RJNMSR
Review Journal of Neurological & Medical Sciences Review

Volume 4, Issue 3, 2026

BEYOND DIGITAL LITERACY: HOW BS NURSING STUDENTS IN PAKISTAN VIEW THE INTEGRATION OF STEM INTO THEIR EDUCATION

STEM INTEGRATION IN BS NURSING EDUCATION

Nadia Sajid[1], Naila Baqir [2], Hafiz Yaseen Khan[*3], Syed Abdul Basit[4], Muhammad Alimullah[5], Rafiullah[6], Abdul Haseeb[7], Arsalan Maqsood[8]

[1]*Principal Farrukh Mukhtar, College of Nursing Multan*
[2]*Senior Nursing Instructor, Nishtar Medical University Multan.*
[*3]*Department of Health sciences, Yaseen Nexus Institute, Peshawar, Pakistan*
[4,5,6,7,8]*Department of Health sciences, Yaseen Nexus Institute, Peshawar, Pakistan*

[1]nadiasajid030@gmail.com, [2]naila.Baqir21@gmail.com, [*3]dryaseenkhan11@gmail.com, [5]alimullah930@gmail.com

Corresponding Author: *
Hafiz Yaseen Khan
DOI: http://doi.org/10.5281/zenodo.22109398

Received	Accepted	Published
31 January 2026	16 March 2026	30 March 2026

ABSTRACT

Background: *Contemporary nursing practice draws heavily on scientific knowledge, digital competence, data-informed decision-making, simulation, and clinical innovation. Embedding Science, Technology, Engineering, and Mathematics (STEM) within nursing education may build scientific reasoning, technological competence, problem-solving ability, and capacity for innovation. Because these are new curricular directions, understanding how students themselves view STEM integration is a necessary first step toward developing approaches suited to the Pakistani context.*

Objective: *To examine BS Nursing students' perceptions of STEM integration in their education, including the benefits and barriers they perceive, and to determine whether perceptions vary by academic year and by prior exposure to STEM-related learning.*

Methods: *A descriptive cross-sectional survey was conducted among 240 BS Nursing students enrolled in Years 1-4 at a Pakistani university. A 25-item, five-point Likert-scale questionnaire measured the perceived relevance of STEM, its educational benefits, students' confidence and readiness, and perceived barriers. Data were summarised using descriptive statistics and examined using Cronbach's alpha, an independent-samples t-test, one-way ANOVA, and Pearson correlation, with statistical significance set at $p < .05$.*

Results: *Participants had a mean age of 21.3 ± 1.7 years, and 68.3% were female. The overall perception score was 3.91 ± 0.52, reflecting generally favourable attitudes. STEM was valued most for its contribution to healthcare technology use (4.18 ± 0.67), clinical problem-solving (4.15 ± 0.71), and evidence-based practice (4.12 ± 0.69). The most frequently reported barriers were limited technological resources (72.9%), inadequate faculty training (68.8%), and increased curriculum workload (64.6%). Students with prior STEM exposure scored significantly higher than those without (4.04 ± 0.47 vs. 3.82 ± 0.54; $p = .001$), and scores rose significantly across academic years ($p = .009$).*

Conclusion: *BS Nursing students in this sample were broadly supportive of STEM integration. Embedding STEM content within existing courses, backed by faculty development, simulation-based learning, interdisciplinary teaching, and institutional resources, may support its implementation in Pakistani nursing education.*

Keywords: *STEM education; nursing education; nursing students; curriculum integration; digital health; clinical reasoning; interdisciplinary education; Pakistan*

1. Introduction

Nursing practice today is closely tied to science, technology, data, and innovation. Nurses regularly work with electronic health records, digital monitoring systems, telehealth platforms, clinical decision-support tools, simulation, mobile health applications, and, increasingly, artificial intelligence. As a result, nursing graduates need more than clinical knowledge and hands-on skills; they also need scientific reasoning, technological competence, the ability to interpret clinical data, problem-solving skills, and confidence in adapting to new healthcare technologies. International bodies have repeatedly stressed the need to prepare nurses for health systems that are becoming more digital and technology-dependent (World Health Organization [WHO], 2025, 2026).

Science, Technology, Engineering, and Mathematics (STEM) offers a useful framework for building these abilities. Within nursing education, STEM integration does not necessarily mean adding separate engineering or advanced mathematics courses to an already crowded curriculum. Rather, STEM-related knowledge and skills can be woven into existing nursing subjects and clinical learning activities. Scientific knowledge, for instance, underpins the understanding of pathophysiology and pharmacology; technology connects naturally with digital health and electronic documentation; quantitative skills support medication calculations, statistical reasoning, and interpretation of clinical data; and engineering thinking contributes to patient safety, medical-device use, ergonomics, workflow improvement, and healthcare innovation.

