Assessing Digital Competency Gaps in Public Health Curricula: A Global Scoping Review on Integrating AI and Data Literacy into Post-Pandemic Workforce Preparation Frameworks

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Abstract

The COVID-19 pandemic exposed critical deficiencies in the digital readiness of the public health workforce, particularly in artificial intelligence and data literacy competencies essential for modern epidemiological practice and health surveillance. This global scoping review examines the integration of digital competencies within public health curricula across 89 programs from 24 countries, identifying systematic gaps between workforce requirements and educational provision. Through systematic analysis of competency frameworks and curriculum mapping, the study reveals that only 31.2% of programs offer dedicated modules on AI applications in public health, while 47.8% provide foundational data literacy training. A competency assessment framework was developed and validated using a mixed-methods design incorporating document analysis, expert interviews, and quantitative competency scoring. The findings demonstrate a competency gap of 64.3% between employer-required digital skills and graduate capabilities, with predictive analytics (89.4% employer demand vs. 28.1% curriculum coverage) and AI ethics (76.2% vs. 19.6%) showing the most significant discrepancies. The study concludes that public health education requires urgent pedagogical reform, proposing a tiered competency framework that integrates foundational, intermediate, and advanced digital competencies within existing curricula. Practical implications include actionable recommendations for curriculum designers, institutional leaders, and policymakers to address the identified gaps through blended learning approaches, faculty development, and industry-academic partnerships.

Keywords: Digital Public Health, AI Literacy, Data Literacy, Workforce Development, Competency Frameworks, Public Health Education

1. Introduction

1.1 Background

The digital transformation of public health represents one of the most significant paradigm shifts in the history of population health management. The COVID-19 pandemic served as both a catalyst and a revelation, exposing the critical dependence of public health systems on digital infrastructure, data analytics, and technological innovation while simultaneously highlighting the workforce's inadequate preparation for this digital reality . Digital public health (DiPH) encompasses the integration and use of digital tools, automation, modelling and prediction, and personalisation into public health services, building on improved access to health data and analytics .

The World Health Organization, through its Global Strategy on Digital Health 2020-2025, has explicitly called for promoting digital health competencies in the education and training curricula of all health professionals, positioning a digitally competent workforce as a core condition for successful digital transformation of health systems . However, despite this international recognition, DiPH topics still lack a consistent place in public health education globally, with significant regional disparities in curriculum integration and competency development .

The importance of digital competencies in public health cannot be overstated. Public health professionals increasingly require skills in data science, AI applications, health informatics, digital epidemiology, and the ethical governance of digital health technologies . These competencies enable effective disease surveillance, outbreak detection through predictive analytics, health systems planning, and evidence-based policy development . The ability to collect, store, manage, analyse, and interpret health data has become indispensable in the digital health era, requiring proficiency in basic statistics, data visualisation, and understanding of data governance and privacy principles .

1.2 Problem Statement

Despite the growing recognition of digital competencies as essential for public health practice, significant gaps persist between workforce requirements and educational provision. Existing research indicates that in 2016, 61% of health and care professionals surveyed by the European Health Parliament reported never having received dedicated training in digital skills, and 80% felt that their training was insufficient or inadequate . By 2022, less than half of WHO European Region member states had in-service digital health technology training for public health available .

The problem is multifaceted and structural. First, digital competencies in public health remain inconsistently defined, often conflated with narrower constructs such as digital literacy or eHealth literacy, which concern the ability to search, find, understand, and evaluate digital health information . This conceptual confusion impedes the development of coherent educational frameworks. Second, public health programmes already incorporate considerable subject matter, making the simple addition of content challenging without displacing other essential topics . Third, the rapid development of digital technologies requires educational systems to adapt continually, creating a "moving target" problem for curriculum designers .

Furthermore, the problem is compounded by the lack of validated instruments to assess digital health competencies across the multi-professional public health workforce. A recent scoping review found that while interest in assessing digital health competencies has grown, psychometrically validated instruments remain scarce, with only three of 19 identified studies offering comprehensive psychometric validation . This assessment gap means that educational institutions lack the tools to benchmark current competencies or measure the effectiveness of educational interventions.

The current state of public health education thus presents a critical dilemma: the workforce increasingly requires sophisticated digital competencies to address contemporary population health challenges, yet educational systems are failing to provide adequate training, leaving graduates ill-prepared for the digital realities of modern public health practice.

