



Exploring Digital Skills Among Pharmacy Students in Vocational Institutions: Evidence from Jiangsu, China

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Abstract

This study investigates the digital literacy of 306 pharmacy students from a vocational college in Jiangsu Province, China, using a mixed-methods design based on the European Digital Competence Framework (DigComp). Five core dimensions—information management literacy, technical proficiency, digital security awareness, digital communication and collaboration, and content creation and knowledge building—were assessed through a structured questionnaire and thematic analysis. The findings reveal a moderate overall level of digital competence ($M=3.03$), with relatively strong performance in technical proficiency and communication, but notable deficiencies in digital security and content creation. Significant disparities were observed across academic year, geographic background, and prior training experience, highlighting uneven development of digital literacy. Qualitative results further indicate insufficient access to pharmacy-specific digital tools and limited curriculum integration. The study concludes by recommending the embedding of digital literacy into core pharmacy courses, enhanced faculty development, and the adoption of authentic, context-driven digital learning tasks. These insights provide empirical evidence and practical implications for advancing the digital transformation of vocational pharmacy education in China.

Keywords: Digital literacy; Pharmacy education; Vocational colleges; DigComp framework; China

1. Introduction

The accelerating pace of digital transformation in healthcare has placed increasing demands on the digital competencies of pharmacy professionals. In modern pharmaceutical practice, digital tools are essential for managing patient data, operating digital prescription systems, and delivering telepharmacy services. Consequently, pharmacy education must evolve to integrate digital literacy as a core component of professional training. While countries such as the UK and those within the European Union have implemented systematic frameworks—such as the European DigComp—to define and develop digital competences in higher education, the integration of digital literacy into pharmacy curricula remains inconsistent, particularly within China's vocational education system.

In China, national strategies such as the 14th Five-Year Plan for the Development of the Digital Economy (State Council, 2022) and guidelines issued by the Ministry of Education

(2017) emphasize the urgent need to equip vocational students with practical digital skills to meet societal and industrial demands. These policies specifically call for enhanced integration of digital technology into teaching and learning across vocational institutions. However, despite this policy momentum, pharmacy students in higher vocational colleges often lack adequate training in essential digital skills. Existing curricula typically focus on foundational pharmaceutical knowledge and laboratory techniques, with limited attention given to digital competencies such as healthcare informatics, data analysis, digital communication, or content creation (Yahui & Manly, 2023; Hu et al., 2024).

Empirical studies further reveal a significant skills gap. For instance, Liu (2023) found that fewer than 40% of pharmacy students felt confident using digital prescription platforms or pharmaceutical databases. Internationally, similar concerns have been raised. Martzoukou et al. (2020) noted insufficient digital literacy among university students for both academic and everyday digital participation, while Tarhan (2022) identified low levels of digital security awareness among pharmacy students. These findings highlight a growing mismatch between educational preparation and real-world digital requirements in pharmacy practice.

In this context, the present study aims to investigate the current status of digital literacy among pharmacy students in vocational institutions in Jiangsu, China. By adopting the DigComp framework and focusing on five key competency dimensions—Information Management Literacy, Technical Proficiency, Digital Security Awareness, Digital Communication and Collaboration Skills, and Content Creation and Knowledge Building—this research seeks to identify competency gaps and provide practical recommendations. The findings will offer valuable insights for curriculum design, teaching practice, and policy alignment, ultimately contributing to the digital transformation of vocational pharmacy education in China.

To this end, the study addresses the following research questions:

What is the current level of digital literacy among pharmacy students in Jiangsu vocational institutions?

What specific digital competencies are well developed, and which require further improvement?

What challenges do students encounter in acquiring and applying digital skills?

What strategies can be implemented to enhance digital literacy in alignment with national policy and industry needs?

2. Theoretical Framework

This study adopts the European Commission's Digital Competence Framework for Citizens (DigComp) as the theoretical foundation for assessing pharmacy students' digital literacy. The DigComp framework offers a comprehensive and widely accepted model for understanding digital competence, integrating both technical and cognitive dimensions required for effective digital participation in academic and professional contexts.

Building on DigComp, this research identifies five core dimensions that are particularly relevant to vocational pharmacy education:

Information Management Literacy – the ability to search, evaluate, and apply digital information effectively in professional and academic settings.

Technical Proficiency – competence in using digital tools, platforms, and software for pharmacy-related tasks such as data entry, digital prescriptions, and electronic health records.