Digital and technology-related education has become an increasingly visible part of nursing preparation worldwide. A recent scoping review of digital health education identified notable gaps in how digital health content is taught to undergraduate and graduate nursing students and called for more systematic integration across nursing curricula (Kleib et al., 2024). In a related vein, a qualitative systematic review found that nursing students generally value digital technology for learning, although how well it is implemented depends on institutional support, curriculum design, available resources, and staff readiness (Ma et al., 2024). Evidence from mobile and online learning during and after the COVID-19 pandemic similarly points to measurable gains in nursing students' knowledge and skills when technology-supported methods are used appropriately (Chen et al., 2021; Kim et al., 2021; Kim & Kim, 2023), while transitions from campus-based to distance and digitally mediated learning have highlighted both the opportunities and the practical difficulties nursing students encounter when adapting to new technologies (Langegård et al., 2021; O'Connor et al., 2023). More recent evidence suggests that integration of artificial intelligence and digital-health competencies into undergraduate nursing curricula remains uneven, with faculty readiness, curriculum constraints, and unequal resources continuing to pose challenges.

These competencies are also recognised at the policy level. The WHO State of the World's Nursing 2025 report calls for sustained investment in nursing education and workforce development, noting that nursing programmes and faculty need adequate technical and financial support to prepare students to use electronic health records, telehealth, decision-support systems, mobile applications, robotics, and artificial intelligence. The report also points to the value of collaboration with disciplines such as computer science and engineering in strengthening nursing education (WHO, 2025). A subsequent WHO landscape analysis of digital health competency frameworks similarly maps common competency domains around data, informatics, communication,

technical proficiency, digital professionalism, and the effective use of digital tools in health practice and education (WHO, 2026), building on the WHO's earlier global strategic direction for nursing and midwifery, which identified education and workforce readiness as priority areas (WHO, 2021).

STEM-related competencies are particularly relevant to undergraduate nursing education in Pakistan. The revised Higher Education Commission curriculum for BS Nursing already covers several STEM-adjacent areas, including natural sciences, research, information and communication technology, quantitative learning, clinical practice, critical thinking, and evidence-based care (Higher Education Commission [HEC], 2024). The foundation for STEM integration therefore already exists within the nursing curriculum; the more pressing task may be building clearer links between scientific, technological, quantitative, and problem-solving skills and their application in nursing practice. Within Pakistan specifically, nursing students have shown generally positive awareness of and openness toward emerging technologies such as artificial intelligence in clinical practice, even as questions remain about how well curricula prepare them to use such tools (Sheraz et al., 2025), and digital learning approaches introduced during the COVID-19 pandemic were found broadly acceptable to health science students despite resource constraints (Soares & Nursalam, 2023).

Understanding students' perspectives matters before any curriculum change is introduced or strengthened. A curriculum can contain technology, research, science, or quantitative content without students necessarily recognising how these areas connect to their future professional roles. Student perceptions can therefore offer useful information about the perceived relevance of STEM, the educational benefits students expect, their confidence and readiness for STEM-related learning, and the barriers that might limit implementation. Such information can help educators and curriculum planners design approaches that are both relevant to students and realistic for the local educational context.

While research on individual components such as digital health, artificial intelligence, simulation, online learning, and nursing informatics continues to grow, comparatively little attention has been paid to STEM as a broader, integrated framework within undergraduate nursing education. This distinction matters because STEM brings together scientific reasoning, technological competence, quantitative understanding, problem-solving, and innovation, rather than focusing on a single technology or teaching method. Evidence on how BS Nursing students in Pakistan view this broader framework remains limited.

This study therefore examined BS Nursing students' perceptions of STEM integration in nursing education at a Pakistani university, focusing on the perceived relevance and educational benefits of STEM, students' confidence and readiness for STEM-related learning, and perceived barriers to implementation. The study also examined whether perceptions differed by academic year and by prior exposure to STEM-related activities.

2. Objectives

The main objective of this study was to assess how BS Nursing students perceive the integration of Science, Technology, Engineering, and Mathematics (STEM) into nursing education. Specifically, the study sought to: (i) assess students' views on the relevance of STEM to nursing education and clinical practice; (ii) identify the educational benefits students associate with STEM integration; (iii) assess students' confidence and readiness for STEM-related learning; (iv) identify the main barriers students perceive to STEM integration; and (v) examine whether STEM perception scores differed according to academic year and prior exposure to STEM-related learning or activities.

3. Research Questions

This study addressed the following questions: (1) How do BS Nursing students perceive the integration of STEM into nursing education? (2) What educational benefits do students associate with STEM integration? (3) What barriers do students perceive to integrating STEM into

nursing education? (4) How confident and ready do students feel about STEM-related learning? (5) Do STEM perception scores differ among students from different academic years? (6) Do STEM perception scores differ between students with and without prior exposure to STEM-related learning or activities?

4. Methods

4.1 Study Design

A descriptive cross-sectional survey design was used to examine BS Nursing students' perceptions of STEM integration in nursing education, including their views on its relevance and benefits, their confidence and readiness for STEM-related learning, and the barriers they perceived. Differences in perception scores by academic year and prior STEM exposure were also examined. Reporting followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidance for cross-sectional studies.