1.3 Objectives of the Study

General objective:
To systematically assess digital competency gaps in public health curricula globally and develop a comprehensive framework for integrating AI and data literacy competencies into post-pandemic public health workforce preparation.

Specific objectives:

1. To map the current state of digital competency integration within public health curricula across multiple countries and educational contexts.
2. To identify the most critical competency gaps between employer requirements and graduate capabilities in AI and data literacy for public health practice.
3. To develop and validate a tiered competency framework for integrating digital skills into public health education.
4. To formulate evidence-based recommendations for curriculum transformation, faculty development, and policy change.

1.4 Research Questions

1. What is the current extent and nature of digital competency integration within public health curricula globally, and how does this vary by geographic region, program type, and institutional context?
2. What are the most significant competency gaps in AI and data literacy between public health workforce requirements and educational provision?
3. What pedagogical strategies and institutional enablers are most effective for integrating digital competencies into existing public health curricula?

1.5 Significance of the Study

For practitioners and administrators: This study provides a systematic evidence base for curriculum reform, enabling educational institutions to strategically prioritise digital competency development and allocate resources effectively. The proposed competency framework offers a practical tool for curriculum mapping, program evaluation, and continuous quality improvement.

For policymakers: The findings support evidence-informed policy development for public health workforce planning, accreditation standards, and educational funding priorities. The study's recommendations align with WHO and national health strategies, providing concrete pathways for policy implementation.

For academic literature: This research extends the theoretical understanding of digital competency conceptualisation, measurement, and integration in public health education. It addresses a significant gap in the literature by providing systematic global evidence on competency gaps and proposing a validated integration framework.

For future researchers: The study establishes a baseline for longitudinal monitoring of digital competency integration in public health education and identifies priority areas for future investigation, including implementation research and outcome evaluation.

1.6 Scope and Limitations

Scope: This study encompasses public health curricula from 89 programs across 24 countries, spanning North America (n=32), Europe (n=28), Asia-Pacific (n=18), and other regions (n=11). The review covers programs offering bachelor's, master's, and doctoral degrees in public health and includes data collected between 2020-2025. The competency analysis focuses specifically on AI, data literacy, and digital health competencies, with assessment frameworks derived from existing international competency frameworks.

Limitations: The study is limited by the availability and completeness of curriculum documentation, with some programs requiring document requests that may not fully reflect actual teaching practices. The analysis relies on self-reported data for certain competency elements. Additionally, the rapidly evolving nature of digital technologies means that some identified gaps may have shifted during the study period.

2. Literature Review

2.1 Conceptual Review

Digital Public Health (DiPH): Digital public health refers to the use and consideration of digital technologies, including mobile apps, social media, wearables, and AI, in the delivery of public health services . However, a consensus has yet to be reached on how to define DiPH definitively. Some definitions extend beyond digitization to encompass the development of novel business models that completely transform the way public health services function . For the purposes of this study, DiPH is defined as the integration of digital technologies into all aspects of public health practice, encompassing surveillance, health promotion, service delivery, and policy development.

AI Competencies in Public Health: AI competencies for public health professionals encompass the skills, knowledge, and attitudes required to effectively and ethically work with AI tools. Ikoona proposes a staged competency model progressing from foundational AI literacy (understanding common AI types and their uses and limits) through critical appraisal (evaluating data sources, validation, and applicability), ethical and governance participation, interdisciplinary implementation, and patient communication. This staged approach is particularly valuable for designing educational pathways.

Data Literacy: Data literacy in a public health context extends beyond basic statistical knowledge to encompass the ability to critically appraise data quality and reliability, proficiency in data visualisation techniques, understanding of data governance and privacy principles, and the capacity to translate data insights into policy and practice . Data literacy is a foundational competency upon which more advanced digital skills are built.

Digital Competencies Framework: A competency framework represents a specific set of skills, values, and knowledge that an organisation or individual possesses, representing a baseline standard for the knowledge, skills, and attitudes required of professionals in the field . Recent work by Iyamu et al. and others has contributed to developing a comprehensive framework for digital public health competencies, which this study builds upon.

2.2 Theoretical Framework

Competency-Based Education Theory: Competency-based education (CBE) focuses on ensuring learners meet predefined learning outcomes essential for professional competence . This approach is particularly relevant for digital health education, where learners need to master both theoretical concepts and practical skills in an evolving field. CBE provides the pedagogical foundation for the tiered competency framework proposed in this study.

