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From classroom to clinic: analyzing the genomics competency gap across undergraduate students, graduate students, and practicing nurses in China

Yang Shen[1], Chen Chen[2], Honglei Jiang[3], Dan Wu[4] and Qian Wang[1*]

Abstract

Background Genomics is increasingly integral to clinical care, spanning areas such as rare diseases, oncology, and pharmacogenomics. Nurses and nursing students play essential roles as frontline providers and educators. However, current evidence suggests a widespread lack of readiness. This study evaluates and compares genomics competency across undergraduate students, graduate students, and practicing nurses in China.

Methods A cross-sectional survey was conducted from September to October 2025 among 502 participants (136 undergraduates, 168 graduates, 198 practicing nurses) using the Chinese version of the Genetics and Genomics Nursing Practice Survey (GGNPS-CN).

Results The overall mean genomics knowledge score was 9.51, with no significant differences observed across cohorts. In contrast, self-rated understanding showed notable differences among cohorts. The proportion of "excellent" or "good" ratings was highest among undergraduate students, followed by practicing nurses and then graduate students ($p < 0.05$). Notably, over one-quarter (25.3%) of respondents reported no formal genomics education in their curriculum.

Conclusion Despite similar knowledge levels, the three nursing cohorts showed a self-assessment bias in genomics. A tiered educational framework is proposed to address stage-specific needs: fostering metacognition in undergraduates, integrating research with practice in graduates, and enhancing ethical decision-making in practicing nurses.

Keywords Genomics competency, Nursing students, Practicing nurses, Cross-sectional study, Genomics education

*Correspondence:
Qian Wang
qwang@cmu.edu.cn
[1]School of Nursing, China Medical University, 77 Puhe Road, North New Area, Shenyang, China
[2]The Research Center for Medical Genomics, Key Laboratory of Cell Biology, Ministry of Public Health, and Key Laboratory of Medical Cell Biology, Ministry of Education, China Medical University, 77 Puhe Road, North New Area, Shenyang, China
[3]General Surgery Department, The Fourth Affiliated Hospital of China Medical University, 4 Chongshan East Road, Huanggu District, Shenyang, China
[4]Infectious Disease Department, The Shengjing Hospital of China Medical University, 39 Huaxiang Road Tiexi District, Shenyang, China

Background

Genomics is undergoing a critical transition from fundamental research to routine clinical integration. Driven by core technologies such as next-generation sequencing, this shift is reshaping medical paradigms and broadening the applications of genomics, including rare genetic diseases, oncology, pharmacogenomics, and chronic disease management [1–3]. For example, comprehensive genomic profiling has become integral to the clinical management of malignancies, including brain tumors. The detection of driver genomic alterations provides a molecular basis for targeted therapies. This approach substantially improves diagnostic accuracy and treatment efficacy [4]. These developments highlight the central role of genomic medicine in tumor classification, prognostic evaluation, and personalized treatment strategies [5–7]. Consequently, genomic considerations now permeate most clinical nursing contexts. Examples include tailoring warfarin doses based on pharmacogenomics, guiding cancer screening due to BRCA variants, and managing inherited heart conditions such as familial hypercholesterolemia. It is therefore essential to integrate genomics knowledge and information into clinical nursing practice to enable more precise assessments, develop personalized care plans, and provide proactive patient education and psychological support [8, 9].

As the most frequent patient-facing healthcare providers, nurses are undergoing a substantial transformation in their roles and responsibilities, evolving from conventional bedside care to a multifaceted role. They act as frontline practitioners, educators, and advocates, integral to interpreting data and guiding patients and families through the associated ethical, legal, and psychosocial considerations for informed decision-making [10–13]. For example, nurses play a critical role in counseling patients with hereditary cancer syndromes about the need for prophylactic complementary therapies and risk-reducing surgeries, helping them weigh the benefits and harms based on genetic test results and personal values [14].

Several countries, including America, Canada, Turkey, and China, have conducted studies using the Genetics and Genomics in Nursing Practice Survey (GGNPS). These studies evaluated genomics competency among nurses [15–18]. The findings consistently indicate a significant deficit in preparedness within the global nursing workforce, manifested as inadequate genomics knowledge, low confidence, and limited self-perceived competence. However, most existing investigations focus exclusively on practicing nurses. As the future backbone of the clinical nursing workforce, nursing students must develop genomics competency, which is crucial for advancing clinical genomics healthcare services. Therefore, evaluating the genomics nursing competency of nursing students and comparing it with that of practicing clinical nurses is crucial to identifying areas for educational improvement. The Genomic Nursing Concept Inventory (GNCI), developed and validated by Ward and colleagues, serves as a key assessment instrument for evaluating genomic literacy among nursing students. Grounded in essential nursing competencies, the GNCI has undergone rigorous psychometric testing for reliability and validity [19]. Importantly, the framework underlying the GNCI highlights how effective genomic teaching and its clinical application can directly improve patient wellbeing through personalized risk assessment and informed decision-making, while also contributing to broader community welfare by reducing health disparities and optimizing preventive care. The GNCI has since been adopted in multiple international studies to assess genomic knowledge across diverse cultural and educational contexts [20, 21]. The establishment of this tool provides a critical methodological foundation for research in this field. This knowledge is necessary to better tailor and optimize genomics nursing education within nursing programs. Furthermore, prevailing competency assessments have predominantly focused on foundational knowledge, with insufficient emphasis on more complex dimensions such as clinical application competency and ethical reasoning [22, 23]. The absence of ethical dimensions in many competency assessments has been criticized in recent reviews [24, 25]. It is therefore a positive development that this crucial element of genomics has been further addressed in the refinement of a widely used instrument(GGNPS). This newly enhanced version of the Genetics and Genomics Nursing Practice Survey (GGNPS-CA), which incorporates ethical considerations, has been utilized in international settings [15, 26]. However, neither of these recent Chinese studies included nursing students or incorporated the updated ethical dimension of the GGNPS-CA [16, 27].

