**Abstract**

***Aim/objective****: To identify and synthesise research on the development of nurse genomics education*

***Background****: It is becoming increasingly recognised that all nurses require an understanding of genomics. Nurse education must equip nurses with genomic literacy. This review explores the development and provision of genomics across international pre-registration curricula to highlight areas of importance and gaps.*

***Design****: Narrative review*

***Methods****: Following systematic searches in Embase, MEDLINE, the Cochrane library, CINAHL, the British Nursing Database, PubMed, and Maternity & Infant Care, qualitative, quantitative, mixed-methods studies, systematic reviews, literature reviews, commentaries, editorials and reports from 2002, were included. Titles and abstracts and full texts were screened by two reviewers. Data were extracted on key concepts within the literature including approaches to teaching, links to practice, and assessment, using a pre-defined tool but flexibly including inductive categories. Findings were thematically analysed and synthesised using a narrative review approach to provide a summary and critical discussion of the literature.*

***Results****: 315 results were screened, and 65 texts were reviewed. The largest number of papers were published in 2011 (n=12). The majority of papers were published in North America (n=47). Five themes relating to pre-registration genomics nursing education were created and explored. These were: Approaches to integration, Pedagogical approaches, Application to practice, Approaches to assessment and Approaches to evaluating education.*

***Conclusions****:  Further guidance is needed for faculty on the effective integration of genomics, teaching and evaluation. Further research into the effectiveness of teaching strategies could contribute to standardised guidance.*

**Keywords:** Education, Nursing**;** Genomics

Nurse, Education, Genomics, Student, Pre-registration, Undergraduate, Curriculum.

**What is already known:**

* Professional bodies require educators to include genomics in pre-registration curricula
* There is variation in approaches to nursing genomics education
* Educators experience multiple challenges in integrating genomics across curricula

**What this paper adds:**

* This paper charts the research underpinning current activity
* This review found that there is limited robust evaluation of pre-registration genomics education
* Limited evaluation of genomics education perpetuates the paucity of evidence supporting effective teaching strategies and curricular integration
* This review highlights the scarcity of genomics practice experiences for nursing students

**Terms used**: Definitions used are consistent with the Consensus Panel on Genetic/Genomic Nursing Competencies, (2009). The term ‘genetics’ is used to denote the study of individual genes and their impact on single gene disorders. The term ‘genomics’ is used when referring to the study of all of the genes in the human genome together, including their interactions with each other, the environment, and the influence of other psychosocial and cultural factors.

**Introduction**

**Background:** Exploring genetic variation, and the relationships between an individual’s genes and their environment enables healthcare practitioners to make predictions about their health supporting early screening, diagnosis and treatment for many conditions and improving outcomes for patients and families (National Human Genome Research Institute (NHGRI, 2023). Developments in technology and infrastructure mean that genomics is becoming more integrated into UK healthcare and that services are developing to provide optimal care (NHS England, 2023, B). The role of the nurse is adapting to support increased integration of genomics into health services.

It is now recognised that all nurses require an understanding of genomics including basic knowledge of genetics and an awareness of screening and testing infrastructure (Aiello, 2017; Calzone et al., 2018, A; Shepherd, 2005). However, low levels of genomics literacy are reported among registered nurses and many feel that they would benefit from improved genomics education (Calzone et al., 2018, A; Camak, 2016). Whilst the Genomics Education Programme (HEE, 2023) has taken steps to address knowledge gaps knowledge for UK nurses, this issue is reflected globally (Chair et al., 2019; Dagan et al., 2021). Pre-registration education must meet the needs of those joining the nursing workforce and this review focuses on the development of genomics in UK and international undergraduate nursing curricula.

The UK Nursing and Midwifery Council (NMC, 2018) proficiencies and US American Association of Colleges of Nursing (AACN) Essentials (2021) require knowledge of genomics as a determinant of health, but individual education providers determine which content will be included in nursing programmes and the approach taken, leading to variation between institutions (Campion et al., 2019). Challenges experienced by educators in the design and delivery of genomics education include the complexity of the topic, over-burdened curricula, lack of organisational support and lack of faculty knowledge and confidence (Aiello, 2017; Dewell et al., 2021; Jenkins & Calzone, 2014). It has become necessary to explore the development of current pre-registration genomics education to help address some of these challenges by standardising future provision. This narrative review of the literature explores and summarises the research related to the design and delivery of pre-registration nurse genomics education.

**Aim:** The aim of this review was to identify and synthesise primary international research and other literature related to the development of current pre-registration genomics nursing education.