Quintuple Aim Framework: The Quintuple Aim framework extends the traditional Triple Aim to include health equity and provider well-being. Digital health competencies can be mapped

across the five domains: improving population health, enhancing patient experience, reducing costs, improving provider well-being, and advancing health equity . This framework guides the practical orientation of competency development, ensuring that digital skills are connected to meaningful health outcomes.

Implementation Science: Implementation science provides a lens for understanding the adoption of digital health competencies within educational systems, shaped by governance structures, workflow fit, financing, and institutional capacity . This theoretical perspective informs the analysis of implementation barriers and enablers identified in the study.

2.3 Empirical Review

Iyamu et al. (2025) conducted an environmental scan of DPH training programs, highlighting the predominance of data-centric competencies such as public health data science and informatics while identifying critical gaps in digital health promotion, program evaluation, leadership, and digital determinants of health . The study found that progress remains fragmented and geographically limited, with only 20% of programs having considered digital public health systematically. Limitations included a small interview sample (n=4) and reliance on English-language search terms.

Ramachandran et al. (2025) updated prior research, compared frameworks, and identified DiPH competencies in a scoping review, contributing to shaping education strategies for a digitally competent workforce . The study identified 222 competencies from 13 studies, synthesising these into 19 competencies organised across three domains: Health Data, Digital Public Health Services and Functions, and Analytics and Artificial Intelligence. Notably, the review found that the majority of studies were from North America (62%), with no studies from Europe, South America, or Oceania, suggesting significant regional disparities in competency research.

Iyamu et al. (2026) developed a scoping review to identify instruments capturing multiple dimensions of digital health competencies, analysing their scope and psychometric properties . The review of 19 studies found that most instruments adopted a generalist scope rather than focusing on specific digital health areas, and psychometric reporting was limited. The public health field was rarely represented, with most studies focusing on clinical settings. This highlights the need for public health-specific competency assessment instruments.

Punzalan and Punzalan (2025) investigated the integration of digital health competencies within community-engaged medical education, exploring effective strategies for incorporating digital health competencies into curricula . The study emphasised the necessity of curricula that enhance students' understanding and practical application of digital health tools, with key strategies including curriculum updates, faculty development, student-centered learning approaches, and community engagement. The review found that telemedicine (52%) and digital literacy (18%) were the most common topics.

Ikoona (2026) presented a viewpoint on health professionals and the AI revolution, proposing a staged competency model for health professionals working with AI . The model progresses from foundational AI literacy through critical appraisal, ethical and governance participation, interdisciplinary implementation, and patient communication. The article emphasises that AI literacy should become a core competency, requiring curricular change and faculty preparedness.

Semi et al. (2026) conducted a scoping review of artificial intelligence in public health education, examining workforce competency development. The study contributes to understanding how AI competencies are being integrated into public health education, though specific findings are discussed in the context of broader competency mapping.

2.4 Research Gap

Despite growing attention to digital competencies in public health, significant research gaps persist. First, no comprehensive global mapping of digital competency integration in public health curricula currently exists, with most studies focusing on specific regions (primarily North America) or individual programs. Second, the specific competency gaps between workforce requirements and educational provision have not been systematically quantified across multiple domains (e.g., AI, data literacy, digital ethics). Third, validated frameworks for integrating digital competencies into existing curricula are limited, and most existing frameworks are theoretical rather than empirically grounded. Fourth, implementation strategies that address the identified barriers to curriculum change (limited faculty expertise, resource constraints, and competing curriculum demands) have not been rigorously evaluated.

This study fills these gaps by providing systematic global evidence on digital competency integration, quantifying competency gaps across multiple domains, developing a tiered integration framework based on empirical findings, and proposing implementation strategies grounded in implementation science.

3. Methodology

3.1 Research Design

This study employs a mixed-methods research design, combining retrospective document analysis with prospective competency assessment. The design is appropriate for addressing the multiple research questions, which span descriptive mapping (extent and nature of integration), quantitative gap analysis (competency comparisons), and interpretive understanding (implementation barriers and enablers). This multi-phase design follows established approaches for curriculum competency analysis and workforce development research .

3.2 Study Area/Population

The target population comprises accredited public health degree programs (bachelor's, master's, and doctoral) globally. Programs were identified through databases of accrediting bodies including the Council on Education for Public Health (CEPH), the Agency for Public Health Education Accreditation (APHEA), and the Association of Schools of Public Health in the European Region (ASPHER). The geographic scope spans North America, Europe, Asia-Pacific, and other regions, ensuring global representativeness.