4.2 Study Setting and Participants

The study was conducted at a university in Pakistan offering a four-year Bachelor of Science in Nursing (BS Nursing) programme. The study population comprised undergraduate nursing students enrolled in Years 1 through 4. Students were eligible if they were currently enrolled in the programme, in any of the four academic years, willing to participate, and able to understand and complete the questionnaire. Students on extended leave, or whose questionnaires had a substantial amount of missing data, were excluded from the analysis.

4.3 Sampling and Sample Size

Eligible BS Nursing students across the four academic years were recruited using convenience sampling. A total of 240 students took part, drawn from Years 1 through 4, all of whom met the eligibility criteria and agreed to participate voluntarily. The final analytic sample consisted of 240 completed questionnaires suitable for analysis.

4.4 Survey Instrument

Data were collected using a structured 25-item questionnaire developed to capture students' perceptions of STEM integration in nursing education. The instrument covered four domains: relevance of STEM to nursing (7 items), perceived educational benefits (7 items), confidence and readiness for STEM-related learning (5 items), and perceived barriers to STEM integration (6 items). Each item was rated on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). Higher scores on the relevance, benefit, and confidence/readiness items reflected more favourable views, while higher scores on barrier items reflected greater perceived difficulty. Five experts in nursing and health education reviewed the questionnaire for clarity and content relevance, and a pilot test with 20 BS Nursing students was used to identify unclear wording and practical issues before minor revisions were made and the final version administered.

4.5 Reliability

Internal consistency was assessed using Cronbach's alpha. The overall questionnaire showed good internal consistency ($\alpha = 0.91$). Alpha values for the four sections were 0.86 (relevance), 0.89 (perceived educational benefits), 0.82 (confidence and readiness), and 0.84 (perceived barriers), indicating good internal consistency within each section.

4.6 Data Collection

Permission was obtained from the relevant university authorities before data collection began. Eligible students were informed about the purpose of the study and invited to take part voluntarily. The questionnaire was administered to participating students during the study period; students were told that participation was voluntary and that declining would carry no academic consequences. No personally identifying information was collected, and completed questionnaires were checked for completeness before being included in the analysis.

4.7 Ethical Considerations

Ethical approval was obtained from the relevant institutional ethics committee prior to data

collection. Participants were informed about the purpose of the study, the voluntary nature of participation, and their right to withdraw without academic consequence. Informed consent was obtained from all participants before questionnaire completion. No personally identifying information was collected, and all data were used solely for research purposes.

4.8 Data Analysis

Data were analysed using appropriate descriptive and inferential statistics. Categorical variables were summarised as frequencies and percentages, and continuous variables as means and standard deviations. Cronbach's alpha was used to assess internal consistency. An independent-samples t-test compared mean STEM perception scores between students with and without prior STEM exposure, and one-way analysis of variance (ANOVA) compared scores across the four academic years. Statistical significance was set at $p < .05$, and results are presented in tables for clarity.

5. Results

5.1 Participant Characteristics

A total of 240 BS Nursing students took part in the study. Ages ranged from 18 to 26 years, with a mean of 21.3 ± 1.7 years. Most participants were female (n = 164, 68.3%), and 76 (31.7%) were male. Participants were fairly evenly distributed across the four academic years: 60 (25.0%) from Year 1, 62 (25.8%) from Year 2, 60 (25.0%) from Year 3, and 58 (24.2%) from Year 4. Regarding prior STEM exposure, 96 (40.0%) students reported some STEM-related exposure before entering the nursing programme, while 144 (60.0%) reported none. Demographic and academic characteristics are presented in Table 1.

Table 1. Demographic and academic characteristics of participants (N = 240)

Characteristic	n	%
Age group		
18-20 years	91	37.9
21-23 years	124	51.7
24-26 years	25	10.4
Gender		
Female	164	68.3
Male	76	31.7
Academic year		
Year 1	60	25.0
Year 2	62	25.8
Year 3	60	25.0
Year 4	58	24.2
Previous STEM exposure		
Yes	96	40.0
No	144	60.0