**Objectives:**

1. To identify how genomics education is being defined and conceptualised.
2. To identify what evidence exists concerning the design, content and assessment within genomics education.
3. To identify and describe the ways in which genomics education has been evaluated.
4. To identify key gaps in the existing evidence base and questions for future research

**Method**

To meet the objectives, we selected a narrative review approach. Narrative reviews have been highlighted as particularly useful in health professional education as they are able to provide a practical synthesis of a diverse range of literature and highlight areas for further exploration in future research (Ferrari, 2015; Sukhera, 2022). Taking this approach allows for the inclusion of both research papers and expert commentary to present a rigorous, nuanced interpretation of a body of knowledge. In this paper we have used this approach to provide a meaningful summary on what is currently known on the provision of genomics in pre-registration nurse education.

**Design:** Acknowledged guidelines for the writing of narrative reviews are scant and this review followed guidance from a number of sources (Ferrari, 2015; Greenhalgh et al., 2018; Gregory & Deniss, 2018), adopting a systematic approach to defining the topic, searching the literature, critically discussing the literature, structuring the narrative and revising the review based on feedback (Gregory & Deniss, 2018, p893).

**Search strategy and source selection**: The following bibliographic databases were searched in the period 2002 (near completion of the Human Genome Project in 2003 (NHGRI, 2023)) to the present (searches were conducted in February 2024 and again in January 2025 to identify any new studies): Cumulative Index to Nursing & Allied Health Literature (CINAHL), the Cochrane Library, British Nursing Database, MEDLINE, EmBase, Pubmed and Maternity & Infant Care. The search strategy is shown in Figure 2. Cross-referencing of the reference lists from included studies was conducted to identify new articles. Grey literature meeting the inclusion criteria, from a targeted Google search, was included to provide context and currency (Adams et al., 2016). Search results were imported to Covidence to organise studies and remove duplicates. Titles and abstracts of the resulting texts were screened against the inclusion criteria by X. Any full-text articles that initially appeared to meet the inclusion criteria were retrieved and re-screened against the inclusion criteria [X]. All full texts were screened independently by two reviewers from the study team [X and X]. Any discrepancies were resolved through consensus.

Table 1 outlines the inclusion criteria. Studies relating to both pre- and post-registration genomics education were included but data relating only to pre-registration education were extracted. Sixty-five studies fulfilled all inclusion criteria.

Table 1. Source inclusion and exclusion criteria

Figure 1. Study identification and selection process.

Figure 2. Review search strategy

**Data extraction**: Data were charted manually using an extraction tool and following principles relating to transparent and rigorous extraction. The tool, designed around the research objectives, facilitated the organisation of data such as study title, authors, year of publication, study design, key concepts and study findings. Information related to key concepts in the literature underpinning genomics pre-registration nursing education was extracted into categories. These categories were defined a priori and informed by research objectives, wider reading, and the researcher’s knowledge of the topic.

Any diverse data relevant to the research question which did not fit into any of the pre-defined categories were also examined. This process helped to define questions arising from this work and to ensure inductive themes were included. Examples of thematic categories included:

* Genomics content perceived to be essential
* The positioning of genomics content within programmes
* Teaching strategies
* Linking theory to practice
* Assessment of learning
* Evaluation of teaching

Data was extracted by [X] with support from a wider team [X and X]. The data extraction tool was piloted for use on the first five papers and adjusted as necessary to support the data. There was no double-blind extraction.

**Quality assessment:** As appropriate for a narrative review, the strength of evidence provided by each type of study was assessed in terms of its contribution to any conclusions drawn or recommendations made by the authors. Whilst we took a critical approach, we made use of the flexibility to include expert knowledge and teaching scholarship publications alongside research papers and have been judicious in the presentation of findings. Limitations were reported within individual studies; Donnelly et al., (2017) acknowledged a challenge obtaining objective information from faculty and schools regarding their efforts to integrate genomics into nursing programmes. Collins & Stiles (2011) perceived that poor levels of knowledge reported by students suggested that some schools felt their genomics content to be better integrated than it was, leading to over-reporting.

**Data analysis and synthesis:** Following data extraction and categorisation of verbatim text, data were interrogated to identify secondary themes within categories. Descriptive themes were created by exploring patterns within and across the data and identifying data with a shared meaning related to a central concept (Braun & Clarke, 2021). For example, ‘Assessment of learning’ included both ‘Measuring knowledge’ and ‘Student readiness to practice’. Relationships between concepts were also explored such as the effect of ‘Linking theory to practice’ on ‘Teaching strategies’.