The current gap in genomic knowledge among nursing professionals' points to deeper systemic issues, including inconsistent integration of genomics into curricula, insufficient faculty training, and limited clinical application opportunities for students [28]. To address these issues, this study translated and culturally adapted the Canadian revised version of the GGNPS scale for use among Chinese nursing students and practicing nurses. The scale assesses knowledge, attitudes, confidence, ethical awareness, and practical behaviors, providing an empirical basis to evaluate current curricula, identify educational limitations, and guide targeted curriculum refinement and faculty development. Ultimately, this study aims to provide data support for the concerted efforts needed to close the genomics competency gap, including curriculum reform, enhanced faculty training, and robust clinical or simulated learning opportunities.

Methods

Study design

This was a cross-sectional study conducted among undergraduate students, graduate students, and practicing nurses from multiple institutions across Liaoning Province, China, including China Medical University, and its affiliated First Affiliated Hospital, Fourth Affiliated Hospital, and Shengjing Hospital. The Canadian revised version (GGNPS-CA), a tool revised from the original GGNPS, was contextually adapted and used for descriptive investigation.

Participants and recruitment

The target population included undergraduate students, graduate students, and practicing nurses. Eligible participants included undergraduate students in their third year or above who had completed genomics-related courses. These courses typically cover foundational topics such as basic genetic concepts, inheritance patterns, and the clinical application of genetic testing in oncology and rare diseases. Graduate students and practicing nurses were also eligible. All participants took part voluntarily. Exclusion criteria included students who had previously participated in similar studies and those who had been suspended. The sample size was calculated in accordance with the principle for cross-sectional survey sample size estimation, where the formula n = number of independent variables× (5–10) was adopted [29]. In this study, a total of 8 demographic variables were defined as independent variables. A sample size of at least 50 was expected, considering a 20% non-response rate. A total of 502 participants were included in the study, comprising 136 undergraduates, 168 graduate students, and 198 practicing nurses. All participants met the preset sample size requirements.

Instruments

GGNPS-CA was revised from the original GGNPS and structured based on Rogers' Diffusion of Innovations theory, covering dimensions such as attitudes, acceptance, confidence, social systems, adoption, genomics knowledge and ethics [18]. The development and structure of GGNPS-CA have been reported in the study by Limoges et al. [15]. The revised tool retained the original framework while incorporating a significant new dimension, ethics. Finnish scholar Laaksonen utilized the new tool to study genomics competency among nursing staff [26]. The strength of GGNPS-CA lies in its ability to assess overall genomics competency in nursing staff rather than focusing solely on specific genetics areas. Therefore, in the current context of China, where there is a lack of genomics competency assessment tools with comprehensive ethical dimensions for nursing undergraduates, graduates, and practicing nurses, the adoption of GGNPS-CA fills this gap. It serves as a key preliminary assessment tool to address the lack of ethical content in existing Chinese versions.

Following approval from the original questionnaire authors, the GGNPS-CA was cross-culturally adapted to create the Chinese version (GGNPS-CN). The process included initial translation, synthesis, back-translation, expert committee review, and pilot testing. Five experts (three nursing experts, one genomics expert, and one ethics expert) evaluated the content validity of GGNPS-CN, and cultural adjustments were made according to the Chinese context. We conducted a pilot study to assess the reliability and validity of the instrument. In the pilot phase, a total of 334 valid questionnaires were collected, and 30 participants were selected from them for test-retest reliability with a two-week interval. The Scale-Level Content Validity Index (S-CVI) was 0.98. The test–retest reliability of each item, assessed using Cohen's kappa coefficient, ranged from 0.278 to 1. The results showed a Cronbach's alpha coefficient of 0.71 for the GGNPS-CN genomics knowledge dimension, which is acceptable. The data from this pilot study were not included in the final analysis.

