A Competency-Based Mapping Model For Modular Curriculum Development In Health Care Workforce Skill Training

Wenzhi Zhang[1] and Xiangli Lin[2*]

[1] Lecturer, College of Rehabilitation, Beihai Vocational College of Wellness, Beihai 536000, China
[2] Associate Professor, Basic Medical Education, Department of Basic Medical Sciences, Beihai Vocational College of Wellness, Beihai 536000, China
[*] Corresponding author. E-mail: Xiangli_Lin77@outlook.com

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The increasing complexity of healthcare delivery and rapid technological advancement demand a workforce equipped with adaptable, job-relevant competencies. This study proposes a competency-based mapping model to develop a modular curriculum framework for healthcare education. Core competencies examined include clinical learning, digital health proficiency, infection control, communication effectiveness, and critical thinking. Using a quantitative cross-sectional survey design, data from 425 participants across healthcare institutions and educational providers were analyzed through chi-square tests and regression analysis. Significant gaps ($p < 0.01$) were identified in digital health, communication, and critical thinking. A modular curriculum with structured competency mapping and visual heatmaps is proposed to enhance workforce alignment and graduate employability.

Keywords: Modular Curriculum, Healthcare Education, Skill Mapping, Industry Requirements, Clinical Skills Training

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1. Introduction

Healthcare is rapidly changing due to demographics, technology, and patient demands [1]. Competency-based mapping focuses on developing skills, knowledge, and attitudes for effective healthcare professionals [2]. The modular curriculum design organizes educational content into competency-based modules, enabling focused learning and continuous professional upskilling. Fig. 1 shows the modular curriculum development in health care workforce skill training.

The CBM model will address the interface between labour standards and modular curriculum development in the training of the health care workforce [3]. The framework maps essential competencies to learning modules and uses stakeholder consultation, task analysis, and outcome-based alignment to support competency-focused curriculum development.

Although CBM is a flexible and structured model of training healthcare skills, it is subject to several issues [4]. The model needs strong stakeholder partnership and engagement, which can be time-consuming and sometimes resource-demanding, involving the industry experts, educators, regulators, and learners. The absence of uniform competency frameworks in various fields of healthcare and geographic areas potentially makes the mapping process challenging and influences the transferability of the model [5]. The integration of mapping and modular delivery with technology and digital platforms can be difficult or encounter resistance due to infrastructure and skills deficiencies in some institutions. Despite these constraints, this analysis presents a CBM model designed to support the development of a modular curriculum framework tailored to the training of the healthcare workforce. Current healthcare education faces fragmented curricula, scalability challenges, and limited accessibility, highlighting the need for a competency-based mapping model. Based on Miller's Pyramid, the WHO health workforce framework, the Calgary-Cambridge model, and Tanner's Clinical Judgment Model, the framework integrates CL, DHP, IC, CE, and CTCS.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 describes the data, preprocessing techniques, and proposed methodology. Section 4 presents the experimental results and performance evaluation. Section 5 discusses the findings, and Section 6 concludes the paper with future research directions.