Digital Security Awareness – knowledge and practices related to data protection, privacy, and responsible digital behavior.

Digital Communication and Collaboration Skills – the ability to interact and work with others in digital environments, including telemedicine, remote consultation, and collaborative

software.

Content Creation and Knowledge Building – skills related to creating, modifying, and sharing digital content for education, professional communication, and public health promotion.

These dimensions provide the conceptual basis for the development of the questionnaire and the subsequent analysis. Each is operationalized through specific indicators adapted from validated scales in existing literature, allowing for a structured evaluation of students' digital competence across multiple domains. This framework supports a systematic investigation into current capability levels and informs the development of targeted strategies for curriculum and instructional improvement.

3. Literature Review

3.1 Defining and Framing Digital Literacy

Digital literacy has evolved from a narrow focus on basic computer skills to a comprehensive competency framework encompassing technical, cognitive, and ethical dimensions. Foundational definitions (Gilster, 1997; Martin & Grudziecki, 2006) have been extended through multi-dimensional models such as those by Eshet-Alkalai (2012) and the European Commission's DigComp 2.2 framework (Vuorikari et al., 2022). These models emphasize information management, content creation, collaboration, security awareness, and problem-solving. Contemporary literature (Spante et al., 2018; Detsom & Vehachart, 2021) further integrates social responsibility, digital ethics, and adaptability as key elements, highlighting digital literacy's role in navigating complex digital environments.

3.2 Digital Literacy in Higher and Vocational Education

Empirical studies consistently show that university students tend to overestimate their digital competencies (Gross & Latham, 2011; Martzoukou et al., 2020). Research across diverse contexts—from the UK and Spain to South Africa and Ukraine—reveals deficiencies in critical areas such as ethical information use, content creation, and digital problem-solving (Olatoye et al., 2021; Blayone et al., 2018). In China, although policies such as the Outline for Action to Enhance Digital Literacy promote digital inclusion, students still exhibit weak performance in advanced digital tasks, such as digital communication and content innovation (Sun, 2023; Ling, 2020). Notably, vocational students face additional challenges due to inconsistent curriculum design and limited access to institutional support (He & Zhu, 2017; Rao & Chen, 2024).

3.3 Digital Literacy in Pharmacy Education

Pharmacy education faces unique demands for digital competence. As digital prescription systems, telepharmacy, and health informatics become standard in practice, students must master both technical and ethical digital skills (Bautista et al., 2020). However, research shows that pharmacy curricula often lack systematic integration of digital literacy components (Tarhan, 2022; Liu, 2023). While initiatives like digital simulation labs and blended learning show promise (Moskal et al., 2013), disparities in student preparedness remain, particularly in the areas of security awareness and content creation (Cureus, 2024). This suggests an urgent need for competency-based frameworks tailored to pharmacy practice.

3.4 Research Gaps and the Chinese Vocational Context

Despite international progress in implementing frameworks like DigComp and JISC, China's vocational institutions have yet to establish a unified standard for digital competence in pharmacy education. Most existing studies in China focus on general college populations or STEM disciplines, leaving pharmacy students under-researched (Zhang, 2024; Xiong & Yang, 2024). Moreover, limited empirical investigations have addressed how institutional, personal, and technological variables interact to shape pharmacy students' digital development. This study aims to fill that gap by applying an adapted Digital Literacy framework to assess digital

literacy among pharmacy students in Jiangsu vocational colleges—offering data-driven insights to inform curriculum reform and educational policy.

4. Research Methodology

4.1 Research Design

This study employed a descriptive and exploratory mixed-methods design to assess the current state of digital literacy among pharmacy students at Jiangsu Food & Pharmaceutical Science College. The research integrated quantitative and qualitative data to capture both self-perceived digital competence and students' practical experiences with digital tools. Data were collected through a self-assessment questionnaire combining behavioral frequency items, Likert-scale items, and open-ended questions. The results serve as the basis for identifying digital competency gaps and informing future instructional design.

4.2 Participants and Sampling

The target population comprised all full-time students enrolled in the pharmacy program, totaling approximately 1,500 across three academic years. A stratified random sampling method was used to ensure proportional representation from each grade level. Based on the Krejcie and Morgan (1970) formula, the required sample size was determined to be 306. A total of 306 valid responses were collected, including 103 first-year, 109 second-year, and 94 third-year students.