To ensure the adapted instrument was appropriate for the Chinese setting, one item from the ethics dimension of the GGNPS-CA was omitted. The omitted statement was: "Access to the social determinants of health (e.g., education and literacy, income and social status, social supports and coping skills, and physical environments) impacts gene expression". This decision was made because expert review and pilot testing indicated that the underlying concept (epigenetics) was not widely understood by Chinese nursing participants, and its inclusion would have compromised response validity. The Chinese adaptation process involved revisions to two items within the knowledge section of the GGNPS-CA questionnaire. The original knowledge item, "A family history that includes only 1st degree relatives such as parents, siblings, and children should be taken for every new patient," was replaced with the question, "Do you think that genetic risk (e.g., as indicated by family history) has clinical relevance for mental health?" Based on expert feedback, another question was revised. The original statement, "The DNA sequences of two randomly selected healthy individuals of the same sex are 90–95% identical," was changed to "The DNA sequences of two randomly selected healthy individuals of the same sex are 99.9% identical." The minimum and maximum scores remained unchanged. The Chinese GGNPS-CN scale consists of 58 items, including multiple-choice questions, binary items (yes/no, true/false), and Likert-scale items. Items in the attitudes, acceptance, confidence, social systems, adoption and ethics domains were analyzed individually without summative scoring. The

knowledge domain comprises 12 items, which were combined to generate a total knowledge score ranging from 0 to 12, with a higher score indicating a higher level of genomic knowledge. Furthermore, demographic questions, adapted to the educational and healthcare context of China, were included to gather data on participant characteristics such as age, gender, and nursing education level.

Data collection

The online survey was administered through an online survey platform Questionnaire Star (Online). Data collection took place from September to October, 2025. An online questionnaire link was distributed through the Student Union and Nursing Association of China Medical University, employing convenience sampling and snowball sampling methods for data collection, with multiple rounds of follow-up conducted. Participation was voluntary and completion of the survey implied informed consent. A unique random code was generated by the Questionnaire Star survey platform for each participant; however, no personally identifiable information was collected.

Table 1 Demographic data

Participants	*n*	%
Age		
≤ 35	432	86.1
>35	70	13.9
Gender		
Male	34	6.8
Female	468	93.2
The total number of years your nursing-related experience		
≤ 10	416	82.9
>10	86	17.1
Ethnicity		
Han	432	86
Other	70	13.9
Marital status		
Other	357	71.1
Married	145	28.9
Level of nursing education		
Associate degree or diploma	20	4
Bachelor's degree	299	59.6
Master's degree	183	36.5
Please indicate your current status (e.g., undergraduate student by year, or employed nursing professional).		
Undergraduate student	136	27.1
Graduate student	168	33.5
Practicing nurse	198	39.4
Have you completed any clinical internships?		
Yes	459	91.4
No	43	8.6
Do you have prior work experience?		
Yes	229	45.6
No	273	54.4

Statistical analysis

All collected data were exported from Excel and imported into Statistical Package for the Social Sciences (SPSS) 26.0 for analysis. In addition, to improve statistical power, categorical variables with sparse responses (1–3 observations in a category) were recategorized during data analysis. Specifically, the 3-point scale ("excellent," "good," "poor") for 4 items was collapsed into a 2-category variable (excellent/good vs. poor).

Descriptive statistics included means, standard deviations, frequencies, and percentages. Normality was assessed by examining skewness and kurtosis to determine the use of parametric or non-parametric tests. Measurement data in this study followed a normal distribution. Independent samples t-tests were used for comparisons between two groups, and one-way Analysis of Variance (ANOVA) was applied for comparisons among multiple groups. If variances were homogeneous, the Least Significant Difference (LSD) post - hoc test was used for pairwise comparisons; if not, Dunnett's T3 test was applied. $P<0.05$ was considered statistically significant.

Ethical considerations

The study was approved by the Ethics Committee of China Medical University (Approval No.: [2025] 247). All research activities were conducted after approval. Participants were fully informed of the study's purpose, participation was voluntary, and the right to withdraw at any stage was assured.

Results

Demographic characteristics

A total of 502 participants were included in this study, with a mean age of 27.17 ± 6.97 years (range: 18–55 years). Among them, 468 (93.2%) were female. The cohort consisted of 136 undergraduate students, 168 graduate students, and 198 practicing nurses. The mean duration of nursing-related experience (including both formal education and clinical practice) was 6.97 ± 5.34 years (range: 2–35 years). Detailed demographic data are presented in Table 1.

Genomics knowledge

The mean score on the genomics knowledge section among all 502 participants was 9.51 (standard deviation, SD = 1.74). The two items with the lowest correct response rates were Item 10 (pertaining to DNA similarity between humans) and Item 11 (addressing whether common diseases are monogenic disorders), with correct response rates of 32.1% and 31.5%, respectively.

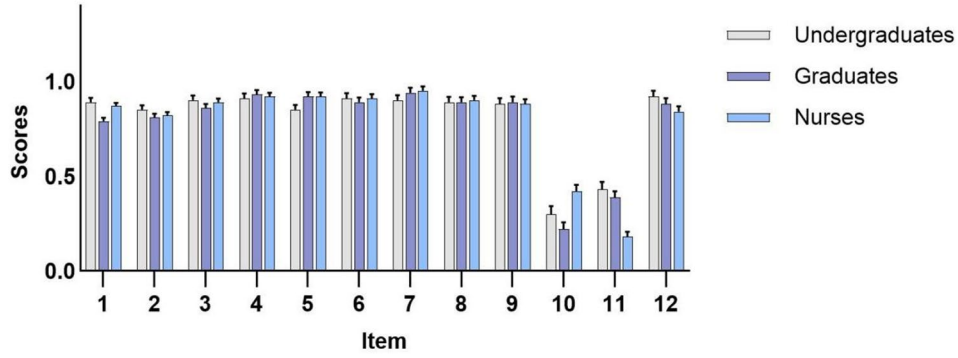

Fig. 1 The average score of the three groups of nursing staff on the 12 knowledge questions. ($n = 502$)