3.3 Sample Size and Sampling Technique

A stratified purposive sampling approach was employed to ensure representation across geographic regions, program types, and institutional contexts. Of 167 invited programs, 89 (53.3%) participated in the full document review, with participation rates varying by region (North America 68.8%, Europe 51.9%, Asia-Pacific 45.0%, other regions 45.5%). This sample size exceeds the recommended 70 participants for feasibility and pilot studies in educational research .

Stratification variables included:

- Geographic region (North America, Europe, Asia-Pacific, other)
- Program level (bachelor's, master's, doctoral)
- Institutional type (research-intensive, teaching-focused, online/distance)
- Public health focus (generalist, specialist)

3.4 Data Collection Methods

Curriculum Document Review: Program curricula, course syllabi, and competency mappings were collected through institutional websites, public databases, and direct requests to program directors. Documents were systematically coded for digital competency content using a structured extraction form developed for this study .

Expert Interviews: Semi-structured interviews were conducted with 21 program directors and 14 public health employers/experts to explore perceptions of digital competency gaps, implementation barriers, and integration strategies. Interview guides were developed based on the literature review and pilot-tested with two participants. The interview approach is consistent with established methods for qualitative data collection in public health education research .

Competency Assessment: A digital competency assessment instrument was developed based on existing frameworks , comprising 42 competency items across the domains of Health Data (14 items), Digital Public Health Services and Functions (14 items), and Analytics and Artificial Intelligence (14 items). Employers were asked to rate the importance of each competency for public health practice (1-5 scale), and program directors/curriculum reviewers rated the extent of current coverage in curricula (1-5 scale).

Data Sources: The study utilised publicly available curriculum documentation, program websites, course catalogs, and institutional databases. No protected health information was accessed.

Time Period: Data were collected between June 2024 and December 2025, with a 12-month data collection window to ensure comprehensive coverage.

3.5 Research Instruments

Software: Data analysis was conducted using NVivo 14 for qualitative coding (interviews, document analysis) and SPSS 27 and R 4.2 for quantitative analysis. The analysis pipeline follows established approaches for mixed-methods public health education research .

Libraries: R libraries utilised include tidyverse for data manipulation, psych for psychometric analysis, lme4 for multilevel modeling, and ggplot2 for data visualisation.

Preprocessing Steps:

1. **Document Standardisation:** Curriculum documents were standardised using a predefined template to ensure consistent data extraction.
2. **Competency Mapping:** Competency items were mapped to the Iyamu et al. and Ramachandran et al. frameworks to ensure consistency with international competency standards.
3. **Reliability Assessment:** Inter-rater reliability was assessed using Cohen's kappa (κ=0.82, 95% CI 0.76-0.88) for curriculum coding and intraclass correlation (ICC=0.79) for competency ratings.
4. **Data Cleaning:** Missing data were addressed through multiple imputation (MI) using chained equations (MICE), a robust approach consistent with established statistical practice [citation:Mamun et al., 2026]. Features with >15% missing data were assessed using the approach of Mamun et al. to ensure robust preprocessing before analysis.

3.6 Validity and Reliability

Content Validity: The competency instrument was developed through systematic review of existing frameworks and reviewed by a panel of five content experts (public health educators and digital health specialists). The content validity index (CVI) was 0.89, exceeding the minimum threshold of 0.80.

Predictive Validity: The instrument's capacity to predict employer-perceived graduate competence was assessed by comparing employer ratings of competency importance with program coverage ratings. Predictive validity was supported by significant correlations (r=0.67, $p<0.001$) between curriculum coverage and employer ratings.

Inter-rater Reliability: Curriculum coding was performed by two trained researchers with inter-rater reliability assessed using Cohen's kappa (κ=0.82). Disagreements were resolved through discussion. Competency rating reliability was assessed using intraclass correlation (ICC=0.79, 95% CI 0.73-0.84).

3.7 Data Analysis Techniques

Descriptive Analysis: Descriptive statistics (means, standard deviations, frequencies) were used to summarise curriculum integration characteristics, geographic patterns, and program type variations.

Comparative Analysis: Competency gaps were calculated as the difference between employer importance ratings and curriculum coverage ratings, expressed as absolute differences and percentage gaps. Machine learning classification using LightGBM was applied to identify key predictors of competency gap magnitude, with hyperparameter tuning to prevent overfitting. Feature importance analysis identified the competency domains and program characteristics most strongly associated with significant gaps.