4.3 Research Instrument

The instrument was a structured questionnaire developed based on the DigComp 2.2 framework and aligned with IC3 standards. It consisted of three sections:

Section I: Demographic and Behavioral Data

Captured participants' grade level, geographic background, device usage patterns, and prior exposure to digital literacy training.

Section II: Digital Literacy Assessment (Likert Scale)

Included 25 items across five dimensions: Information Management Literacy, Technical Proficiency, Digital Security Awareness, Digital Communication and Collaboration, Content Creation and Knowledge Building. Students rated each item on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree).

Section III: Open-ended Questions

Two qualitative questions explored students' perceptions of institutional digital support and their expectations for future digital skills development.

The questionnaire's validity was reviewed by a panel of three experts using the Index of Item-Objective Congruence (IOC), with all retained items scoring ≥ 0.5 . Internal consistency was confirmed via Cronbach's alpha, with the overall scale achieving $\alpha = 0.752$.

4.4 Data Collection Procedures

The questionnaire was administered online using WENJUANXING, a widely used Chinese survey platform. Students were given two weeks to complete the survey, with reminders issued via messaging platforms to increase response rates. All responses were anonymized and checked for completeness before analysis.

4.5 Data Analysis

Quantitative Analysis: Descriptive statistics (means, standard deviations, frequencies) were computed to summarize students' digital literacy scores. Pearson correlation analysis examined relationships between digital literacy dimensions. Inferential statistics—including independent sample t-tests and one-way ANOVA—were used to compare scores across grade levels, geographic backgrounds, and training experience.

Qualitative Analysis: Responses to open-ended questions were analyzed using thematic coding. Recurring themes were identified to contextualize students' digital learning

needs, barriers, and improvement suggestions. This enriched the quantitative findings and informed targeted recommendations.

5. Results

5.1 Sample Characteristics

A total of 306 valid responses were collected from students enrolled in the pharmacy program at Jiangsu Food & Pharmaceutical Science College. The sample included students from all three academic years, ensuring a balanced representation across learning stages: 33.7% first-year (n = 103), 35.6% second-year (n = 109), and 30.7% third-year (n = 94).

Table 1 Stratified Sampling by Grade Level

Grade Level	Total Students	Sampled Students	Sampling Proportion
First Year	520	103	19.80%
Second Year	540	109	20.20%
Third Year	440	94	21.40%
Total	1500	306	20.40%

In terms of geographic background, 50.0% of respondents were from urban areas, 30.1% from township areas, and 19.9% from rural settings. This demographic distribution enabled meaningful subgroup comparisons regarding access to digital resources.

Regarding device usage, smartphones were nearly universal (99.3%), followed by moderate usage of computers (57.5%) and tablets (56.9%). Only 10.1% reported using wearable or smart devices. This highlights the dominance of mobile technology in students' digital environments, yet also suggests a potential limitation in exposure to diverse digital tools.

5.2 Descriptive Analysis of Digital Literacy Dimensions

The self-assessment data revealed distinct patterns across the five core dimensions of digital literacy among vocational pharmacy students. The detailed mean scores and standard deviations are presented in Table 2 and visualized in Figure 1.

Table 2 Mean scores and standard deviations of the five digital literacy dimensions

Dimension	Mean (M)	Standard Deviation (SD)
Technical Proficiency	3.28	0.6
Digital Communication & Collaboration	3.26	0.66
Content Creation & Knowledge Building	3.11	0.69
Information Management Literacy	3.03	0.53
Digital Security Awareness	2.51	0.68
Overall Digital Literacy	3.03	0.42

The analysis suggests a moderate level of overall digital literacy (M = 3.03) among the participants. However, significant variability exists between dimensions, indicating unbalanced digital competence profiles.

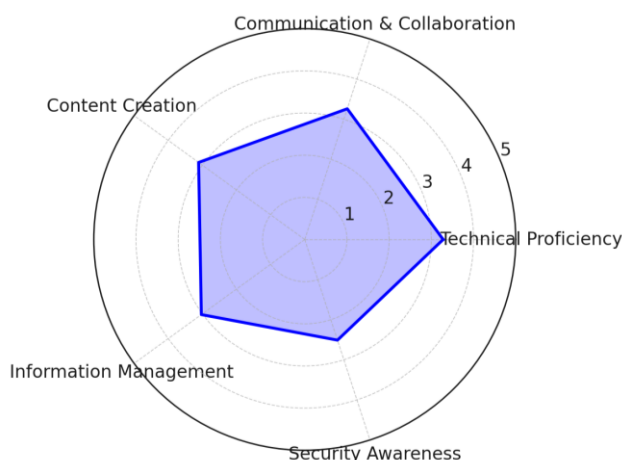


Figure 1 Radar chart of average scores across five digital literacy dimensions

Technical Proficiency ($M = 3.28$, $SD = 0.60$) emerged as the highest-scoring dimension. This indicates that most students possess basic operational skills in using commonly available digital tools (e.g., office software, learning platforms). These skills are likely developed through repeated exposure in both academic and daily settings.