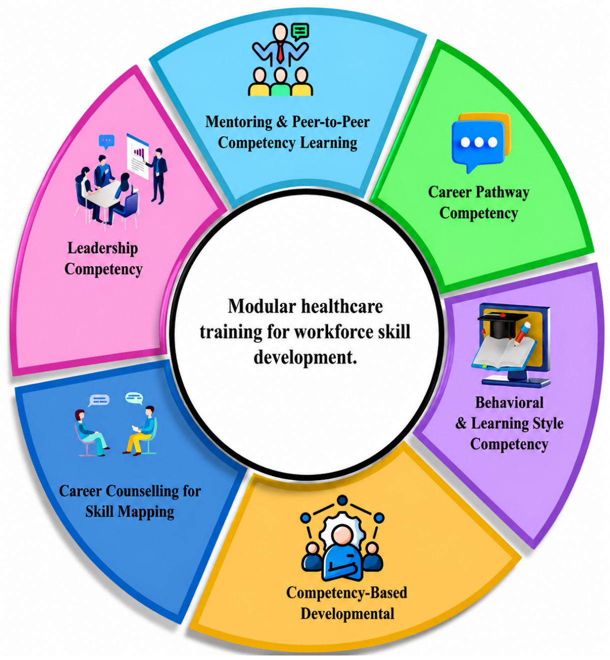

Fig. 1. Modular Curriculum Development in Health Care Workforce Skill Training

2. Related work

A mixed-methods assessment of a person-centered approach based on a competencies training course on caregiver-centered treatment for the healthcare workforce was examined in [6]. Medical, nursing, and allied health trainees, as well as healthcare professionals from five different healthcare settings, were engaged through social media and email. The diagnosis, organization, and creation of future treatment strategies for chronic illnesses all depend heavily on telemedicine in patient-centered healthcare delivery [7]. While the other characteristics (responsiveness, awareness, and capabilities) were usual, the attitude towards telemedicine was positive among the mental healthcare clinicians.

Digital tools have transformed teaching strategies and enhanced student learning in higher education [8]. Remote health monitoring systems have enabled scalable and cost-effective real-time healthcare data processing [9]. Furthermore, ECG abnormality detection algorithms have improved early diagnosis and clinical decision support through advanced computational techniques [10]. It explored digitalization approaches in nursing education, including gamification, mobile learning, simulation, virtual reality, and blended learning. As shown in Table 1, existing studies address individual competencies, whereas the proposed model integrates CL, DHP, IC, CE, and CTCS within a unified competency-based framework.

Although prior studies have explored competency-based education, curriculum mapping, and digital healthcare training independently, the proposed study combines competency assessment, statistical analysis, and competency-to-curriculum mapping within a modular framework.

2.1. Problem Statement

Healthcare education faces fragmented curricula and limited scalability [6–8]. Telemedicine training shows moderate competency levels among providers [11, 12]. The proposed framework integrates simulation, telemedicine, and caregiver modules using scalable digital platforms to improve workforce preparedness. Fragmented curriculum refers to isolated delivery of healthcare competencies. It is defined using Likert-scale competency alignment indicators measuring gaps between expected and perceived CL, DHP, IC, CE, and CTCS domains.

3. Methodology

A survey of 425 educators, trainees, and healthcare professionals assessed CL, DHP, IC, CE, and CTCS using descriptive, regression, and chi-square analyses to identify competency gaps and curriculum alignment (Fig. 2).

3.1. Data Collection

Data were collected through a structured questionnaire administered to 425 healthcare educators, trainees, and professionals to evaluate key healthcare workforce competencies. Clinical Learning (CL), Digital Health Proficiency (DHP), Infection Control (IC), Communication Effectiveness (CE), and Critical Thinking and Clinical Skills (CTCS). Participants rated competencies using a 5-point Likert scale, while demographic data supported analysis of stakeholder-based competency variations. The sample size of 425 was determined through G*Power analysis, and

Table 1. Comparative related works

Ref.	Area Focused	Procedures	Limitations	Performance
Poore et al., [11]	Simulation-Based Nursing Education	Developed 7 online modules using simulation best practices, grounded in pedagogy, frameworks, and debriefing	Financial and time constraints limit facilitator training	Provided a cost-effective, asynchronous, and accessible training method to enhance educator preparedness.
Majerník et al., [12]	Medical Curriculum Management and Harmonization	Needs analysis at 5 universities, methodological guideline development, and healthcare portfolio platform creation	Variability in curricula across healthcare institutions ; initial limitation in capturing all hidden curriculum relationships	Successfully revealed overlaps, gaps, and hidden relations in healthcare Anatomy curricula
Dwyer et al., [13]	Online Continuing Professional Development (CPD) for Healthcare Redesign	Structured into 6 weekly modules with quizzes, videos, and communication activities	Limited to initial feedback and Australian participants; 20% completion rate	81% user satisfaction; 82% intend to apply knowledge in practice; 578 enrolled, 118 completed (20%)
Proposed study	CBM-based modular healthcare curriculum	Competency mapping + statistical validation (descriptive, regression, chi-square)	Regional sampling ; institutional variation	Integrates CL, DHP, IC, CE, CTCS with improved curriculum-industry alignment

stratified sampling ensured proportional representation across stakeholder groups.