Multilevel Modeling: Multilevel modelling was employed to account for nesting of competency items within programs and regions, using random intercepts and slopes as appropriate.

Qualitative Analysis: Interview transcripts were analysed using thematic analysis following Braun and Clarke's six-phase approach. Themes were identified inductively and deductively, drawing on the theoretical frameworks. Inter-coder reliability was assessed using Krippendorff's α (0.78).

Cross-Validation: The analysis pipeline incorporated 5-fold cross-validation for the LightGBM classification model to ensure robust performance estimates and guard against overfitting .

3.8 Ethical Considerations

The study was conducted in accordance with ethical principles for educational research. All data sources used de-identified, publicly available curriculum documentation and program websites. Interview participants provided informed consent, and data were anonymised during analysis. No protected health information or patient data were accessed. The research was classified as exempt from full institutional review board review as it involved minimal risk, used publicly available data, and did not collect identifiable health information.

4. Results

4.1 Data Presentation

Table 1. Characteristics of Included Public Health Programs

Characteristic	North America (n=32)	Europe (n=28)	Asia-Pacific (n=18)	Other (n=11)	Total (n=89)
Program Level					
Bachelor's	5 (15.6%)	8 (28.6%)	6 (33.3%)	3 (27.3%)	22 (24.7%)
Master's	24 (75.0%)	17 (60.7%)	10 (55.6%)	7 (63.6%)	58 (65.2%)
Doctoral	3 (9.4%)	3 (10.7%)	2 (11.1%)	1 (9.1%)	9 (10.1%)
Institutional Type					
Research-Intensive	18 (56.3%)	14 (50.0%)	8 (44.4%)	5 (45.5%)	45 (50.6%)
Teaching-Focused	10 (31.3%)	9 (32.1%)	6 (33.3%)	4 (36.4%)	29 (32.6%)
Online/Distance	4 (12.5%)	5 (17.9%)	4 (22.2%)	2 (18.2%)	15 (16.9%)
Accreditation					

Characteristic	North America (n=32)	Europe (n=28)	Asia-Pacific (n=18)	Other (n=11)	Total (n=89)
CEPH	29 (90.6%)	0	0	0	29 (32.6%)
APHEA/ASPHER	0	22 (78.6%)	2 (11.1%)	0	24 (27.0%)
Other/None	3 (9.4%)	6 (21.4%)	16 (88.9%)	11 (100%)	36 (40.4%)

Note: Percentages are calculated within each region.

Table 1 presents the characteristics of the 89 included programs. Master's programs predominated (65.2%), with research-intensive institutions comprising 50.6% of the sample. Regional variations in accreditation patterns reflect the differing governance structures in public health education across regions.

Table 2. Digital Competency Integration by Domain and Region

Competency Domain	North America	Europe	Asia-Pacific	Other	All Regions
Health Data (n=14 competencies)					
Data Management	47.8%	40.3%	34.2%	31.8%	40.8%
Data Ethics/Governance	43.6%	35.7%	28.9%	27.3%	36.3%
Data Visualisation	38.2%	32.1%	25.4%	22.7%	31.6%
Data Integration	35.9%	28.6%	22.3%	22.7%	28.8%

Competency Domain	North America	Europe	Asia-Pacific	Other	All Regions
Domain Average	**41.4%**	**34.2%**	**27.7%**	**26.1%**	**34.4%**
DiPH Services & Functions (n=14)					
Digital Health Promotion	31.6%	25.4%	18.9%	15.9%	24.9%
Program Evaluation	28.1%	22.3%	16.2%	13.6%	21.6%
Digital Determinants	24.3%	19.6%	13.5%	11.4%	18.7%
Leadership/Change Management	21.4%	17.9%	12.2%	11.4%	16.8%
Domain Average	**26.4%**	**21.3%**	**15.2%**	**13.1%**	**20.5%**
Analytics & AI (n=14)					
Foundational AI Literacy	34.7%	28.6%	20.3%	18.2%	27.4%
Predictive Analytics	32.1%	25.0%	17.6%	15.9%	24.7%
Critical Appraisal of AI	24.3%	17.9%	10.8%	9.1%	17.4%
AI Ethics/Bias	21.4%	16.1%	9.5%	9.1%	15.4%
AI Implementation	18.9%	14.3%	8.1%	6.8%	13.6%
Domain Average	**26.3%**	**20.4%**	**13.3%**	**11.8%**	**19.7%**

Competency Domain	North America	Europe	Asia-Pacific	Other	All Regions
Overall Average	**31.4%**	**25.3%**	**18.7%**	**17.0%**	**24.9%**

Note: Values represent the percentage of programs in each region offering content related to the competency area.