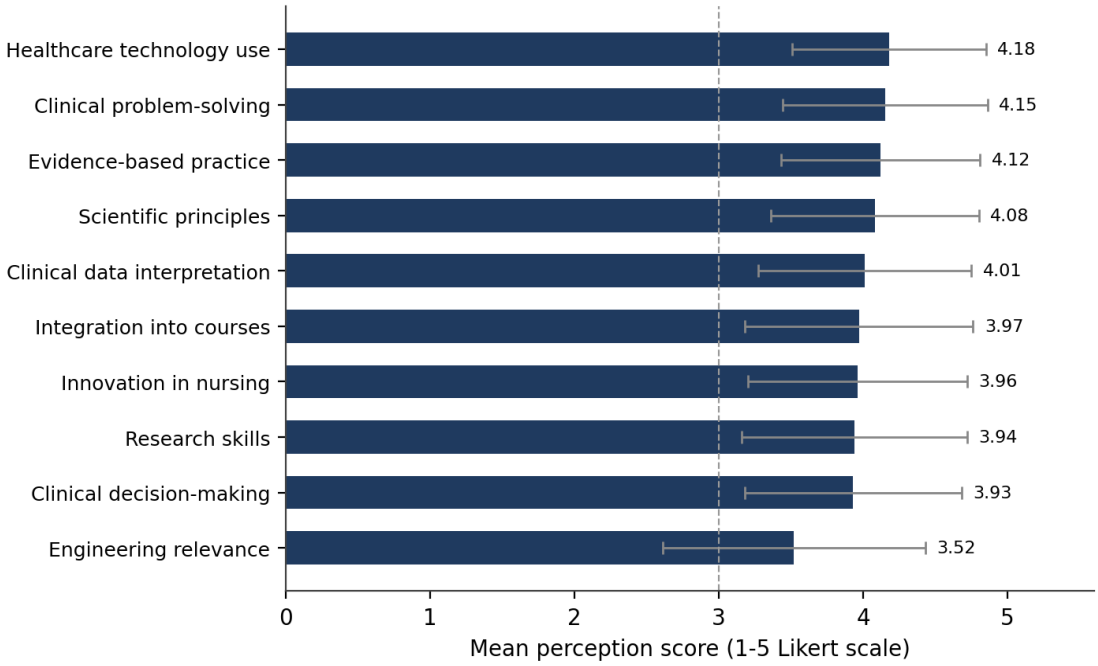
5.2 Students' Perceptions of STEM Integration

The overall perception score for STEM integration was 3.91 ± 0.52 out of 5, indicating generally favourable views. The highest-rated item concerned the potential of STEM to improve students' use of healthcare technology (4.18 ± 0.67), followed by its perceived contribution to clinical problem-solving (4.15 ± 0.71) and evidence-based nursing practice (4.12 ± 0.69). Students also rated STEM positively for understanding scientific principles, interpreting clinical data, integrating STEM-related learning into existing nursing courses, promoting innovation, strengthening research skills, and improving clinical decision-making. The lowest-rated item concerned the relevance of engineering concepts to everyday nursing practice, though its mean score remained above the scale midpoint (3.52 ± 0.91). Item-level scores are shown in Table 2 and Figure 1.

Table 2. Students' perceptions regarding STEM integration

Statement	Mean ± SD
STEM can improve students' use of healthcare technology	4.18 ± 0.67
STEM can strengthen clinical problem-solving	4.15 ± 0.71
STEM can support evidence-based nursing practice	4.12 ± 0.69
STEM can improve understanding of scientific principles in nursing	4.08 ± 0.72
STEM can improve interpretation of clinical data	4.01 ± 0.74
STEM-related learning should be integrated into existing nursing courses	3.97 ± 0.79
STEM can encourage innovation in nursing	3.96 ± 0.76
STEM can strengthen research skills	3.94 ± 0.78
STEM can improve clinical decision-making	3.93 ± 0.75
Engineering concepts are relevant to nursing practice	3.52 ± 0.91
Overall perception score	3.91 ± 0.52

Figure 1. Students' perceptions of STEM integration by item (mean ± SD)



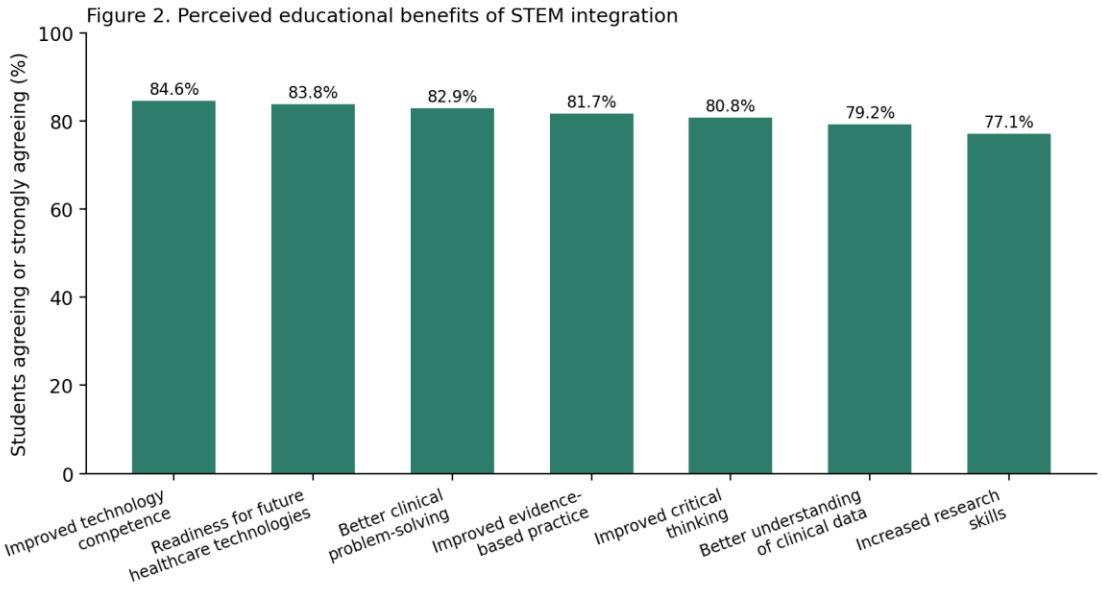
Note. Error bars represent ± 1 SD. The dashed line marks the scale midpoint (3.0).