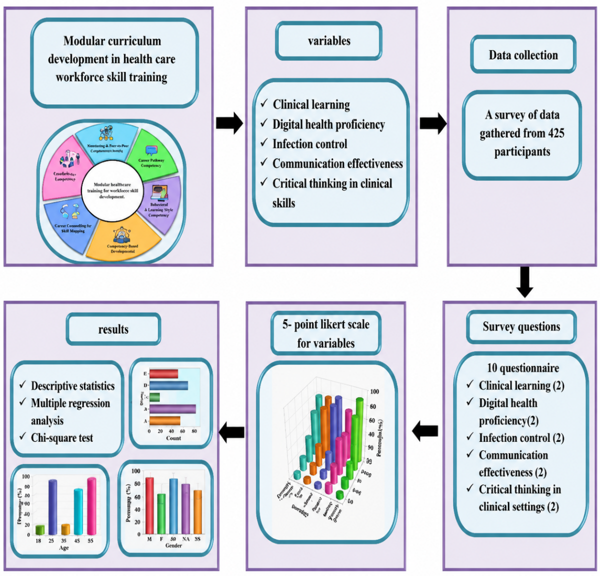

Fig. 2. Overall methodology flow of healthcare workforce skill training

Participants from multiple healthcare institutions across three regions were recruited using stratified purposive sampling to represent educators (n=120), trainees (n=180), and healthcare professionals (n=125). Data cleaning excluded incomplete responses, and diverse institution types enhanced the representativeness and validity of competency-based mapping outcomes.

Table 2 shows satisfactory reliability with Cronbach's alpha (0.816–0.902) and composite reliability (0.851–0.926) above 0.70, and AVE (0.587–0.748) above 0.50, confirming validity.

Table 2. Reliability and Convergent Validity Assessment of the Structured Questionnaire

Construct	Cronbach _Alpha	Composite _Reliability	AVE
CL	0.842	0.876	0.641
DHP	0.889	0.912	0.721
IC	0.816	0.851	0.587
CE	0.861	0.892	0.673
CTCS	0.902	0.926	0.748

The sample (N=425) included educators (28.2%), trainees (42.4%), and industry professionals (29.4 %). Gender was balanced (50.6% male, 48.2% female). Most were aged 18–34 (70.5%), held bachelor's degrees (47.0%), worked full-time (65.9%), and specialized in nursing (37.6%) or allied health (24.8%). Institutions included academic (44.7%), hospital-based (34.1%), and private centers (21.2%).

3.2. Structure of Questionnaire

The questionnaire comprised ten Likert-scale items across five competency domains–CL, DHP, IC, CE, and CTCS–assessing confidence, preparedness, knowledge, practical application, communication ability, digital proficiency, and clinical decision-making skills.

3.3. Research Design

A structured online questionnaire with 15 Likert-scale questions evaluated CL, DHP, IC, CE, and CTCS competencies. Digital Health Proficiency (DHP) includes AI-driven tools, advanced health data systems, and digital decision-support technologies aligned with modern clinical practice and healthcare digital transformation. The questionnaire evaluated perceived significance and sufficiency of training among 425 educators, trainees, and healthcare professionals.

3.4. Statistical Assessment

SPSS 25 used descriptive statistics, regression, and chi-square tests to analyze demographics, curriculum alignment, and competency differences. Chi-square test verified independence and expected cell frequencies; multiple regression confirmed linearity, normality, homoscedasticity, and absence of multicollinearity. Enabled deeper analysis of competency alignment and modular curriculum development. Meanwhile, Likert-scale responses combined with chi-square tests and multiple regression analysis were used to identify competency gaps across domains. Statistical analyses identified competency priorities, training gaps, and stakeholder differences, supporting competency-to-curriculum mapping. Results enable heatmap-based visualization for adaptive curriculum design. The proposed model maps CL, DHP, IC, CE, and CTCS into modular curriculum development using assessment, feedback, and reassessment.