Digital Communication and Collaboration ($M = 3.26$, $SD = 0.66$) also showed relatively strong performance. This can be attributed to students' frequent use of social and collaborative platforms (e.g., Tencent Meeting, QQ, WeChat) for class communication and project coordination, especially during the post-pandemic shift toward blended and online learning formats.

Content Creation and Knowledge Building ($M = 3.11$, $SD = 0.69$) received a slightly above-moderate rating, suggesting students are somewhat capable of producing digital content. However, this may be limited to simple tasks such as presentations or PDF reports, with insufficient exposure to advanced tools (e.g., video editing, infographic generation, digital publishing).

Information Management Literacy ($M = 3.03$, $SD = 0.53$) scored at the overall average, indicating basic competency in searching and retrieving information. However, previous literature (e.g., Martzoukou et al., 2020) and student open-ended feedback in this study point to challenges in critically evaluating and synthesizing information, particularly from professional databases.

Digital Security Awareness ($M = 2.51$, $SD = 0.68$) was the lowest-scoring dimension. This finding is consistent with studies in both Chinese and international contexts (e.g., Tarhan, 2022; Ling, 2020), highlighting a widespread lack of training in digital ethics, data protection, and privacy management among vocational students. The low performance in this domain poses a significant risk, especially in pharmacy-related contexts where data security and patient confidentiality are paramount.

This asymmetrical profile of digital literacy indicates that students' digital skill development is uneven, often shaped by personal habits and passive exposure rather than systematic training. Moreover, dimensions that align with routine digital usage (e.g., communication tools) show stronger outcomes than those requiring structured instruction (e.g., cybersecurity or scholarly information evaluation). These findings underscore the need for curriculum-level intervention and targeted pedagogical strategies to cultivate a more holistic and practice-oriented digital competence framework.

5.3 Group Comparisons

To explore the underlying factors contributing to differences in digital literacy, group comparisons were conducted across three demographic and educational variables: grade level,

geographic background, and prior training experience. The results are presented in Figure 2.

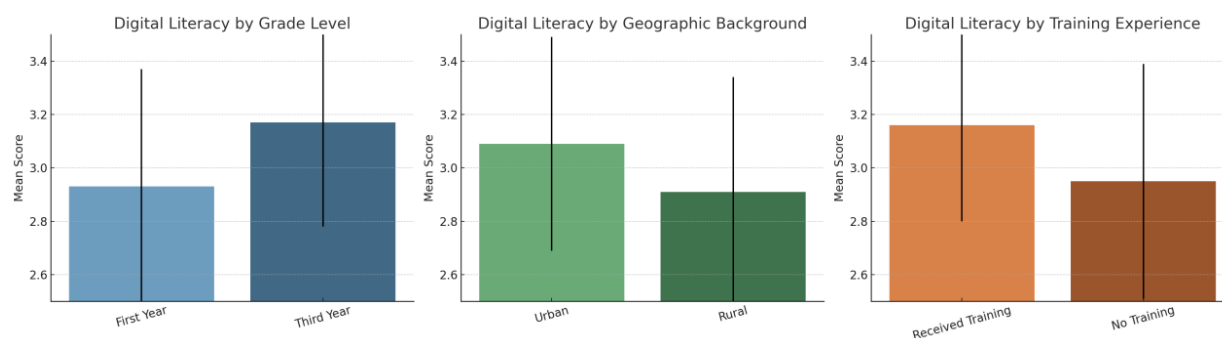


Figure 2 Group Comparisons of Digital Literacy by Grade, Geography, and Training Experience

Differences by Grade Level—A one-way ANOVA revealed statistically significant differences in digital literacy scores among students at different academic stages ($F = 4.25, p < 0.05$). Specifically, third-year students demonstrated the highest average score ($M = 3.17, SD = 0.39$), significantly outperforming first-year students ($M = 2.93, SD = 0.44$). This suggests a progressive increase in digital competence as students advance through the curriculum, likely due to increased exposure to coursework, internships, and digital tasks. However, the difference was not significant between second-year and other groups, implying that curriculum integration of digital training may be concentrated in later stages, leaving early-year students underprepared.