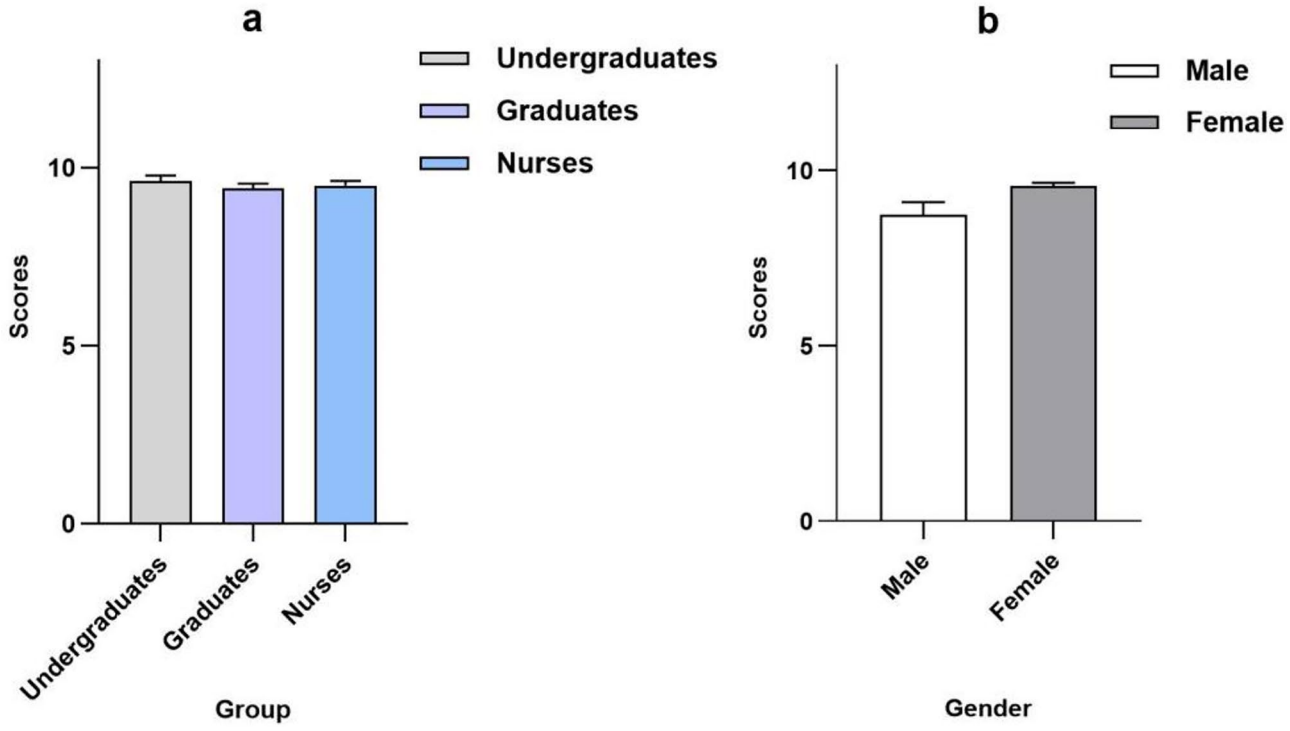

Fig. 2 **a**. Comparison of genomics knowledge scores across different nursing groups. **b**. Comparison of knowledge scores between males and females

The scores of undergraduates, graduates, and nurses for genomics knowledge items 1–12 are illustrated in Fig. 1.

Among the participants, undergraduate students ($n = 136$) scored 9.63 ± 1.69 (range: 4–12). Item 12 had the highest correct response rate, whereas Item 10 had the lowest, with a correct response rate of 30.1%. Graduate students ($n = 168$) scored 9.42 ± 1.67 (range: 3–12). Item 7 exhibited the highest correct response rate, and Item 10 the lowest, with a correct response rate of 22.0%. Practicing nurses ($n = 198$) scored 9.50 ± 1.82 (range: 3–12). Item 7 showed the highest correct response rate, while Item 11 had the lowest, with a correct response rate of 17.7%. No statistically significant difference was observed in genomics knowledge scores among the three groups ($P > 0.05$) (Fig. 2a).

Relationship between genomics knowledge and demographic variables

Among the 34 male respondents, the mean knowledge score (8.74) was slightly lower than that of their 468 female counterparts (9.56). (Fig. 2b). No statistically significant associations were observed between knowledge scores and other variables, including duration of nursing education, ethnicity, marital status, educational level, clinical practicum experience, or work experience. ($P > 0.05$)(Table 2).

