
Total	187.563	253			

Table 7. Post-hoc LSD comparisons for knowledge scores across academic years

Comparison	Mean Difference	Std. Error	P-value	95% CI Lower	95% CI Upper
1st Year vs 2nd Year	0.420	0.149	0.005	0.128	0.713
1st Year vs 3rd Year	0.207	0.134	0.125	-0.057	0.471
1st Year vs 4th Year	0.096	0.136	0.479	-0.171	0.364
2nd Year vs 3rd Year	-0.214	0.133	0.110	-0.476	0.049
2nd Year vs 4th Year	-0.324	0.135	0.017	-0.590	-0.058
3rd Year vs 4th Year	-0.110	0.119	0.353	-0.345	0.124

Table 8. Pearson correlation analysis between knowledge, attitude, and practices (n = 254)

Variable	Knowledge (r)	Attitude (r)	Practices (r)	p-value
Knowledge	1	0.754	0.688	<0.001
Attitude	0.754	1	0.698	<0.001
Practices	0.688	0.698	1	<0.001

Table 8 presents the correlation analysis among knowledge, attitude, and practices. A strong positive correlation was observed between knowledge and attitude ($r = 0.754$, $p < 0.001$), indicating that students with higher digital health knowledge tended to report more positive attitudes toward digital health technologies. Knowledge was also positively correlated with practices ($r = 0.688$, $p < 0.001$), suggesting

that greater knowledge was associated with more frequent use of digital health-related practices. Similarly, attitude showed a strong positive correlation with practices ($r = 0.698$, $p < 0.001$). All correlations were statistically significant at the 0.001 level, demonstrating a consistent and meaningful relationship among the three domains. Numerically, the strongest association was between knowledge and attitude, followed by attitude and practices, and then knowledge and practices, although all three relationships were substantial in magnitude.

Taken together, the table findings show that undergraduate nursing students had moderate knowledge, attitudes, and practices related to digital health technologies, with practices having the highest mean score among the three domains. Public college students performed better than private college students in knowledge and attitude, but not in practices. Academic year was significantly associated with knowledge and attitude, although not with practices, and the correlation analysis demonstrated that the three domains were strongly and positively interrelated.

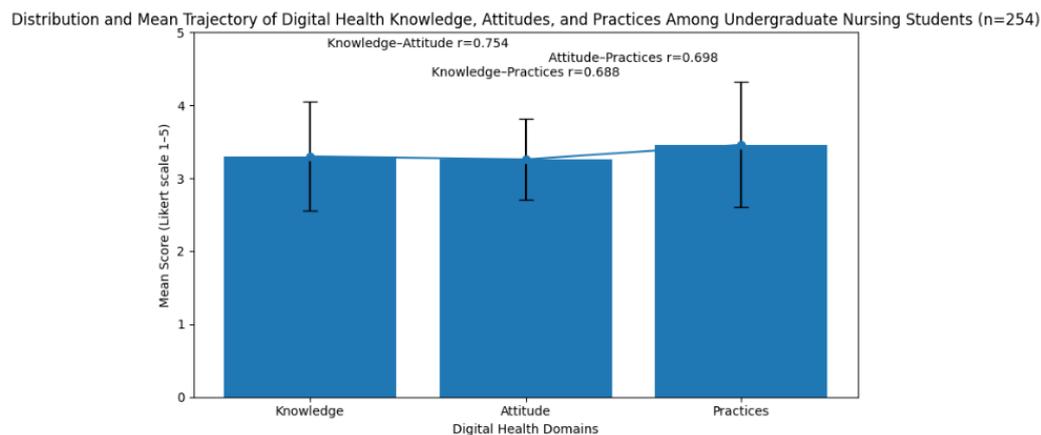


Figure 1 Distribution and Mean Trajectory of Digital Health Knowledge, Attitudes, and Practices Among Undergraduate Nursing Students (N=254)