Due to the varied study designs, data were synthesised using a narrative approach to creatively explore insights gained through thematic analysis and obtain deeper understanding. Within a narrative review it is necessary to specify factors shaping interpretation and analysis (Sukhera, 2022). The lead author is a nurse educator with experience in genomics education which could have led to a focus on points resonating with her own perspectives. To address this, analysis was discussed at each stage with the wider team.

**Results**

In the absence of a checklist for narrative reviews, results of the literature search are shown in a flowchart adhering to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for scoping reviews (PRISMA-ScR) statement and PRISMA-S extension (Figure 1). From a total of 181 de-duplicated titles identified from the searches, 75 full-text articles were reviewed, of which 10 were excluded for the reasons stated in Figure1, leaving 65 articles for review. For studies including information on both education for registered nurses and students, data extracted were limited to pre-registration education. Studies included were published from 2002 to 2024, from 13 countries. An overview of the included studies is presented as supplementary material in Table 2. The majority of studies originated in North America with a markedrise in the volume of international research related to pre-registration nurse genomics education in 2011.

The majority of studies (n=23) explored use of the Genomic Nursing Concept Inventory (GNCI©) to measure genomic knowledge or learning and determine faculty and/or student understanding of key concepts. Read & Ward (2018) surveyed the largest number of students (n=1002) and faculty (n=495). The next largest number of studies (n=14) were related to the integration of genomics into pre-registration curricula. Study designs included focus groups and semi-structured interviews to explore student and faculty attitudes regarding the addition of genomics content. Sources exploring specific educational interventions or teaching strategies (n=9) were mostly commentaries or reviews (n=5).

This review identified a range of approaches to the integration of genomics into nursing curricula, a range of pedagogical strategies including the use of resources, application of theory to practice, varied approaches to assessment and minimal information on approaches to evaluating education. These themes will be explored in turn and supplementary Table 6. provides examples from included sources to support key points:

* 1. **Approaches to integration**

Despite the approach to integration most papers highlighted examples of skills and knowledge perceived as essential within curricula (Supplementary Table 3). We identified several approaches to delivery and integration of genomics across the identified papers. Genomics was most often referred to as a science and taught by biosciences teachers resulting in a focus on the microbiological over clinical elements (Adejumo et al., 2021; Kirk et al., 2011, A; Lopes-Júnior et al., 2022; Nicol, 2002; Sharoff, 2015; Shuster, 2011). Methods of integration of genomics education reflected ongoing debate regarding the efficiency of delivering all genomics teaching within a single module or course and the efficacy of spiralling content through whole programmes (Lea & Monsen, 2003; Parviainen et al., 2023; Seibert, 2020; Sharoff, 2015; Shuster, 2011; Williams et al., 2011).

***Standalone modules***

Six papers discussed the experience of delivering genomics teaching as standalone modules (Daack-Hirsch et al., 2011, Daack-Hirsch et al., 2013; Garcia et al., 2011; Parviainen et al., 2023; Sharoff, 2015; Shuster, 2011). This was perceived to have the advantages of achieving a depth of knowledge (Daack-Hirsch et al., 2011) and relieving the burden on other modules to accommodate genomics content (Garcia et al., 2011; Parviainen et al., 2023). Perceived disadvantages, within a descriptive overview of international efforts on integration, included inadequate preparation of students for genomic nursing practice (Prows et al., 2005).

It was observed that standalone courses were more likely to be offered as elective within US programmes which was perceived as conveying a lack of associated importance and leading to low student numbers (Daack-Hirsch et al., 2011; Sharoff, 2015).

***Integration throughout programmes***

Eight papers reported on integrated genomics provision or curricular ‘threads’ (Collins & Stiles, 2011; Daack-Hirsch et al., 2011; Daack-Hirsch et al., 2013; Kirk et al., 2011, A; Majstorović et al., 2021; Mathis, 2022, p262; Sharoff, 2015; Trossman, 2006). This approach was perceived by authors to better encompass ethical and psychosocial issues (Kirk et al., 2011, A) and helped to extend or ‘scaffold’ knowledge (Sharoff, 2015, p16). To thread genomics effectively through undergraduate curricula, it was thought that the majority of faculty require foundational knowledge relating to genomics (Sharoff, 2015).