A total of 262 respondents (52.2%) rated their understanding of general genomics as excellent or good. Among these, the proportion of undergraduates who rated their understanding as excellent/good was 66.9%, compared to 39.3% of graduate students and 53.0% of

Table 2 Univariate analysis of knowledge scores

Variable	Category	Mean	Standard Deviation	Statistic	*P*
Gender	Male	8.7353	2.07888	-2.705a	0.007*
	Female	9.5641	1.69713		
Age	≤ 35	9.5291	1.67505	0.357	0.721
	>35	9.4493	2.00394		
Years of Nursing Education	≤ 10	9.4976	1.69194	0.2294	0.769
	>10	9.5581	1.94395		
Ethnicity	Han	9.5093	1.72867	0.041a	0.967
	Other	9.5	1.79169		
Marital Status	Other	9.5350	1.63770	0.547	0.584
	Married	9.4414	1.96099		
Education Level	Below Bachelor	9.3	1.78001	0.255b	0.775
	Bachelor	9.5452	1.80802		
	Graduate	9.4699	1.61311		
Current Status	Undergraduate Student	9.6324	1.6901	0.583b	0.559
	Graduate student	9.4167	1.66836		
	Practicing nurse	9.5	1.82412		
Clinical Internship Experience	No	9.814	1.40163	1.209a	0.227
	Yes	9.4793	1.76239		
Work Experience	No	9.5311	1.5904	0.326a	0.744
	Yes	9.4803	1.89778		

Note: *$p < 0.05$, ***$p < 0.001$; *a* represents t-test, *b* represents ANOVA

practicing nurses. Intergroup comparisons revealed a statistically significant difference ($P < 0.001$) (Fig. 3a). In contrast, 240 participants (47.8%) rated their understanding as poor. When asked about their understanding of the genetics of common health conditions, responses were more evenly distributed; 247 respondents (49.2%) rated their comprehension as excellent/good, while 255 (50.8%) rated it as poor. Among those who self-rated their understanding as excellent/good, the proportion was 64.0% for undergraduates, 35.7% for graduate students, and 50.5% for practicing nurses. Again, a significant difference was observed among the group ($P < 0.001$) (Fig. 3b).

Attitudes and acceptance

The majority of respondents considered it very important (65.5%, $n = 329$) or somewhat important (22.1%, $n = 111$) for nurses to receive more education on the genomics of common diseases. Among all participant subgroups, including undergraduate students, graduate students, and practicing nurses, a majority exceeding 80% rated such education as important, with the "very important" and "somewhat important" responses combined.

Confidence

Both undergraduate (97.1%) and graduate (96.4%) students reported the highest level of confidence in collecting family history information regarding genetic susceptibility to common diseases, whereas confidence was relatively lower for assisting patients with referrals to genetic services for common diseases (92.6% and 86.3% respectively). Among practicing nurses, the highest confidence was in providing culturally sensitive care integrating genomics knowledge (97.5%), while lower confidence relative to other competencies was reported for discussing the impact of family history on disease screening intervals (91.9%).

Social system

Most nursing students and practicing nurses reported that their curriculum already included genomics content. However, 25.3% of respondents indicated that their courses did not cover this topic, with the highest proportion (39.3%) observed among graduate students. Regarding willingness for further learning, 64.5% expressed intent to learn more about genomics, with practicing nurses showing the strongest interest (70.7%). Regarding course participation, 59.0% were willing to attend genomics courses during work hours, with undergraduates showing the highest willingness (65.4%). Additionally, 53.2% were willing to participate in such courses during their spare time, with practicing nurses demonstrating the highest enthusiasm (62.1%).

Ethical issues

Among the 502 participants, 429 (85.4%) regarded training in genomics ethics as very important or somewhat important. Among undergraduates, graduates, and nurses, the proportion considering such training important (combining very important and somewhat important) exceeded 80%. A neutral stance was taken by 58