The integrated visualization illustrates the comparative distribution and trajectory of mean scores across the three digital health domains among undergraduate nursing students ($n = 254$). Practices demonstrated the highest mean score (3.46 ± 0.86), followed by knowledge (3.30 ± 0.75) and attitude (3.26 ± 0.56). Although the overall pattern shows relatively similar moderate levels across domains, the trajectory indicates a slight increase from attitude to practices, suggesting that students may engage with digital health tools more frequently than their theoretical knowledge or perceptions alone might predict. The wider variability observed in practices ($SD = 0.86$) compared with knowledge ($SD = 0.75$) and attitude ($SD = 0.56$) indicates greater heterogeneity in students' real-world use of digital health resources. The figure also contextualizes the strong inter-domain relationships observed in the study: knowledge showed a strong positive correlation with attitude ($r = 0.754$), and substantial correlations with practices ($r = 0.688$), while attitude was also strongly correlated with practices ($r = 0.698$), all statistically significant ($p < 0.001$). These patterns suggest that although average scores remain within the moderate range, incremental improvements in digital health knowledge could be associated with meaningful gains in both attitudinal acceptance and practical engagement with digital health technologies among nursing students.

DISCUSSION

The present study assessed digital health-related knowledge, attitudes, and practices among undergraduate nursing students in public and private institutions in Mirpurkhas, Pakistan, and examined differences across institutional types and academic years. Overall, the findings revealed moderate levels across all three domains, with practices demonstrating the highest mean score (3.46 ± 0.86), followed by knowledge (3.30 ± 0.75) and attitude (3.26 ± 0.56). These results suggest that while nursing students demonstrate a reasonable level of engagement with digital health resources, their

theoretical understanding and perceptions remain only moderately developed. The findings are consistent with previous international studies reporting moderate digital health literacy and informatics competencies among nursing students, indicating that many students are familiar with basic digital tools but lack comprehensive training in advanced digital health systems and clinical informatics applications (8,17).

The moderate knowledge level observed in this study may reflect limited exposure to formal digital health education within undergraduate nursing curricula. Several studies have highlighted that although nursing students frequently use digital technologies for educational and information-seeking purposes, their understanding of structured digital health systems such as electronic health records, telehealth platforms, and digital clinical decision-support tools remains insufficient without targeted training (2,18). Educational programs that integrate health informatics and digital health competencies into nursing curricula have been shown to significantly improve students' digital literacy and readiness for technology-enabled healthcare environments (19). Therefore, the moderate knowledge levels identified in this study underscore the need for structured educational interventions that emphasize both theoretical understanding and practical application of digital health technologies.

Students in the present study also demonstrated moderately positive attitudes toward digital health technologies. This finding aligns with prior research indicating that younger populations and university students generally perceive digital technologies as beneficial tools for accessing health information, improving learning outcomes, and facilitating communication within healthcare systems (20). Positive attitudes toward digital health are important because they can influence students' willingness to adopt technological innovations in clinical practice. However, attitudes alone are insufficient to ensure effective technology integration unless accompanied by adequate knowledge and practical training. Studies have shown that students who receive hands-on exposure to digital health tools during their education are more likely to develop stronger confidence and acceptance of health information technologies (21).

The practices domain demonstrated the highest mean score among the three domains, suggesting that students frequently engage with digital platforms such as online health information sources, educational applications, and internet-based resources for academic learning. Similar patterns have been observed in previous studies where university students reported high levels of digital engagement despite having only moderate formal training in digital health systems (22). This discrepancy may reflect the widespread availability of internet-based health information and mobile technologies, which allow students to interact with digital health resources informally outside structured educational environments. Nevertheless, reliance on informal digital engagement without appropriate guidance may lead to inconsistent use of evidence-based digital health resources.