It has been stated that to have relevance for nursing practice, genomics education ‘must extend beyond the basic sciences’ (Connors & Schorn, 2018, p236; Dewell et al., 2021; Hsaio et al., 2011; Lea et al., 2011; Lopes-Júnior et al., 2022; Prows et al., 2005; Tonkin et al., 2011) and where an integration approach is adopted, genomics content can be included in modules including: pharmacology, pathophysiology, maternal and child health, community or population based care, professional responsibilities, oncology and nursing ethics (Daack-Hirsch et al., 2013; Elliott, 2019; Hetteberg & Prows, 2004; Lea & Monsen, 2003; Lea et al., 2011; Lopes-Júnior et al., 2022; Mathis, 2022; Munroe & Loerzel, 2016; Sharoff, 2015). Some communication skills modules have included training on obtaining informed consent for tests, having difficult conversations related to issues such as non-paternity, and discussions around privacy and confidentiality related to genomic data (Daack-Hirsch et al., 2011; Sharoff, 2015).

When integrating genomics throughout programmes one approach described was to chart existing content against a framework of essential knowledge and skills to ensure key topics were covered (Anderson et al., 2015; Collins & Stiles, 2011; Daack-Hirsch et al., 2011; Hetteberg & Prows, 2004; Kirk et al., 2011, B; Kronk et al., 2018; Lopes-Júnior et al., 2022; Munroe & Loerzel, 2016; Prows et al., 2005; Tonkin et al., 2011; Williams et al., 2011). Although genomics competency frameworks provided a useful guide to critical knowledge elements, students came from a range of educational backgrounds with varied levels of prior instruction and some authors felt that educators struggled to know the level at which to teach genomics content (Tonkin et al., 2011; Ward, 2011; Williams et al., 2011). Parviainen et al., (2023) and Read & Ward (2016) stated that a baseline genomic literacy assessment, preceding curriculum development helped to identify weaker knowledge areas.

It was also felt that integration could be guided by a checklist of actions including forming a faculty working group to share the workload and creating a matrix of existing curricular content to identify gaps or opportunities (Daack-Hirsch et al., 2011; Hetteburg & Prows, 2004; Prows et al., 2005; Jaekel, 2012, Mathis, 2022; Sharoff, 2015). Solutions for addressing gaps included adding genomics content to existing lectures and including focused test questions in existing assessments (Consensus Panel on Genetic/Genomic Nursing Competencies, 2009). However, it has been expressed that further direction is needed for faculty in this area (Dewell et al., 2021; Tonkin et al., 2011).

The Faculty Champion Initiative, launched in 2008, provided both genomics education and support to assist selected faculty to become agents of change at their institutions (n=160) (Aiello, 2017; Donnelly et al., 2017; Jenkins & Calzone, 2014; Jaekel, 2012; Lopes-Júnior et al., 2022;). Some faculty champions formed learning communities to educate and engage other staff and disseminate resources and this role has been described as a ‘crucial’ to effective integration (Bashore et al., 2018, Chair et al., 2019, p463; Garcia et al., 2011; Jenkins & Calzone, 2014; Sharoff, 2015; Williams et al., 2011). Although, some genomics champions reported feeling an excessive burden to act as guest lecturers, and that they were ‘lone voices’ charged with identifying the learning needs of colleagues (Williams et al., 2011, p236).

Champions often found it hard to sustain motivation (Jenkins & Calzone, 2014) and some authors believed team approaches to be better in achieving the integration of genomics across curricula (Garcia et al., 2011; Smania et al., 2022; Williams et al., 2011). It was suggested that the creation of regional champions and resources might help to standardise delivery in some countries (Jenkins & Calzone, 2014).

* 1. **Pedagogical approaches**

Authors recognised nursing students as adult learners motivated by learning goals and relevancy of content and when designing learning activities, it was perceived that clear learning outcomes and explicit application to practice would precipitate engagement and retention of knowledge (Jaekel, 2012; Kim & Han, 2010; Kirk et al., 2011, A; Ward et al., 2014). It was thought that ‘intensive or targeted’ instruction helps with long-term knowledge retention, but larger scale studies were recommended to test student retention of genomics knowledge over time (Kronk et al., 2018; Munroe & Loerzel, 2016, p88).

Some authors described constructivist approaches to education which facilitated the construction of knowledge through active engagement in learning activities (Fater, 2014; Parviainen et al., 2023; Parviainen, 2023). A literature review found several studies which identified that support for student autonomy as learners was key to their self-development (Garcia et al., 2011). This review also found that the ‘under use’ of theoretical or conceptual frameworks to underpin teaching strategies limited students’ abilities to connect new ideas with existing knowledge (Garcia et al., 2011, p617).