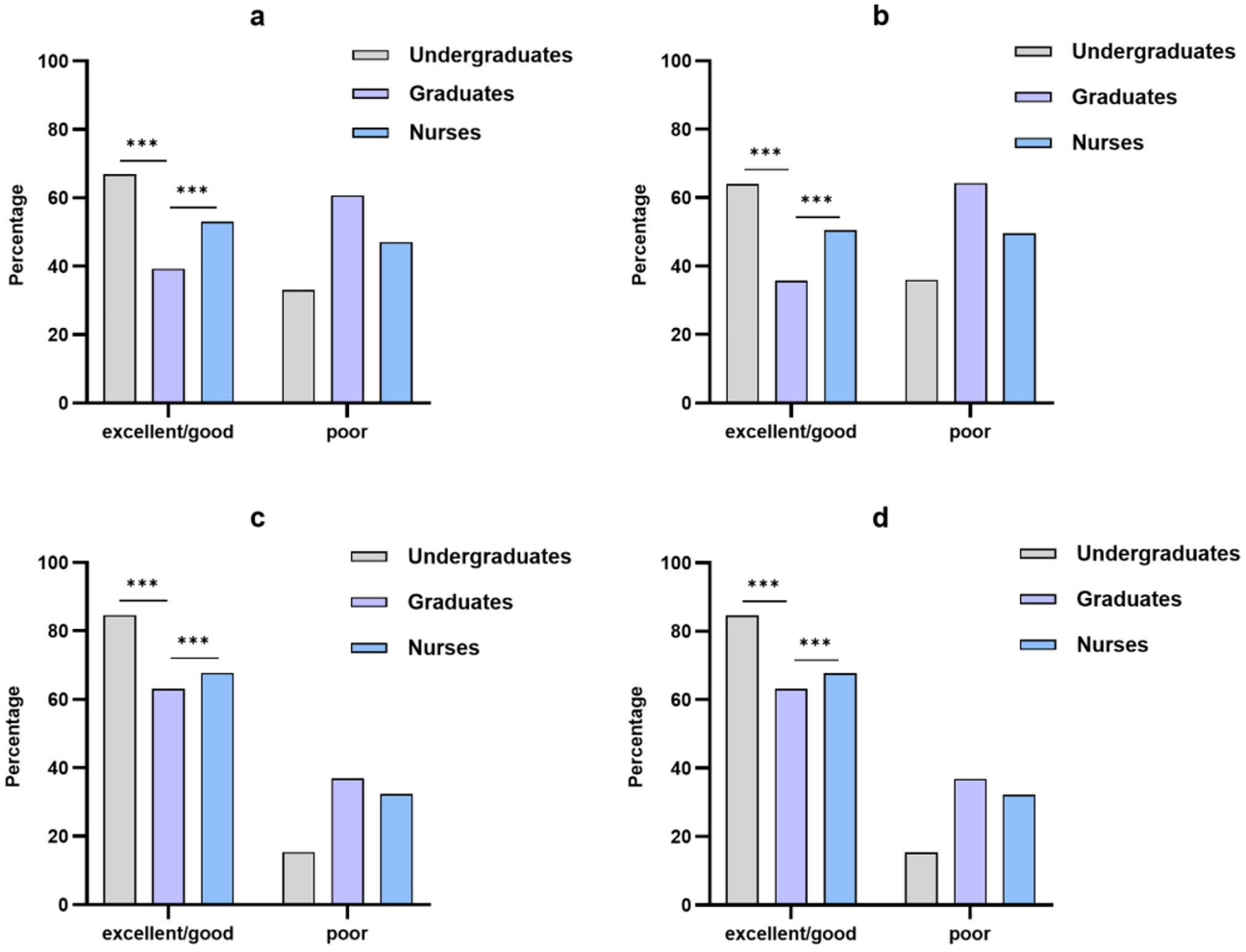

Fig. 3 The self-assessed competency distributions for four genomics-related items (**a**) understanding of general genomics knowledge, (**b**) comprehension of genetics of common health conditions, (**c**) awareness of ethical issues in genomics, and (**d**) understanding of equity in genomics. Each stacked bar chart shows the proportion of undergraduate students, graduate students, and practicing nurses who rated their competence as "Excellent," "Good," or "Poor." Statistical significance is indicated as ***$P < 0.001$

respondents (11.6%), while 14 (2.8%) considered further ethics education not very important or not important at all.

A majority of respondents (70.7%) self-rated their understanding of genomics ethical issues as excellent or good, with proportions of 86.0%, 69.6%, and 73.2% among undergraduates, graduate students, and practicing nurses, respectively. Intergroup comparisons revealed a statistically significant difference ($P < 0.001$) (Fig. 3c). Regarding self-reported understanding of genomics equity, 75.5% rated their comprehension as excellent or good, with corresponding proportions of 84.6%, 63.1%, and 68.0%. Again, a significant difference was found among the groups ($P < 0.001$) (Fig. 3d).

Decision-making and adoption

The decision-making and adoption domains were not assessed among the undergraduate and graduate participants since some of the participants had not yet participated in the clinical internship and thus would not have valid decision-making and adoption abilities in the practice of clinical genomics. This implies that there were no statistical comparisons among the participants and the nursing practitioners. For the cohort of practicing nurses, the decision-making and adoption domains were analyzed. The findings indicated that 88.89% ($n = 176$) of practicing nurses were actively taking care of patients. Among these nurses, only 27.2% ($n = 48$) stated that they had consistently collected complete family medical histories over the past three months, while 59.01% ($n = 104$) reported that they had occasionally, rarely, or never collected complete family medical histories from patients during the same period. Furthermore, 88.1% ($n = 155$) of practicing nurses indicated that they had occasionally, rarely, or never assisted with referrals to genetic services in the past three months. A total of 94.32% ($n = 166$)

reported that they had occasionally, rarely, or never used family history information when making clinical decisions or formulating recommendation plans during this period. Additionally, 57.9% ($n = 102$) of practicing nurses stated that no patients had actively discussed genetics-related topics with them in the past three months.

Discussion

Genomics knowledge scores and cross-country comparisons

This study aimed to systematically examine the genomics competency gap across the educational to clinical continuum, specifically comparing nursing undergraduates, graduate students, and practicing nurses. The results showed that the mean knowledge score of 502 Chinese respondents was 9.51 (SD = 1.74), with no statistically significant difference among the three cohorts. Compared to international studies, Chinese practicing nurses scored 9.50, which appears to be within a similar range or modestly higher than the scores reported in Finland (9.12), Canada (8.59), Turkey (9.36), and a previous Chinese study (8.30) [15, 26, 27, 30]. These differences may be partly influenced by demographic and educational factors [31–33]. From a demographic perspective, the Chinese cohort was younger and had completed genomics training more recently. From an educational perspective, Chinese nursing curricula emphasize foundational knowledge, which may enhance performance on knowledge tests. Undergraduate and graduate students obtained scores of 9.63 ± 1.69 and 9.42 ± 1.67, respectively. Given that the existing literature has focused exclusively on practicing nurses, no directly comparable data are currently available for student populations. Future research that collects comparable data from nursing professionals at different educational stages and across diverse national contexts would facilitate a more systematic understanding of the global genomics competency gaps among education, training, and clinical practice.