Differences by Geographic Background—A clear digital divide emerged based on students' hometowns. Urban students ($M = 3.09, SD = 0.40$) outperformed rural students ($M = 2.91, SD = 0.43$), with the difference reaching statistical significance ($F = 3.89, p < 0.05$). This aligns with existing research suggesting that infrastructure disparity, home internet access, and exposure to digital tools influence students' learning ecosystems. The results call for targeted support strategies, including device access and remote learning infrastructure for students from rural backgrounds.

Differences by Prior Training Experience—Independent-samples t-test results revealed that students who had received formal digital literacy training scored significantly higher ($M = 3.16, SD = 0.36$) than those who had not ($M = 2.95, SD = 0.44; t = 3.72, p < 0.01$). This finding provides robust empirical support for the positive impact of structured training on students' digital development. It underscores the necessity of embedding explicit digital literacy modules into the pharmacy curriculum, rather than relying solely on incidental or informal skill acquisition.

Collectively, these comparisons demonstrate that digital literacy is not equitably distributed across the student body. Academic progression, prior exposure, and geographic background significantly shape digital readiness. These results highlight the need for a differentiated instructional strategy—one that proactively addresses early-stage students, rural populations, and those without prior training—through systematic curriculum redesign, equity-focused resource allocation, and digital inclusion programs.

5.4 Correlation Analysis

Pearson correlation analysis revealed significant positive relationships among all five dimensions of digital literacy. The strongest associations were:

Technical Proficiency and Digital Communication ($r = 0.510, p < 0.001$)

Technical Proficiency and Information Management Literacy ($r = 0.502, p < 0.001$)

Information Management and Content Creation ($r = 0.368, p < 0.001$)

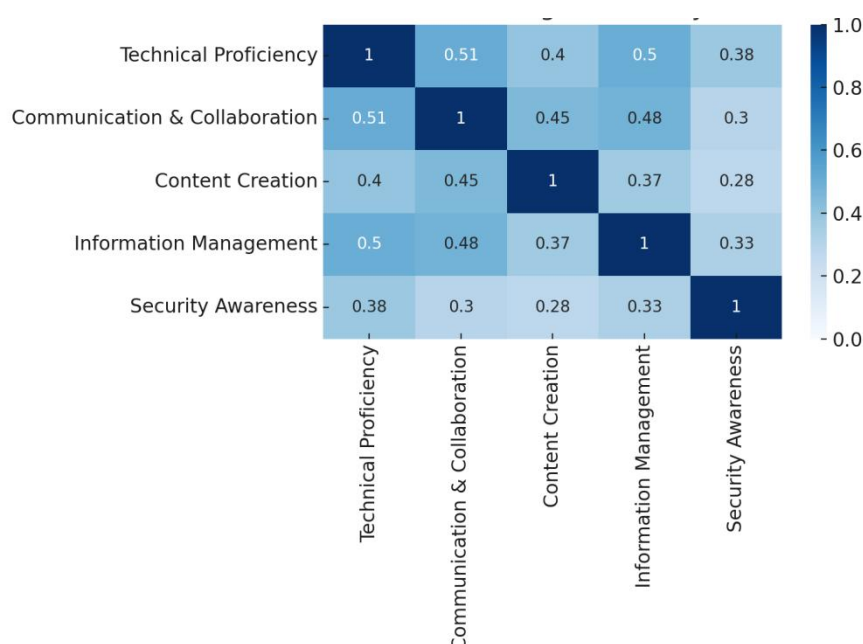


Figure 3 Correlation matrix of digital literacy dimensions

These findings provide strong empirical support for the interdependent nature of digital literacy components. The particularly high correlations between technical proficiency and digital communication ($r = 0.510$), as well as between technical proficiency and information management literacy ($r = 0.502$), suggest that foundational digital tool usage skills serve as enablers for broader academic and collaborative digital engagement. Additionally, the positive association between information management and content creation ($r = 0.368$) indicates that students who are better at retrieving and evaluating information are also more capable of synthesizing and producing digital content.