A key finding of the present study was the statistically significant difference in knowledge and attitudes between students from public and private nursing institutions. Students enrolled in public colleges demonstrated slightly higher knowledge (3.39 ± 0.60) and attitude scores (3.32 ± 0.50) compared with those from private colleges. Although the mean differences were modest, these findings may reflect variations in academic environments, faculty expertise, or institutional emphasis on digital health education. Previous research has indicated that institutional support, access to digital infrastructure, and availability of trained educators play important roles in shaping students' digital competencies and learning experiences (23). However, the absence of significant differences in practices between institutional groups suggests that students from both sectors engage similarly with digital health technologies in their daily academic activities.

The analysis of academic-year differences revealed significant variation in knowledge and attitude scores across study levels, while practices remained relatively consistent across years. These findings suggest that progression through the nursing program may contribute to gradual improvement in students' conceptual understanding and perceptions of digital health technologies. Similar trends have been

observed in other educational studies, where senior students demonstrated greater familiarity with health informatics and digital healthcare systems due to increased clinical exposure and academic experience (24). However, the absence of significant differences in practices across academic years suggests that students may begin using digital technologies early in their academic journey, primarily for information-seeking and learning purposes, independent of formal curricular progression.

Another important finding was the strong positive correlation between knowledge, attitudes, and practices related to digital health technologies. Knowledge demonstrated a strong correlation with attitude ($r = 0.754$, $p < 0.001$) and a substantial correlation with practices ($r = 0.688$, $p < 0.001$), while attitude also showed a strong correlation with practices ($r = 0.698$, $p < 0.001$). These findings support the conceptual assumptions of the Knowledge–Attitude–Practice (KAP) framework, which proposes that individuals' knowledge influences their attitudes and ultimately shapes behavioral practices (25). Similar relationships have been documented in previous studies examining digital health literacy among university students and healthcare professionals, where higher knowledge levels were associated with greater acceptance and utilization of digital health technologies (26). The strong correlations observed in this study highlight the importance of strengthening digital health knowledge among nursing students, as improved knowledge may positively influence both their perceptions and their practical engagement with digital healthcare tools.

LIMITATIONS

Despite its contributions, the study should be interpreted within the context of several limitations. The use of a cross-sectional design restricts the ability to establish causal relationships among knowledge, attitudes, and practices. The reliance on self-reported data may introduce response bias, including social desirability bias. Additionally, the study was conducted in selected institutions within a single geographic region, which may limit the generalizability of the findings to other nursing programs across Pakistan. Future research should consider multi-center studies with larger samples and longitudinal designs to explore how digital health competencies evolve throughout nursing education and clinical training.

CONCLUSION

This study evaluated digital health related knowledge, attitudes, and practices among undergraduate nursing students in public and private nursing colleges in Mirpurkhas, Pakistan. The findings indicate that students demonstrated moderate levels across all three domains, with practices slightly higher than knowledge and attitudes. Significant differences were observed between institutional types in knowledge and attitudes, while practices did not differ significantly. Academic progression was associated with differences in knowledge and attitudes but not practices. Strong positive correlations among knowledge, attitudes, and practices suggest that improving digital health knowledge may contribute to more favorable perceptions and increased engagement with digital health technologies. These findings highlight the importance of integrating digital health literacy, health informatics training, and technology-based learning strategies into undergraduate nursing education to better prepare future nurses for increasingly digital healthcare systems.

RECOMMENDATIONS

Curriculum Integration of Digital Health: Nursing education programs should include comprehensive digital health and informatics training in their undergraduate courses, emphasizing hands-on experience with telemedicine, electronic health records, and mobile health technologies.

Alignment with Global Digital Health Strategies: Nursing education programs need to align their training with global standards like WHO's Global Strategy on Digital Health, making certain that future nurses are digitally enabled.

Faculty Capacity Development: Educators must pursue ongoing professional development in digital health and health informatics to effectively mentor students in technology-driven clinical practice.

Strengthening Institutional Digital Infrastructure: Nursing colleges should invest in e-learning platforms, digital libraries, and clinical informatics tools to facilitate technology-enhanced learning environments.

Future Research Expansion: Future research should include larger sample sizes from various regions and examine other elements like institutional preparedness, digital training availability, and obstacles to the adoption of digital health among nursing students.

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