Self-assessment bias and the Dunning-Kruger effect

Nurses with less experience tended to have higher confidence levels in genomics concepts, while nurses who had higher levels of experience tended to rate their own understanding lower rather than higher. Despite no significant differences in foundational knowledge scores across the three groups ($P > 0.05$), marked divergence emerged in self-evaluation ($P < 0.001$). Undergraduate students consistently rated themselves higher than graduate students and practicing nurses across all domains, including general genomics, genetics of common health conditions, genomics ethics, and equity in genomics. This pattern aligns closely with the Dunning-Kruger effect [34–36]. The effect suggests that individuals with lower competence tend to overestimate their performance due to metacognitive deficits. In contrast, those with higher competence display more cautious self-appraisals. In this study, the high self-ratings among undergraduate students, potentially stemming from insufficient exposure to real-world clinical complexities, may reflect an inadequate understanding of the complexity of these issues [37]. Graduate students, through immersion in advanced research and scholarly discourse, develop a more nuanced and critical self-awareness. Practicing nurses, meanwhile, continually calibrate their self-assessment standards within clinical care contexts, demonstrating a cognitive developmental trajectory from theoretical confidence to practical consciousness [38].

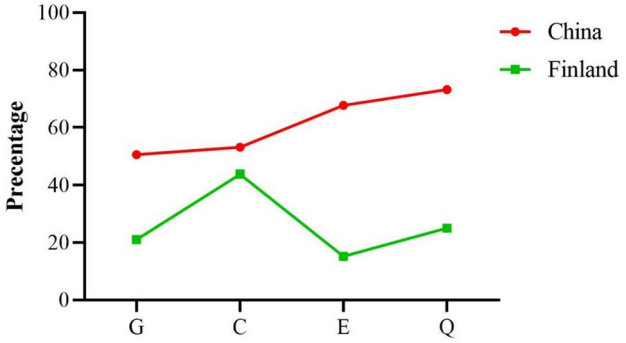

Fig. 4 Comparative trends in self-assessed genomics competence between Chinese and Finnish nurses. The line chart displays the proportion of nurses in each country who rated their competence as "Excellent" or "Good" across four items. Each item is marked on the plot with the corresponding label: G (General genomics knowledge), C (Genetics of common health conditions), E (Ethical issues in genomics), and Q (Equity in genomics)

The basic knowledge score of Chinese practicing nurses ($N = 198$, M = 9.50, SD = 1.82) was comparable to that of Finnish registered nurses ($N = 216$, M = 9.12, SD = 1.44). However, their self-assessment profiles revealed significant variation. Specifically, the percentage of Chinese participants rating themselves as excellent or good was markedly higher across four competencies: understanding general genomics (50.5% vs. 21.0%), comprehension of genetics concerning common health challenges (53.1% vs. 43.8%), understanding of genomics equity (67.7% vs. 15.2%), and awareness of genomics ethical issues (73.2% vs. 25.0%) (Fig. 4). This finding can be explained through the combined lens of cognitive psychology, international contextual factors, and differences in professional career stage. Firstly, the cautious self-assessment observed among Finnish nurses may represent an advanced stage of the Dunning-Kruger effect termed conscious competence [39]. Working in highly autonomous clinical environments, Finnish nurses develop a profound appreciation for the inherent complexity and uncertainty of genomics. As a result, they apply a much more rigorous, practice-informed standard to what constitutes "understanding", surpassing the simplified options captured by

the questionnaire. Secondly, the observed differences in self-assessment between Chinese and Finnish nurses may be explained by variations in genomic education frameworks. Finland has established a national genomic nursing competency framework and is a member of the Global Genomics Nursing Alliance (G2NA), while China currently lacks such a systematic national framework, with curricula varying substantially across institutions [27]. These differences likely shape nurses' understanding of what constitutes adequate genomic competence, leading to divergent self-assessment patterns. Finally, differences in professional career stage may further elucidate the observed discrepancy in self-assessment between the two cohorts. In this study, the average age of Chinese respondents was 33.68 years (range: 22–55), whereas the average age of Finnish nurses was 43.93 years (range: 24–70). This gap represents not merely a chronological difference but, more significantly, distinct phases of professional experience and cognitive maturity. Older Finnish nurses, with their extensive clinical practice, are likely more acutely aware of the inherent complexities and uncertainties involved in genomics ethical decision-making. In contrast, their younger Chinese counterparts may still be in the early stages of translating theoretical knowledge into practical competence; their self-perception of capability thus derives more from academic mastery than from experiential learning in real-world decision-making contexts [40, 41]. Therefore, the observed differences in self-assessment between the two groups may be better explained by differences in professional career stage and accumulated clinical experience, rather than age alone.