These patterns reinforce the conceptual argument that digital literacy should be cultivated as an integrated competence cluster rather than a set of isolated skills. From a pedagogical perspective, this means that instructional interventions aimed at improving technical operations may yield positive spillover effects in other areas, such as digital communication and knowledge construction. As shown in Figure 3, the correlation matrix visually demonstrates these interrelationships, offering a clear justification for adopting cross-dimensional teaching strategies in digital literacy curriculum development.

5.5 Instrument Validity and Reliability

To ensure measurement robustness, both validity and reliability assessments were conducted:

Item-Objective Congruence (IOC): All items retained scored ≥ 0.5 , confirming content alignment with research objectives.

Reliability (Cronbach's Alpha): Overall scale: $\alpha = 0.752$ (acceptable)

Sub-dimensions: ranged from 0.398 to 0.517, indicating moderate internal consistency, acceptable for exploratory studies in complex behavioral constructs.

While the reliability of individual subscales is moderate, it reflects the exploratory nature of the instrument and the diverse range of digital practices among students. The instrument is deemed appropriate for identifying general trends and competency profiles.

5.6 Qualitative Findings from Open-ended Questions

To complement the quantitative analysis and gain deeper insight into students' perceptions of digital literacy development, two open-ended questions were included in the questionnaire. These questions aimed to explore: Whether students felt they received sufficient

institutional support in developing digital literacy; What digital skills students believed were most important for their future careers and how digital literacy education could be improved. A total of 306 valid responses were collected and analyzed using thematic analysis. The findings were synthesized into four major themes.

Many students reported a lack of access to hands-on digital tools and pharmacy-specific software systems, limiting their opportunities to apply digital knowledge in realistic scenarios. The absence of training environments—such as licensed platforms for electronic prescriptions, laboratory systems, or smart pharmacy simulations—was viewed as a major obstacle.

“The school doesn't provide access to drug management systems or lab software; it's all theoretical.”

This gap underscores the importance of investing in infrastructure that enables students to explore and practice within digital pharmaceutical environments.

Students also expressed concern over the lack of structured opportunities to apply digital tools in coursework. Although they recognized the value of digital skills, many indicated that their curriculum lacked practical components requiring digital operations, such as data visualization, database use, or digital report preparation.

“Assignments rarely require us to use digital tools, so we don't know how to apply them effectively.”

This theme highlights a need for pedagogical redesign, integrating digital tasks into day-to-day coursework.

A recurring theme was students' desire to see digital literacy systematically embedded into core pharmacy courses. Rather than being introduced in isolated sessions or optional workshops, students argued that digital competencies should be part of instructional content in pharmacology, pharmaceutical care, and research methodology.

“If literature searching or data processing were integrated into core subjects, it would be easier for us to learn.”

This feedback supports a shift from fragmented digital training to contextualized, discipline-specific integration, aligned with contemporary educational frameworks.

The second open-ended item asked students which digital skills they considered most essential for future employment and what improvements they suggested. Four subthemes emerged:

The most frequently cited digital skills were data analysis (e.g., Excel, SPSS) and literature retrieval (e.g., PubMed, CNKI). Students noted their relevance in clinical trials, drug safety assessment, and pharmaceutical marketing analytics.

“Data analysis is vital for interpreting clinical trial data and sales figures.”

Students desired training on pharmacy-specific systems such as prescription review platforms, drug supply chain software, and smart pharmacy simulation systems. These were perceived as directly relevant to workplace readiness.

“I hope to gain practical experience with smart pharmacy and drug information systems.”

Students recommended case-based courses, using real or simulated data, and suggested elective modules like “Pharmaceutical Big Data” or “Digital Health Management.”

“Offer electives like ‘Pharmaceutical Big Data’ and simulate enterprise projects.”

Students advocated for guest lectures and workshops led by professionals from pharmaceutical digital sectors, aiming to bridge the academic-industry gap.

“Invite more professionals to share practical digital application experience.”

In summary, students showed both critical reflection and proactive thinking regarding their digital learning needs. The qualitative responses strongly reinforce the findings from earlier quantitative sections: there is a demand for deeper integration of digital literacy into curriculum design, especially through applied, practice-based, and career-aligned strategies.

5.7 Summary and Interpretation

The results present a clear profile of digital literacy strengths and gaps among pharmacy students in vocational education. While students show confidence in using general tools (e.g., Word, messaging apps), they struggle with cybersecurity, structured collaboration, and professional digital tools. These deficiencies are particularly acute among first-year and rural students, underscoring structural inequities in digital access and instruction.