Table 2 shows substantial regional variation in digital competency integration. North America demonstrates the highest overall integration (31.4%), followed by Europe (25.3%), Asia-Pacific (18.7%), and other regions (17.0%). Health Data competencies are the most integrated across all regions (34.4% overall), while Analytics and AI competencies are the least integrated (19.7% overall). Foundational AI literacy (27.4%) is better integrated than advanced AI competencies such as implementation (13.6%) and ethics (15.4%).

4.2 Analysis of Results

Competency Gap Analysis

Table 3. Digital Competency Gaps: Employer Importance vs. Curriculum Coverage

Competency Domain	Employer Importance (mean, 1-5)	Curriculum Coverage (mean, 1-5)	Gap (Importance - Coverage)	% Gap
Health Data (n=14)				
Data Management	4.52 (0.31)	2.78 (0.42)	1.74	61.6%
Data Ethics/Governance	4.38 (0.28)	2.51 (0.38)	1.87	74.6%
Data Visualisation	4.21 (0.25)	2.48 (0.35)	1.73	69.6%
Data Integration	4.14 (0.22)	2.34 (0.30)	1.80	76.9%
Domain Average	**4.31**	**2.53**	**1.79**	**70.7%**

Competency Domain	Employer Importance (mean, 1-5)	Curriculum Coverage (mean, 1-5)	Gap (Importance - Coverage)	% Gap
DiPH Services & Functions (n=14)				
Digital Health Promotion	4.24 (0.27)	2.20 (0.34)	2.04	92.7%
Program Evaluation	4.16 (0.24)	2.12 (0.28)	2.04	96.2%
Digital Determinants	4.08 (0.22)	2.05 (0.26)	2.03	99.0%
Leadership/Change Management	3.98 (0.20)	2.00 (0.24)	1.98	99.0%
Domain Average	**4.12**	**2.09**	**2.02**	**96.7%**
Analytics & AI (n=14)				
Foundational AI Literacy	4.41 (0.29)	2.33 (0.36)	2.08	89.3%
Predictive Analytics	4.47 (0.28)	2.23 (0.32)	2.24	**100.4%**
Critical Appraisal of AI	4.23 (0.24)	2.11 (0.28)	2.12	**100.5%**
AI Ethics/Bias	4.37 (0.26)	2.10 (0.30)	2.27	**108.1%**
AI Implementation	4.18 (0.22)	2.03 (0.24)	2.15	**105.9%**

Competency Domain	Employer Importance (mean, 1-5)	Curriculum Coverage (mean, 1-5)	Gap (Importance - Coverage)	% Gap
Domain Average	**4.33**	**2.16**	**2.17**	**100.5%**
Overall Average	**4.25**	**2.26**	**1.99**	**89.4%**

Note: Gap = Importance - Coverage. Percentage gap = (Gap / Coverage) × 100. A positive gap indicates lower curriculum coverage than employer importance.

Table 3 presents the most striking finding of this study. Overall, the competency gap between employer requirements and curriculum coverage is 89.4%, meaning that curricula cover approximately half of the digital competencies employers deem important. The largest gaps are in Analytics and AI competencies (100.5% gap), followed by DiPH Services and Functions (96.7%), and Health Data (70.7%). AI Ethics/Bias shows the largest individual gap (108.1%), indicating that curricula cover less than half of the importance employers place on this competency. Predictive Analytics (100.4%) and AI Implementation (105.9%) also show gaps exceeding 100%.

Predictors of Competency Gaps

Table 4. Key Predictors of Digital Competency Gap Magnitude

Predictor	Coefficient (β)	95% CI	p-value	Relative Importance (%)
Program geographic region (ref: North America)				
- Europe	0.42	(0.28, 0.56)	<0.001	12.3%
- Asia-Pacific	0.71	(0.54, 0.88)	<0.001	18.7%

Predictor	Coefficient (β)	95% CI	p-value	Relative Importance (%)
- Other	0.86	(0.67, 1.05)	<0.001	20.4%
Program level (ref: Master's)				
- Bachelor's	0.34	(0.18, 0.50)	<0.001	8.9%
- Doctoral	-0.12	(-0.31, 0.07)	0.21	3.1%
Institutional resources (faculty digital expertise)	-0.47	(-0.58, -0.36)	<0.001	14.5%
Competency domain (ref: Health Data)				
- DiPH Services	0.23	(0.10, 0.36)	<0.001	6.7%
- Analytics & AI	0.35	(0.22, 0.48)	<0.001	9.8%
Curriculum constraints (credit hours required)	0.28	(0.16, 0.40)	<0.001	8.2%

Note: Model $R^2 = 0.64$, $p < 0.001$. Positive coefficients indicate larger gaps. Relative importance calculated from LightGBM feature importance analysis.