The competency-based mapping process is formally described in Algorithm 1, which illustrates the step-by-step procedure for mapping CL, DHP, IC, CE, and CTCS into curriculum modules.

4. Result

A survey of 425 participants assessed curriculum alignment and competencies using descriptive, regression, and chi-square analyses.

4.1. Descriptive statistics

Descriptive analysis showed curriculum alignment influences training effectiveness, with notable disparities in digital health readiness and patient communication (Eq. (1)).

$$\underline{W} = \frac{\sum_{j=1}^{m} W_j}{m} \tag{1}$$

Here, $\underline{W}$ represents the average curriculum alignment score derived from participant responses, providing statistical support for targeted curriculum refinement and competency-based mapping. The average alignment score (W) is computed as the arithmetic mean of participant ratings, assuming linear aggregation of Likert-scale responses, with equal weighting of all responses. A higher W indicates stronger curriculum-industry alignment, while a lower value reflects greater alignment gaps requiring improvement.

The mapping outputs were quantitatively evaluated using competency-specific mean scores derived from participant survey responses across CL, DHP, IC, CE, and CTCS. Higher mean scores indicated stronger curriculum-industry alignment, whereas lower scores identified competency gaps requiring targeted curriculum refinement. CL (4.58) and IC (4.39) were strongest competencies, CE (3.87) was moderate, while DHP (3.21) and CTCS (3.49) showed improvement needs, especially in digital health training (Table 3).

Table 3. Descriptive Statistics Outcomes

Variable	Mean	SD	Median	Min	Max
CL	4.58	0.42	4.60	4.16	5.00
DHP	3.21	0.76	3.20	2.45	3.97
IC	4.39	0.53	4.40	3.86	4.92
CE	3.87	0.62	4.00	3.25	4.49
CTCS	3.49	0.69	3.50	2.80	4.18

4.2. Multiple regression analysis

Multiple regression analysis evaluated the influence of curriculum components on healthcare workforce training effectiveness using β coefficients, t-values, and p-values (Eq. (2)).

$$Z = \beta_0 + \beta_1 W_1 + \beta_2 W_2 + \cdots + \beta_l W_l + \varepsilon \tag{2}$$

Algorithm 1: Competency-Based Mapping and Heatmap Generation Model

Input: Likert-scale responses for CL, DHP, IC, CE, and CTCS (n=425)
Output: Competency-based curriculum modules and heatmap visualization
Begin

1. Load and preprocess data containing competency responses (CL, DHP, IC, CE, CTCS), and compute descriptive statistics (mean and standard deviation).
2. Normalize competency scores using Min-Max normalization:
$$C_{\text{norm}} = \frac{C_i - C_{\text{min}}}{C_{\text{max}} - C_{\text{min}}}$$
3. Perform statistical analysis by applying multiple regression to estimate competency contributions:
$$M = \sum \left(\beta_i \cdot C_{\text{norm},i}\right) + \epsilon$$
4. Conduct validation tests, including chi-square analysis and assumption checks
5. Compute competency gaps between expected and observed competency levels:
$$G = \left|C_{\text{expected}} - C_{\text{observed}}\right|$$
6. Map competencies to curriculum modules:
   - CL → Clinical Practice
   - DHP → Digital Health
   - IC → Infection Control
   - CE → Communication
   - CTCS → Clinical Reasoning
7. Generate a heatmap and a curriculum framework using competency gap values to visualize priority areas and produce the competency-based modular curriculum.

End

DHP had the strongest influence ($\beta = 0.42$, $p < 0.001$), followed by CE, CL, and CTCS, while IC was not significant (Fig. 3).

Multicollinearity diagnostics showed VIF values below 5, confirming independence and supporting reliable regression estimates in Table 4.