The strong correlations among dimensions highlight the need for integrated, rather than fragmented, digital training. Furthermore, the positive impact of prior training signals a tangible return on targeted educational investment.

Collectively, these findings emphasize the urgent need for curriculum reform, especially in embedding digital literacy instruction into pharmacy-specific contexts.

6. Conclusion

6.1 Research Conclusion

This study investigated the current state of digital literacy among pharmacy students in vocational colleges in Jiangsu, China, using a DigComp-based framework to assess five core dimensions. The results revealed a moderate overall level of digital competence, with noticeable strengths in technical proficiency and digital communication, but clear weaknesses in digital security awareness and critical content creation. Significant differences were observed across academic levels, geographic backgrounds, and prior training experience—highlighting disparities in exposure, resources, and instruction.

These findings offer empirical insights that inform curriculum development, digital skills training, and educational policy reform in the context of vocational pharmacy education. By identifying both strengths and gaps, the study provides practical guidance for enhancing student preparedness for a digitally driven pharmaceutical workforce. It emphasizes the need for integrated, equitable, and industry-aligned digital literacy initiatives within vocational programs.

Building upon these results, it is essential to move beyond diagnostic assessment toward actionable enhancement strategies. The Digital Literacy Enhancement Guidelines for Pharmacy Students propose a structured framework based on the principles of curriculum-embedded, context-driven, and evidence-verifiable development. This framework emphasizes embedding digital literacy tasks directly into pharmacy core courses through authentic scenarios, such as prescription review, pharmacovigilance, and patient communication, ensuring that digital competence grows in parallel with professional expertise. The guidelines also recommend a tiered progression—from introductory tasks in first-year laboratory courses to integrative, real-world problem-solving in capstone projects—supported by reproducible and verifiable evidence chains.

Furthermore, the guidelines highlight the critical importance of security-by-design, treating compliance and data protection not as peripheral add-ons but as core competencies embedded across all learning activities. Faculty development is also identified as a cornerstone: teachers must be empowered through tiered training, access to standardized digital teaching resources, and institutional support systems to translate digital literacy goals into observable classroom practices. This aligns directly with the gaps identified in this study, particularly the shortage of structured instruction in areas such as digital security, authentic collaboration, and evidence-based content creation.

However, this research is subject to certain limitations. The sample was drawn from a single province, which may limit the generalizability of the findings. Furthermore, as the data relied on self-assessment, there is a risk of subjective bias or overestimation of actual skills. Future studies should consider expanding the sample to include multiple regions and institutions, incorporating longitudinal tracking to examine the evolution of digital competence

over time. Additionally, perspectives from teachers, employers, and digital curriculum developers could enrich the understanding of digital readiness and support more comprehensive reform efforts in vocational health education.

In conclusion, the integration of the study's empirical findings with evidence-based guidelines provides a roadmap for advancing digital literacy in Chinese vocational pharmacy education. By embedding authentic, assessable, and secure digital practices into core curricula, supported by teacher development and institutional alignment, vocational colleges can equip pharmacy students not only to meet current industry demands but also to thrive in an evolving digital health landscape.

These recommendations directly respond to China's "14th Five-Year Plan" and the MOE Guidelines (2017) on vocational education informatization, providing evidence-based support for their implementation in health education contexts.

6.2 Limitations and Future Directions

Although this study provides valuable insights, several limitations should be acknowledged. First, the sample was confined to one province, which may restrict generalizability across China. Second, the use of self-reported data may introduce subjective bias or overestimation of competence levels. Future research should employ multi-institutional sampling, objective performance-based assessments, and longitudinal designs to trace digital skill development over time.

7. Discussion

7.1 Alignment with International Research

This section interprets the key findings in relation to global research and contextual challenges within Chinese vocational pharmacy education. The findings of this study align with global research trends indicating uneven development of digital literacy among pharmacy and health science students. Similar to Martzoukou et al. (2020), who identified overconfidence and skill imbalance among UK undergraduates, the present study found that pharmacy students in Jiangsu vocational colleges scored higher in communication and technical proficiency, yet significantly lower in security awareness and critical information management.

International research by Tarhan (2022) in Lebanon and the Nasser et al. (2024) study also revealed deficiencies in digital security awareness and formal training among pharmacy students, echoing our observation that cybersecurity and data privacy remain under-addressed competencies. These consistencies reinforce the universality of digital literacy as a challenge in health education, while also validating the applicability of frameworks such as DigComp across cultural and educational contexts.