5.3 Perceived Educational Benefits

Students reported several potential educational benefits of STEM integration. The most frequently endorsed benefit was improved technology competence, agreed or strongly agreed by 203 (84.6%) students, followed by greater readiness for future healthcare technologies (201, 83.8%) and better clinical problem-solving (199, 82.9%). Improved evidence-based practice and critical thinking were also commonly endorsed, by 196 (81.7%) and 194 (80.8%) students respectively. In addition, 190 (79.2%) students reported a better understanding of clinical data, and 185 (77.1%) reported increased research skills as a potential benefit. These findings are summarised in Table 3 and Figure 2.

Table 3. Perceived educational benefits of STEM integration

Perceived benefit	Agree/Strongly agree, n (%)
Improved technology competence	203 (84.6)
Greater readiness for future healthcare technologies	201 (83.8)
Better clinical problem-solving	199 (82.9)
Improved evidence-based practice	196 (81.7)
Improved critical thinking	194 (80.8)
Better understanding of clinical data	190 (79.2)
Increased research skills	185 (77.1)



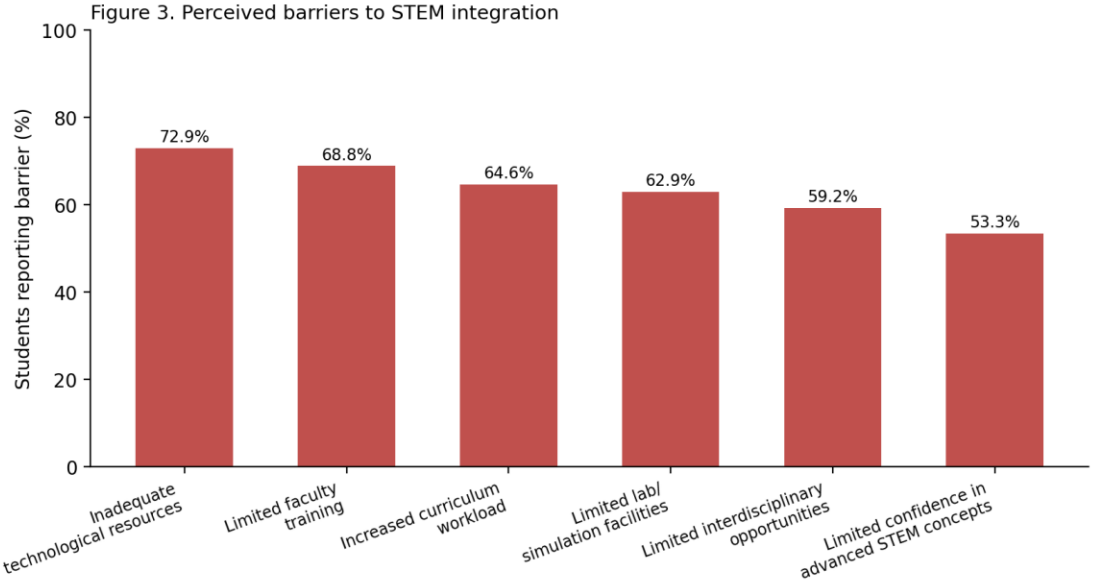
5.4 Perceived Barriers to STEM Integration

Despite generally positive perceptions, students identified several barriers to STEM integration. Inadequate technological resources was the most commonly reported barrier (175, 72.9%), followed by limited faculty training (165, 68.8%) and increased curriculum workload (155, 64.6%). Limited laboratory and simulation facilities were reported by 151 (62.9%) students, and 142 (59.2%) identified limited opportunities for interdisciplinary learning. A further 128 (53.3%) students reported limited confidence in advanced STEM concepts as a potential barrier. These findings are presented in Table 4 and Figure 3.

Table 4. Perceived barriers to STEM integration

Perceived barrier	n (%)
Inadequate technological resources	175 (72.9)
Limited faculty training	165 (68.8)
Increased curriculum workload	155 (64.6)
Limited laboratory/simulation facilities	151 (62.9)
Limited interdisciplinary learning opportunities	142 (59.2)
Students' limited confidence in advanced STEM concepts	128 (53.3)

Figure 3. Perceived barriers to STEM integration



5.5 Differences According to Previous STEM Exposure

Students with prior exposure to STEM-related activities reported higher mean perception scores than those without such exposure (4.04 ± 0.47 vs. 3.82 ± 0.54). An independent-samples t-test confirmed that this difference was statistically significant (t = 3.36, p = .001), indicating that students with prior STEM exposure held more favourable perceptions of STEM integration than those without prior exposure. The comparison is presented in Table 5.