Table 4. Multiple Regression Analysis Outcomes

Variable	Coefficient (β)	t-value	p-value
CL	0.28	4.00	<0.001
DHP	0.42	6.63	<0.001
IC	0.09	1.38	0.168
CE	0.35	5.65	<0.001
CTCS	0.26	3.75	<0.01

Table 5 shows tolerance 0.618–0.883 and VIF 1.132–1.618, indicating no multicollinearity among CL, DHP, IC, CE, and CTCS.

Table 5. Multicollinearity Diagnostics of Regression Predictors

Variable	Tolerance	VIF
CL	0.742	1.348
DHP	0.618	1.618
IC	0.883	1.132
CE	0.667	1.499
CTCS	0.693	1.443

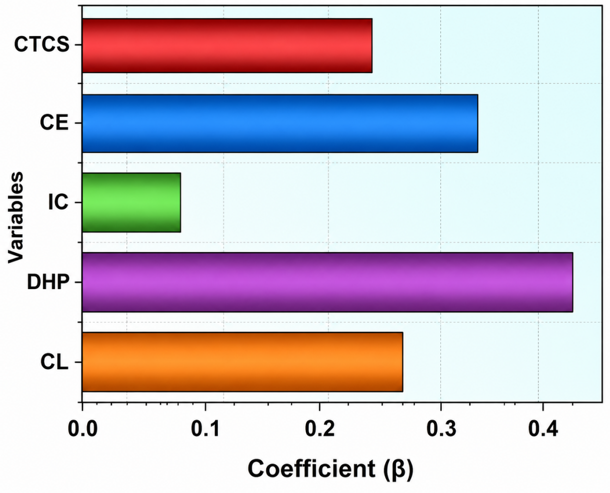

Fig. 3. Comparative Coefficients of Multiple Regression Analysis Outcomes

4.3. Chi-square test

Chi-square showed role-based differences supporting curriculum customization and effectiveness (Eq. (3)).

$$\chi^2 = \Sigma \left[\frac{\left(P_j - F_j\right)}{F_j} \right] \quad (3)$$

Chi-square analysis identified significant role-based differences in DHP (χ^2=15.32, p=0.0004), CTCS (χ^2=13.65, p=0.0011), and CE (χ^2=11.78, p=0.0028), whereas CL and IC showed no significant differences. The chi-square analysis showed significant differences in competency perceptions across stakeholder roles (educators, trainees, and professionals), indicating role-dependent variation in competency priorities. These findings highlight the need for role-specific curriculum customization, supporting tailored modules to improve training relevance and effectiveness in healthcare education. Digital competencies and CTCS require strengthening due to variation (Table 6).

Table 6. Chi-square Outcomes

Variable s	χ^2 Value	degrees of freedom (df)	p-value
CL	3.21	2	0.201
DHP	15.32	2	0.0004
IC	2.89	2	0.235
CE	11.78	2	0.0028
CTCS	13.65	2	0.0011

Table 7 presents Bonferroni-adjusted post-hoc comparisons identifying significant differences among educators, trainees, and industry professionals for DHP, CE, and CTCS, highlighting role-based competency variations and curriculum alignment requirements.

Competency mapping and heatmap visualization prioritized DHP (mean = 3.21, β = 0.42) and CTCS (mean = 3.49, β = 0.26) using Likert-scale, chi-square, and regression analyses. DHP showed the strongest effect on curriculum-industry alignment (β = 0.42, p $<$ 0.001), followed by CE and CL, supporting digital health, communication, and clinical module prioritization.