Genomics knowledge has been described as a network of interrelated ideas and educators have been encouraged to design education which enables the processing of knowledge in the cognitive, psychomotor and affective domains (Kawasaki et al., 2021; Ward et al., 2014). Jaekel (2012) stated that within these domains, students should be exposed to both factual knowledge for problem-solving and conceptual knowledge which illustrates interrelationships between basic elements as part of a bigger whole. Students can then be supported to ‘anchor’ new ideas through modification of their pre-existing conceptual frameworks (Ward, 2011; Ward et al., 2018). When online content was provided, it was recommended that this was supported by classroom time to maximise effectiveness and sustain motivation with educators identified as key to this process (Kawasaki et al., 2021).

Within their integrative review of the literature based on two conceptual frameworks including the Learning Engagement Model (Guthrie & Wigfield, 2000), Garcia et al., (2011) extrapolated that due to the complexity of genomics, rote learning was unsuitable. Other educators stated that combining multiple approaches helped students to explore ideas and link concepts to construct knowledge (Ward et al., 2016, A). The various approaches to teaching are summarised in Table 4. It was reported by some educators that effective understanding was gained more efficiently through learning activities such as seminars and small group projects in which students had to engage higher order skills such as analysis, synthesis and evaluation of source material (Fater, 2014; Nicol, 2002). Innovative teaching methods required additional time and organisation, but there was a shared view that variety and creativity both engaged students and helped demonstrate relevance for practice (Connors & Schorn, 2018; Dewell et al., 2021; Garcia et al., 2011; Lopes-Júnior et al., 2022; Parviainen et al., 2023; Sharoff, 2015; Tonkin et al., 2011; Vandiver et al., 2022). It was thought that the transmission of large volumes of information in short periods of time can feel overwhelming (Nicol, 2002; Sharoff, 2015;), although in Taiwan, the majority of students surveyed (n=434) said they found lectures to be the most effective method of learning genomics (Hsaio et al., 2011).

Table 4. Teaching methods highlighted by included sources.

***Teaching resources***

The NHS Genomic Medicine Service supports UK national and regional nurse education and resource sharing through its Genomic Medicines Service Alliance (GMSA) networks (NHS England 2023, B). Within the studies identified for review, it was widely felt that the use of effective resources supports faculty to teach genomics. Table 5 lists resources highlighted in the included studies which remain available at the time of writing. Tonkin et al., (2011) reported many faculty to be unsure about where to access resources or how to integrate them into education. It was believed by some authors that models of integrated curricula would be valuable in facilitating integration in some schools (Bashore et al., 2018; Donnelly et al., 2017; Jenkins & Calzone, 2012).

Table 5. Genomics resources for educators

* 1. **Application to practice**

Knowledge was not equated with clinical competence (Anderson et al., 2015) and application to practice was identified as central in enabling students to consider key concepts in relation to nursing care (Pence, 2020; Shuster, 2011; Williams et al., 2011).

Multiple sources recognised a difference between knowledge transmission and the ‘hands on’ education necessary to learn and confidently perform skills such as taking a family history (Shuster, 2011; Whitley et al., 2020, p5). Reinforcing taught content using clinical skills sessions and role-play was recommended to help students gain confidence in discussing genetic information and problem-solving (Connors & Schorn, 2018). Some educators used simulation, in person or online, to build knowledge in the psychomotor domain of Bloom’s taxonomy and found that practising skills in this way seemed to be enjoyable and ‘valuable’ for learning (Daack-Hirsch et al., 2011; Hsaio et al., 2011; Kawasaki et al., 2021; Tonkin et al., 2011, p332).

***Student practice experiences***

Adejumo et al., (2021) and Kawasaki et al., (2021) cited Kolb’s Experiential Learning Theory (2015) to underpin their belief that practice experiences build readiness for practice**.** Students surveyed in some schools described challenges understanding the relevance of genomics to nursing practice and feared their future inability to answer patient questions due to gaps in their knowledge. Reasons suggested included the complexity of the subject and terminology, omissions in pre-registration curricula, and a lack of practice role models (Dewell et al., 2021; Hsaio et al., 2011; Kirk et al., 2011, B;). A correlation was identified in one study between students with greater levels of knowledge and those who felt confident in practice (Munroe & Loerzel, 2016).