Table 5. Comparison of STEM perception scores according to previous STEM exposure

Previous STEM exposure	n	Mean perception ± SD	t	p
Yes	96	4.04 ± 0.47	3.36	.001
No	144	3.82 ± 0.54		

5.6 Differences in Perception Across Academic Years

STEM perception scores also varied across academic years, rising from 3.78 ± 0.56 among Year 1 students to 4.03 ± 0.46 among Year 4 students. A one-way ANOVA showed a statistically significant difference across the four academic years (F = 3.91, p = .009), with post-hoc analysis indicating that the main difference lay between Year 1 and Year 4 students. Because this study used a cross-sectional design, these results reflect differences between academic-year groups at a single point in time and should not be interpreted as evidence that progression through the programme itself causes more favourable STEM perceptions.

6. Discussion

BS Nursing students in this study held generally positive views about integrating STEM into their education, with an overall perception score of 3.91 out of 5. The highest ratings went to the role of STEM in improving the use of healthcare technology, clinical problem-solving, and evidence-based practice. These results suggest students see STEM as relevant to modern nursing practice rather than as a separate, add-on subject area. This is consistent with recent literature indicating that digital health and technology-

related competencies are becoming increasingly central to nursing education, and that nursing students generally recognise the value of digital technology for learning and clinical practice, even though its implementation varies with the educational and institutional context (Ma et al., 2024).

The strong rating for healthcare technology is understandable given how routinely nurses now use electronic records, digital monitoring systems, telehealth, and clinical decision-support tools. However, STEM integration should not be reduced to teaching students how to operate digital devices; it should also help students understand the scientific reasoning behind clinical decisions, interpret data, identify problems, evaluate solutions, and use technology safely. Viewed this way, STEM can support a broader set of competencies needed for contemporary nursing practice. Recent work on digital health education similarly argues that nursing programmes need structured opportunities for students to build digital and technology-related competencies, rather than relying on informal or incidental exposure to technology (Kleib et al., 2024).

Clinical problem-solving and evidence-based practice were also rated highly, suggesting that students recognise a link between STEM-related skills and the reasoning nursing practice demands. Scientific thinking, data interpretation, critical thinking, and problem-solving all come into play when nurses assess patients, interpret clinical information, identify risks, and make care decisions. This points to STEM integration being most useful when connected directly to real clinical situations, rather than taught as separate theoretical content — an approach echoed in evidence on simulation-based interprofessional learning, where students' perceptions of collaboration improved most when technical content was embedded in realistic clinical scenarios rather than delivered abstractly (Stehlik et al., 2018).

One notable finding was that the item on the relevance of engineering concepts to nursing practice received the lowest mean score, although it remained above the scale midpoint. This may reflect lower familiarity with the engineering component of STEM, which can appear less directly related to nursing when presented as a separate technical discipline. Yet engineering-based thinking has clear practical applications in patient safety, ergonomics, medical devices, healthcare workflow, assistive technologies, and simulation. Nursing educators may therefore need to introduce engineering concepts through concrete clinical examples rather than as abstract technical knowledge.

Students with prior STEM exposure reported significantly higher perception scores than those without such exposure (4.04 vs. 3.82), suggesting that early exposure to STEM-related learning may be associated with more favourable views of STEM in nursing education. Because the design is cross-sectional, however, a causal interpretation is not possible: it cannot be determined whether prior STEM exposure improved students' perceptions, or whether students who were already more interested in STEM were simply more likely to have sought out that exposure.

Perception scores also rose across academic years, with Year 4 students scoring higher than Year 1 students. One possible explanation is that senior students have had more exposure to clinical practice, research activities, healthcare technology, and complex patient-care situations, which may help them appreciate the practical value of scientific, technological, and quantitative skills. This finding should nonetheless be interpreted cautiously, since the study compared different groups of students at a single point in time; a longitudinal design would be needed to determine whether individual students' perceptions actually shift as they progress through the programme.

The barriers students reported are an important part of the picture. Inadequate technological resources was the most frequently cited barrier, followed by limited faculty training and increased curriculum workload. Positive attitudes alone are unlikely to be sufficient for successful STEM integration: students may support the idea of STEM while still having limited practical opportunities to use technology, simulation, or digital platforms if the necessary infrastructure is not in place. Institutional resources, curriculum structure, and faculty preparedness have similarly been identified as key factors shaping the implementation of digital and technology-based

education in nursing elsewhere (Kleib et al., 2024; Ma et al., 2024), and difficulties adapting to digitally mediated learning environments have been documented even in well-resourced settings (Langegård et al., 2021; O'Connor et al., 2023).