5. Discussion

Generative AI in curriculum design, teaching, assessment, and DEI was examined in [14], while [15] explored healthcare system evolution. Descriptive statistics show CL (4.58) and IC (4.39) are highest, while DHP (3.21) and CTCS (3.49) are lowest, indicating targeted improvement needs. Higher CL and IC scores reflect strong foundational training, while lower DHP and CTCS scores indicate areas needing improvement. Enhancing digital health, clinical reasoning, and simulation-based learning can improve communication and overall training effectiveness. Multiple regression identified DHP (β = 0.42, p $<$ 0.001), CE (β = 0.35, p $<$ 0.001), and CL (β = 0.28, p $<$ 0.001). Chisquare showed DHP (χ^2 = 15.32, p = 0.0004), CTCS (χ^2 = 13.65, p = 0.0011), CE (χ^2 = 11.78, p = 0.0028) differences. Descriptive statistics identified competency gaps, regression confirmed their impact on training effectiveness, and chi-square analysis revealed role-based variations, supporting curriculum-industry alignment. Collectively, these results highlight the growing importance of digital literacy and cognitive reasoning in modern healthcare training and demand for adaptive, competency-specific curriculum development. The competency-based modular curriculum framework faces challenges from institutional, resource, and technological variations. Generative AI can support adaptive learning, automated assessment, simulation-based training, and competency-focused curriculum development.

6. Conclusion

The increasing complexity of healthcare services and technological integration highlights the urgent need for adaptive, skill-focused training models. This analysis established a competency-based mapping model to inform modular development of the curriculum on training of the healthcare workforce. The research involved 425 respondents in healthcare facilities and providers of education and conducted data analysis using chi-square tests, multiple regression analysis, and descriptive statistics to compare

Table 7. Post-hoc Pairwise Analysis of Competency Differences Across Stakeholder Groups

Competency	Group_Comparison	Mean_ Difference	Adjusted_ P_ Value	Significant
DHP	Educators vs Trainees	0.44	0.0009	Yes
DHP	Educators vs Industry Professionals	0.27	0.018	Yes
DHP	Trainees vs Industry Professionals	0.18	0.041	Yes
CE	Educators vs Trainees	0.31	0.011	Yes
CE	Educators vs Industry Professionals	0.24	0.027	Yes
CE	Trainees vs Industry Professionals	0.09	0.118	No
CTCS	Educators vs Trainees	0.41	0.001	Yes
CTCS	Educators vs Industry Professionals	0.3	0.009	Yes
CTCS	Trainees vs Industry Professionals	0.12	0.072	No

how industry expectations align with the delivery of education. Descriptive results show CL (mean= 4.58) and IC (mean= 4.39) as top-priority competencies. In response to multiple regression analysis, DHP ($\beta = 0.42$, $p < 0.001$) and CE ($\beta = 0.35$, $p < 0.001$) show significant effects on supposed curriculum relevance. Chi-square analysis identified significant misalignments in DHP ($\chi^2 = 15.32$, p $= 0.0004$) and CTCS ($\chi^2 = 13.65$, p $= 0.0011$). These results provide importance to curriculum assimilation to adapt to the changes in the workforce requirements, especially with the influence of the digital construct and human-centered healthcare. The model provides a flexible approach for supporting educational and practice gaps. Limitations include regional sampling and inconsistent practices of institutions. Regional sampling (three areas) limits generalizability. Inconsistent institutional practices add variability. Self-reported data may have social desirability bias. A cross-sectional design does not measure longitudinal changes. Further development can consider AI-supported curriculum customization, longitudinal evaluation of the impacts, and cross-regional verification to guarantee wider applicability and sustained innovation of healthcare education.

Declaration

Data Availability

No dataset found.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Author Contributions

Wenzhi Zhang contributed to study design, data collection, data analysis, and manuscript drafting. Xiangli Lin supervised the research, contributed to methodological design, validated the statisticals.

Ethical Approval

The study involved survey data collected from educators, trainees, and healthcare professionals. Ethical approval was obtained from the institutional academic review committee of Beihai Vocational College of Wellness prior to data collection.

Consent to Participate

Informed consent was obtained from all participants involved in the study.

Consent to Publication

All authors have reviewed and approved the manuscript and consent to its publication.

Competing Interests

The authors declare that they have no competing interests.

Code Availability

Statistical analyses were performed using standard statistical software. Any analytical procedures or scripts used in this study are available from the corresponding author upon reasonable request.

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