Gap between clinical practice and genomic nursing standards

Although 88.89% (n = 176) of practicing nurses were engaged in direct patient care, the implementation of genomic-related nursing practices was limited. Only 27.2% (n = 48) had consistently collected complete family histories over the past three months, and 59.01% (n = 104) reported irregular or no collection. The family history, known as "the first genetic test," reflects the combined effects of genetics and environment and serves as a key basis for assessing genetic disease risk. However, in this study, 94.32% (n = 166) did not use family history information in clinical decision-making, 88.1% (n = 155) rarely assisted with referrals to genetic services, and 57.9% (n = 102) had not received any patient-initiated discussions about genetics. These findings suggest a significant gap between current nursing practice and the professional requirements of the genomic era, consistent with global evidence that nurses lack adequate genomics knowledge reserves [42–44]. Given the rapid development of precision medicine, improving nurses' genomic literacy is crucial for implementing genomics-related care and connecting patients to genetic services [45].

Positive attitudes and motivation for learning

Despite this practice gap, nursing staff and students held overwhelmingly positive attitudes toward genomics education. The vast majority (87.6%) considered continuing education in this field to be very important, with this consensus exceeding 80% across all subgroups. All groups also reported high self-confidence (above 90%) across various professional competencies, though variations were noted depending on specific tasks. Furthermore, 64.5% expressed willingness to pursue further education, with practicing nurses showing the strongest interest (70.7%). These proportions are higher than those reported in previous Chinese studies [16, 27, 28], reflecting nurses' growing recognition of genomics as these technologies become increasingly integrated into clinical practice. More than half also expressed willingness to attend courses during work hours (59.0%) or in their personal time (53.2%).

Challenges in genomics education integration

At the educational system level, although genomics-related content was introduced into Chinese nursing curricula as early as 1990 [46], curriculum reform has been inconsistent across regions and institutions. Consequently, 25.3% of respondents reported no prior exposure to genomics courses, with this proportion rising notably to 39.3% among postgraduate students. This indicates that nurses who completed their basic training in earlier decades may not have received systematic genomics education comparable to current standards, highlighting room for curricular improvement.

Educational implications and a tiered framework for genomics competency development

These findings support the development of a differentiated genomics education system aligned with different stages of nursing professional development. Undergraduate students should experience strengthened ethical scenario simulations and reflective teaching to cultivate self-awareness commensurate with their knowledge level [47]. At the graduate level, the focus must shift to cultivating clinical reasoning and research ethics literacy, strengthening the link between academic training and clinical practice [48]. For practicing nurses, case-oriented continuing education should be implemented, emphasizing the enhancement of genomics ethical decision-making capabilities in complex clinical situations. This staged, differentiated educational approach will contribute to systematically improving nursing professionals' practical competency in the field of genomics [49–51].

Limitations

The primary limitation of the current self-report instruments lies in their greater suitability for assessing standardized ethical knowledge, as opposed to effectively capturing the practical ethical wisdom that is crucial in complex clinical environments. Future research plans to adopt mixed-methods approaches, such as incorporating qualitative interviews, to compensate for the shortcomings of relying solely on self-reported measures. This will enable a more comprehensive and culturally sensitive assessment of genomics nursing ethics competency, thereby providing a more robust scientific foundation for education and practice in this field.

Another limitation lies in the imbalanced gender distribution of the sample. Although this study found that female participants scored higher in genomics knowledge than males, male participants accounted for only 6.8% of the sample. This substantial imbalance implies that gender-based comparisons derived from this sample are limited in both statistical robustness and generalizability to broader populations, particularly male nursing professionals. Therefore, the specific finding regarding gender differences should be interpreted with caution.

Furthermore, direct cross-study comparisons should be interpreted with caution due to cross-cultural modifications made to several items in the Chinese version of the survey.

Conclusion

This study reveals a nuanced genomics competency profile among Chinese nursing students and practicing nurses. Despite no significant differences in foundational knowledge scores across the three groups, marked divergence emerged in self-evaluation. This discrepancy suggests that self-perceived competence does not necessarily reflect actual knowledge, highlighting the need for educational interventions that foster metacognitive awareness alongside knowledge acquisition. Undergraduate students consistently rated themselves higher than graduate students and practicing nurses across all domains, including general genomics, genetics of common health conditions, genomics ethics, and equity in genomics. This discrepancy may be attributed to differences in clinical exposure, metacognitive awareness, and professional experience across the three groups. Furthermore, although attitudes toward genomics education were overwhelmingly positive across all groups, approximately one-quarter of participants had received no formal genomics coursework. These findings highlight the need for tiered, targeted genomics education at different professional stages, as well as greater curriculum integration by nursing educators and administrators.

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Author contributions
Yang Shen and Qian Wang authored the main manuscript text, with Yang Shen conducting the primary statistical analysis and preparing Figure. Both Yang Shen and Qian Wang were involved in designing the study and provided critical reviews of the entire manuscript. Qian Wang interpreted the data and made significant contributions to the writing of the manuscript. Chen Chen was responsible for the questionnaire cross-cultural adaptation, with Honglei Jiang and Dan Wu contributing to its distribution and collection. All authors reviewed and approved the final version of the manuscript.

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Data availability
All data generated or analyzed during this study is included in this published article.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. It was approved by the Ethics Committee of China Medical University (Approval No: [2025]247), and all methods were performed in compliance with the relevant guidelines and regulations. All participants provided informed consent to participate in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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