Faculty preparation deserves particular attention. Teachers may need support in digital health, data interpretation, simulation, research methods, artificial intelligence, and interdisciplinary teaching. The WHO has similarly stressed the need for investment in nursing education and workforce development as health systems become more technology-dependent (WHO, 2025), and faculty development should therefore be treated as a core part of any plan to strengthen STEM-related learning.

Curriculum workload was another recurring concern. Nursing programmes already carry substantial theoretical, laboratory, and clinical requirements, and adding several new STEM courses could increase workload without necessarily improving learning outcomes. A more practical route may be to embed STEM-related competencies within existing subjects: quantitative skills linked to medication calculations and research methods, technology integrated into digital documentation and health information systems, scientific reasoning reinforced through pathophysiology and pharmacology, and engineering concepts introduced through medical devices, ergonomics, patient safety, and simulation. Interdisciplinary approaches, in which nursing students learn alongside students or content from computing, engineering, and other STEM-related fields, have also been associated with more favourable attitudes toward collaborative and integrated learning in related health-professions research (Köse Tosunöz et al., 2021; Rose et al., 2009).

Taken together, these findings suggest the central question is not whether STEM belongs in nursing education, but how it can be integrated in a way that is clinically relevant, manageable, and matched to available resources. The positive perceptions reported by students provide a useful starting point, while the barriers they identified point to specific areas institutions need to address. In the Pakistani context, a gradual approach that builds on STEM-related content already present in the nursing curriculum is likely to be more practical than introducing an entirely separate STEM programme.

7. Implications for Nursing Education in Pakistan

These findings carry several implications for nursing education in Pakistan. First, STEM-related learning should be connected to existing nursing subjects rather than introduced as additional standalone courses; this may ease pressure on an already demanding curriculum while helping students see how science, technology, quantitative skills, and problem-solving apply to nursing practice. Second, faculty development should be strengthened, with training in digital health, data interpretation, simulation, emerging technologies, research methods, and interdisciplinary teaching. Third, institutions should gradually expand access to relevant technological and simulation resources, including reliable internet, digital learning systems, simulation facilities, electronic health record training platforms, and appropriate software. Fourth, interdisciplinary learning could be encouraged through collaboration between nursing and fields such as computing, engineering, statistics, and other health sciences. Finally, STEM-related activities should remain closely tied to clinical practice, so that students can see their value in patient monitoring, clinical decision-making, medication safety, research, documentation, and healthcare innovation.

8. Strengths and Limitations

This study has several strengths. It examined STEM integration from the perspective of undergraduate nursing students across all four years of a BS Nursing programme, and covered multiple dimensions of STEM integration, including perceived relevance, educational benefits, confidence and readiness, barriers, prior STEM exposure, and academic year. The questionnaire also showed good internal consistency, with an overall Cronbach's alpha of 0.91. Several limitations should nonetheless be considered. The cross-sectional design does not permit conclusions about cause and effect. Convenience sampling may have introduced

selection bias, and the single-university setting means findings may not generalise to all BS Nursing students or nursing institutions in Pakistan. The data relied on students' self-reported perceptions, which may be shaped by personal experience or social desirability. Finally, although the questionnaire showed good internal consistency and was reviewed by experts and piloted before use, further validation in larger and more diverse nursing student samples would strengthen confidence in the measurement tool.

9. Conclusion

BS Nursing students in this study held generally positive views about integrating STEM into their nursing education, particularly recognising its potential to improve healthcare technology skills, clinical problem-solving, evidence-based practice, critical thinking, and readiness for future healthcare technologies. At the same time, students identified meaningful barriers, particularly inadequate technological resources, limited faculty training, curriculum workload, and limited simulation and interdisciplinary opportunities. Students with prior STEM exposure held more favourable perceptions, and perceptions also differed across academic years. Taken together, these findings suggest STEM integration may have a useful place in Pakistani nursing education, provided it is introduced practically and gradually. Rather than adding unnecessary courses, STEM-related skills can be woven into existing nursing subjects and clinical activities, with faculty development, institutional support, appropriate technology, simulation, and interdisciplinary learning central to successful implementation. Future studies should move beyond perceptions to examine whether STEM-integrated teaching improves students' actual knowledge, skills, confidence, clinical reasoning, and performance.

10. Recommendations

Based on these findings, STEM-related competencies should be integrated gradually into existing BS Nursing courses rather than added as unnecessary new subjects. Nursing institutions should invest in faculty development covering digital health, data literacy, simulation, artificial intelligence, research methods, and emerging healthcare technologies, alongside investment in simulation facilities, digital learning resources, reliable internet access, and appropriate educational technology. Interdisciplinary learning involving nursing, computing, engineering, statistics, and related disciplines may give students practical opportunities to apply STEM skills to healthcare problems, and STEM activities should be linked to clinical situations such as patient monitoring, medication safety, data interpretation, electronic documentation, research, and clinical decision-making. Students should be given opportunities to build these skills progressively across the four-year programme. Future research should include students from multiple nursing institutions and different regions of Pakistan, further validate the questionnaire in larger samples, and use objective measures of STEM-related knowledge and skills. Longitudinal and intervention studies would be particularly valuable in establishing whether STEM-integrated teaching improves students' learning, clinical reasoning, confidence, and professional performance.