Table 4 demonstrates that geographic region is the strongest predictor of competency gaps, with programs in other regions (20.4%) and Asia-Pacific (18.7%) showing larger gaps than North American programs. Institutional resources, particularly faculty digital expertise (14.5%), are a

significant predictor, indicating that faculty development may be a key intervention point. Competency domain also predicts gaps, with Analytics and AI (9.8%) showing larger gaps than Health Data competencies.

5. Discussion

5.1 Interpretation

Major Finding 1: Widespread Digital Competency Gaps in Public Health Education

The finding of an 89.4% overall competency gap represents a significant challenge for public health workforce development. This gap indicates that current curricula are not adequately preparing graduates for the digital realities of modern public health practice. The 100.5% gap in Analytics and AI competencies is particularly concerning, given the rapid proliferation of AI applications in public health, including outbreak detection, surveillance analytics, predictive modelling, and health systems planning . The even larger AI Ethics/Bias gap (108.1%) suggests a critical deficiency in ethical training, raising concerns about graduates' ability to identify and mitigate algorithmic bias, a problem recognised as central to responsible AI governance in public health .

This finding aligns with previous research demonstrating the predominance of data-centric competencies in existing DPH training programs while identifying gaps in digital health promotion, program evaluation, leadership, and digital determinants of health . The current study extends these findings by quantifying the magnitude of these gaps and revealing regional variations, suggesting that the problem is global but particularly acute in Asia-Pacific and other non-Western regions.

Major Finding 2: Regional Variations in Competency Integration

The substantial regional variations in competency integration (31.4% North America vs. 17.0% other regions) reflect underlying differences in educational infrastructure, policy priorities, and professional accreditation requirements. North American programs, particularly those with CEPH accreditation, appear to have greater integration of digital competencies, likely influenced by accreditation standards that increasingly incorporate informatics competencies. European programs show moderate integration, consistent with ASPHER's efforts to update core curriculum documents . The findings of limited evidence from Europe in the Ramachandran et al. review parallel the lower integration levels observed in this study's European sample.

However, these regional differences also raise equity concerns, as public health professionals in less well-resourced regions are less likely to receive digital competency training yet may face the

greatest population health challenges requiring digital solutions . This finding supports concerns about the digital divide and health equity, highlighted in the competency framework for the Quintuple Aim .

Major Finding 3: Predictors of Competency Gaps

The multilevel analysis revealed that institutional resources, particularly faculty digital expertise, are a significant predictor of competency gaps. This finding is consistent with the implementation science perspective that adoption is shaped by capacity and governance structures . Programs with higher faculty expertise in digital health showed smaller gaps, suggesting that faculty development is a key intervention point. This aligns with the emphasis of Punzalan and Punzalan on continuous professional development for faculty to remain adept at teaching advanced digital concepts.

Curriculum constraints, specifically credit hours required for the degree, were also significant predictors of gaps. This supports the concern raised by the European Public Health Conference that public health programmes already incorporate considerable subject matter, making the simple addition of content challenging . This suggests that curriculum transformation, rather than addition, is needed.

5.2 Implications

Academic Implications

This study contributes to the growing body of literature on digital health competencies by providing systematic empirical evidence on the magnitude and nature of competency gaps in public health education. It extends the theoretical frameworks of competency-based education and implementation science to the digital competency domain, identifying specific gaps and their predictors.

The study also contributes to the conceptual development of digital public health competencies by validating and extending existing frameworks . The identification of AI Ethics/Bias as the competency with the largest gap (108.1%) highlights the need for greater attention to ethical dimensions of AI use in public health education, a dimension that has received relatively limited attention in previous competency frameworks.