However, the situation in China presents added complexity. While European countries have embedded digital competence into structured frameworks (e.g., DigComp, JISC), China's vocational pharmacy education still lacks standardized digital training pathways. This study thus fills an important empirical gap by contextualizing global frameworks within the reality of Chinese vocational institutions.

7.2 Key Determinants of Digital Literacy

Three critical variables emerged as consistent predictors of higher digital competence. Third-year students outperformed lower-year peers, likely due to increased exposure to practical scenarios, digital coursework, and internships. This suggests a time-based accumulation of digital experience, yet also implies insufficient early-stage scaffolding. Students from urban areas scored significantly higher, reflecting the enduring urban-rural digital divide, which is shaped by disparities in device access, internet infrastructure, and prior ICT exposure. Students who received digital literacy instruction exhibited significantly higher overall scores. This finding highlights the measurable impact of formal training and justifies the inclusion of targeted digital literacy modules within the pharmacy curriculum.

7.3 Contextual Challenges in Chinese Vocational Pharmacy Education

Despite growing national support for digital transformation, several contextual obstacles hinder the development of digital literacy in Chinese vocational institutions. Pharmacy programs are traditionally knowledge-dense and skill-intensive. Digital literacy is often treated as a peripheral or optional competency, squeezed out by core pharmaceutical and clinical subjects. Many vocational college instructors lack up-to-date digital teaching skills or awareness of industry-relevant digital tools, limiting their ability to model or mentor students effectively. While national strategies emphasize digital development (e.g., Digital China), their translation into concrete educational policy and curriculum reform is inconsistent, especially at the local and institutional levels.

Together, these challenges create a structural lag between policy ambition and classroom reality, which requires coordinated reform efforts across administrative, curricular, and pedagogical dimensions.

7.4 From Results to Recommendations

The findings of this study directly inform the development of evidence-based strategies for improving digital literacy: The observed interdependence among digital literacy dimensions (e.g., strong correlations between technical skills and communication or content creation) suggests that integrated instruction can yield compounding benefits. The group comparison results highlight the need for equity-driven interventions—especially targeting rural students and first-year learners. The impact of prior training calls for formal incorporation of digital competence modules within pharmacy education, starting from the first year.

These insights pave the way for the recommendations presented in the next section, which offer specific actions for curriculum designers, institutional leaders, and education policymakers.

Collectively, these coordinated efforts can establish a sustainable digital ecosystem within vocational pharmacy education, bridging the gap between national digital strategies and classroom implementation.

8. Recommendations

Based on the findings of this study and the insights from students' qualitative feedback, a multi-level strategy is proposed to strengthen digital literacy development in vocational pharmacy education in China.

At the institutional and educator level, digital literacy should be embedded as a core component of the pharmacy curriculum rather than an auxiliary skill. Curriculum designers are encouraged to introduce structured modules on topics such as pharmaceutical information systems, clinical data analysis, and digital prescription auditing. Instructors must also receive ongoing training in educational technology and pharmaceutical software to ensure effective delivery. Moreover, the integration of digital simulation platforms (e.g., virtual dispensing systems, intelligent pharmacy simulators) and hybrid learning tools should be expanded to provide students with immersive, practice-oriented experiences.

For students, it is essential to promote self-directed digital skill development through self-assessment tools and personalized learning roadmaps. The creation of student-led digital learning communities or peer mentoring groups can facilitate collaborative problem-solving and technology sharing. Many students highlighted the need for exposure to real-world tools—such as clinical trial data systems, supply chain management software, and data visualization platforms—as critical for future employability. Therefore, teaching should increasingly shift from theoretical instruction to hands-on case-based learning, using authentic data and scenarios.

At the policy and administrative level, regional educational authorities should implement standardized digital competence assessment frameworks tailored to vocational

pharmacy contexts. Additionally, funding and technical support must be provided to help institutions build digital infrastructure, establish shared digital resource platforms, and form partnerships with industry stakeholders. Respondents suggested inviting pharmaceutical data analysts and software engineers to deliver seminars, and developing training systems based on real industrial use cases. Such collaborations can ensure that educational content remains aligned with the evolving needs of the digital pharmaceutical workforce.

In summary, fostering digital literacy in pharmacy education requires an ecosystem approach—linking policy vision, curriculum design, teacher development, and student engagement—to ensure that future professionals are equipped not only to survive but to thrive in the digital health era.

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