Declarations

All procedures were conducted in accordance with the ethical standards of the institutional research committee and the 1964 Declaration of Helsinki and its later amendments.

Informed Consent: Informed consent was obtained from all individual participants included in the study.

Conflict of Interest: The authors declare that they have no conflict of interest.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data Availability Statement: The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Author Contributions: All authors contributed equally.

Acknowledgments: The authors thank the students who participated in this study and the university administration for permitting data collection.

REFERENCES

Chen, B., Wang, Y., Xiao, L., Xu, C., Shen, Y., Qin, Q., Li, C., Chen, F., Leng, Y., Yang, T., & Sun, Z. (2021). Effects of mobile learning for nursing students in clinical education: A meta-analysis. Nurse Education Today, 97, 104706. https://doi.org/10.1016/j.nedt.2020.104706

Higher Education Commission. (2024). Curriculum of BS Nursing (BSN) and MS Nursing (MSN), 2024. Government of Pakistan.

Kim, J. Y., & Kim, M. E. (2023). Can online learning be a reliable alternative to nursing students' learning during a pandemic? A systematic review and meta-analysis. Nurse Education Today, 122, 105710. https://doi.org/10.1016/j.nedt.2023.105710

Kim, S. Y., Kim, S. J., & Lee, S. H. (2021). Effects of online learning on nursing students in South Korea during COVID-19. International Journal of Environmental Research and Public Health, 18(16), 8506. https://doi.org/10.3390/ijerph18168506

Kleib, M., Arnaert, A., Nagle, L. M., Ali, S., Idrees, S., da Costa, D. D., Kennedy, M., & Darko, E. M. (2024). Digital health education and training for undergraduate and graduate nursing students: Scoping review. JMIR Nursing, 7, e58170. https://doi.org/10.2196/58170

Köse Tosunöz, İ., Karaçay Yıkar, S., Çerçer, Z., Kara, P., Arslan, S., & Nazik, E. (2021). Perceptions of interdisciplinary education and readiness for inter-professional education of nursing students: A sample of three different cities in Turkey. Nurse Education Today, 97, 104673. https://doi.org/10.1016/j.nedt.2020.104673

Langegård, U., Kiani, K., Nielsen, S. J., & Svensson, P.-A. (2021). Nursing students' experiences of a pedagogical transition from campus learning to distance learning using digital tools. BMC Nursing, 20, 23. https://doi.org/10.1186/s12912-021-00542-1

Ma, H., Niu, A., Tan, J., Wang, J., & Luo, Y. (2024). Nursing students' perception of digital technology in clinical education among undergraduate programs: A qualitative systematic review. Journal of Professional Nursing, 53, 49-56. https://doi.org/10.1016/j.profnurs.2024.04.008

O'Connor, S., Wang, Y., Cooke, S., Ali, A., Kennedy, S., Lee, J. J., & Booth, R. G. (2023). Designing and delivering digital learning (e-learning) interventions in nursing and midwifery education: A systematic review of theories. Nurse Education in Practice, 69, 103635. https://doi.org/10.1016/j.nepr.2023.103635

Rose, M. A., Smith, K., Veloski, J. J., Lyons, K. J., Umland, E., & Arenson, C. A. (2009). Attitudes of students in medicine, nursing, occupational therapy, and physical therapy toward interprofessional education. Journal of Allied Health, 38(4), 196-200.

Sheraz, S., Shuaib, N., Khan, S., Sultan, A., Shahid, A., & Hussain, H. (2025). Nursing student's awareness, intention and perception towards the utilization of artificial intelligence (AI) in nursing practice. Journal of the Pakistan Medical Association, 75(10), 1598-1600. https://doi.org/10.47391/JPMA.21258

Soares, D., & Nursalam. (2023). The use of digital technology in health learning during the COVID-19 pandemic: A systematic review. Journal of the Pakistan Medical Association, 73(2), S135-S139. https://doi.org/10.47391/JPMA.Ind-S2-32

Stehlik, P., Frotjold, A., & Schneider, C. R. (2018). Effect of hospital simulation tutorials on nursing and pharmacy student perception of interprofessional collaboration: Findings from a pilot study. Journal of Interprofessional Care, 32(1), 115-117. https://doi.org/10.1080/13561820.2017.1366897

World Health Organization. (2021). Global strategic directions for nursing and midwifery 2021-2025. https://www.who.int/publications/i/item/9789240033863

World Health Organization. (2025). State of the world's nursing 2025: Investing in education, jobs, leadership and service delivery. https://doi.org/10.2471/9789240110236

World Health Organization. (2026). Competency frameworks and standards for digital health: A landscape analysis. https://www.who.int/publications/i/item/9789240119765