Practical Implications

For Curriculum Designers and Educators:

1. **Prioritise Foundational AI Literacy:** Given the large gap (89.3%) in foundational AI literacy, programs should begin with core AI concepts, ensuring graduates can describe common AI types and understand their uses and limits in public health .
2. **Integrate AI Ethics Across the Curriculum:** The 108.1% gap in AI Ethics/Bias suggests that programs should integrate ethical considerations throughout the curriculum,

not just in standalone ethics courses. Students should learn to identify bias, evaluate data sources, and understand the governance of AI systems .

3. **Adopt Blended Learning Approaches:** The success of blended learning in other health professional training contexts suggests that combining self-directed online learning with facilitated virtual sessions and face-to-face application may enhance digital competency development. The blended learning approach has been found to be feasible and cost-effective, with 86% of participants in one study accessing online sessions via mobile phones .

For Institutions:

1. **Invest in Faculty Development:** The finding that faculty digital expertise is a significant predictor of smaller gaps suggests that institutions should invest in faculty development in digital health, potentially through workshops, sabbaticals, or partnerships with technology-focused departments.

2. **Develop Strategic Partnerships:** The rapid development of digital technologies requires closer collaboration with experts in information and communication technologies . Institutions should develop partnerships with computer science, data science, and engineering departments, as well as industry partners, to access expertise and co-develop curricula .

For Accreditation Bodies and Policymakers:

1. **Include Digital Competencies in Accreditation Standards:** The regional variation suggests that accreditation standards may influence competency integration. Accreditation bodies should consider including explicit digital competency requirements in their standards .

2. **Fund Curriculum Transformation:** Given the curriculum constraints that predict larger gaps, policymakers should consider funding initiatives that support curriculum transformation, including release time for faculty to develop new courses, equipment and software for data science training, and partnerships with technology providers.

5.3 Limitations

1. **Curriculum Documentation Completeness:** The study relied on publicly available curriculum documentation, which may not fully reflect actual teaching practices. Some programs may teach digital competencies without explicitly documenting them, leading to underestimation of coverage.

2. **Limited Interview Sample:** While the overall sample size of 89 programs is adequate, the interview sample was limited to 35 participants, which may restrict the

generalisability of qualitative findings. However, the breadth and depth of conversations in the interviews ensured useful insights .

3. **Self-Reported Competency Assessment:** Competency ratings were self-reported by program representatives and employers, introducing potential social desirability bias. Future research should consider objective competency assessment through standardised testing.
4. **Regional Representativeness:** While the study includes programs from 24 countries, the sample is weighted towards North America and Europe, limiting representativeness in other regions. The inclusion of only English-language program documentation may have introduced bias, similar to concerns raised in previous research .
5. **Static Analysis:** The rapidly evolving nature of digital technologies means that competency gaps may change quickly. The findings represent a snapshot at a particular time, and longitudinal monitoring is needed.

5.4 Future Research Directions

1. **Longitudinal Tracking of Competency Gaps:** Future research should track competency gaps over time to assess whether curriculum changes are effective in reducing gaps and to identify emerging competency needs as technologies evolve.
2. **Implementation Research on Integration Strategies:** Research should evaluate the effectiveness of different integration strategies (e.g., standalone courses, integrated across curriculum, capstone projects) in developing digital competencies, using quasi-experimental or experimental designs.
3. **Development of Competency Assessment Instruments:** Given the limited psychometrically validated instruments for assessing digital health competencies , research should focus on developing and validating instruments specifically for public health professionals.
4. **Cross-Professional Comparison:** Research should compare competency gaps in public health education with other health professional training programs (medicine, nursing, pharmacy) to identify common challenges and potential collaborative solutions.
5. **Impact of Generative AI:** Future research should examine the implications of generative AI (e.g., large language models) for public health practice and education, exploring how curricula should adapt to this rapidly developing technology.

6. Conclusion

This study provides compelling evidence of significant digital competency gaps in public health curricula globally, with an overall gap of 89.4% between employer requirements and curriculum coverage. The most substantial gaps are in Analytics and Artificial Intelligence competencies, where curricula cover approximately half of what employers deem important, with AI Ethics showing the largest discrepancy at 108.1%. The study's main contribution is the development of an empirically validated tiered competency framework for integrating AI and data literacy into public health education, offering a practical pathway for curriculum transformation. For administrators and curriculum designers, the message is clear: digital competency integration is not an optional addition but an urgent necessity requiring strategic investment in faculty development, institutional partnerships, and pedagogical innovation. The challenge is considerable, but so are the opportunities. As public health systems globally undergo digital transformation, the workforce must be prepared to lead, not merely follow, and this preparation begins in the classroom.

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