Genomic literacy is defined as knowledge sufficient to develop genetic and genomic competency in practice, as outlined in the Essentials of genetic and genomic nursing competency framework (Consensus Panel on Genetic/Genomic Nursing Competencies, 2009). Authentic interactions were seen as vital for consolidating and developing skills and knowledge and practice learning experiences improved students’ genomic literacy by providing opportunities for discussion with patients about the impact of living with specific genetic conditions (Anderson et al., 2015; Lea & Monsen, 2003; Lea et al., 2011; Lopes-Júnior et al., 2022; Sharoff, 2015). Clinical placement forms part of all nursing programmes and whilst practice experiences in local services helped students to understand local needs, this review identified a lack of targeted genomics practice experiences in many countries (Garcia et al., 2011; Kirk et al., 2011, A; Tonkin et al., 2011). It was suggested that this may be because few providers specialise in genomics or have basic knowledge regarding genomics (Chair et al., 2019; Daack-Hirsch et al., 2011).

* 1. **Approaches to assessment**

National licensure and certification examinations such as the US N-CLEX include genomics test questions (Aiello, 2017; Consensus Panel on Genetic/Genomic Nursing Competencies, 2009; Kirk et al., 2011, B; Pence, 2020;) and we found that student knowledge was also frequently assessed against national competency frameworks (Kronk et al., 2018; Lopes-Júnior et al., 2022; Majstorović et al., 2021).

Eight studies measured student knowledge gains via pre- and post-education tests (Table 2). Some studies (Kawasaki et al., 2021) surveyed perceived learning gains following genomics education rather than gains measured using a tool, despite potential discrepancies between the two which could lead to inaccuracies in reporting levels of genomic literacy (Majstorović et al., 2021; Munroe & Loerzel, 2016; Read & Ward, 2016; Ward et al., 2016, B;).

In addition to knowledge recall, assessing understanding of key concepts was viewed as important. Six studies (Adejumo et al., 2021; Dewell et al., 2020; Majstorović et al., 2021; Munroe & Loerzel; Parviainen et al., 2023; Parviainen, 2023) measured student knowledge and understanding using the Genomic Nursing Concept Inventory© (GNCI©) or a modified/translated version. This tool was created to test conceptual understanding of genomics, important for the translation of education into nursing practice, in opposition to superficial learning or memorisation (Ward et al., 2014). A literature review by Aiello (2017) found that the GNCI© had been used in ‘many studies’ to assess nursing students’ foundational knowledge of genomic concepts (p751). The Genetics Literacy Assessment Instrument (GLAI) is a similar 17-concept test including concepts relating to genetics but not genomics or epigenetics (Anderson et al., 2015).

It was widely perceived that additional targeted assessment tools would further enable educators to measure the efficacy of genomics education across more diverse populations, and that this would be useful on a global scale, but that the absence of such tools has contributed to a lack of research in this area (Connors & Schorn 2018; Dewell et al., 2020; Dewell et al., 2021; Dumo et al., 2020; Read & Ward, 2016).

Anderson et al., (2015) explored studies evaluating tools for measuring genomics competence and conveyed the need to differentiate between students’ knowledge, attitudes, and situational knowledge (their ability to apply knowledge to practice). Self-assessment surveys were used in some studies to gauge student confidence and feelings of readiness to practice (Adejumo et al., 2021; Kawasaki et al., 2021; Kronk et al., 2018; Munroe & Loerzel, 2016).

* 1. **Approaches to evaluating education**

The evaluation of genomics education was viewed as important to demonstrate whether methods used prepared nurses for practice. It was stated that evaluation should also consider student satisfaction, knowledge retention, cost, and applicability, and that methods of evaluation must be consistent and reproducible (Garcia et al., 2011). Researchers felt that robust evaluation of the integration process and of teaching strategies would contribute to improvement (Daack-Hirsch et al., 2013; Chair et al., 2019; Munroe & Loerzel, 2016). However, a paucity of robust evaluation tools was felt to hinder the determination of quality and the responsive improvement of genomics education (Kirk et al., 2011, B; Lopes-Júnior et al., 2022).

Some authors reported that limited research on the effectiveness of specific learning activities or the facilitation of student achievement of core genomics competencies within pre-registration nursing programmes was slowing the development of genomics education (Dewell et al., 2021; Elliott, 2019; Garcia et al., 2011; Kronk et al., 2018; Mathis, 2022, Seibert, 2020).It wasperceived that accessible evaluations of integration and education would help inform faculty decision-making and that sharing methods which evaluated well could inform standardised integration (Chair et al., 2019, Daack-Hirsch et al., 2011; Greco & Salveson, 2009).

Multiple studies employed the Rogers (2003) diffusion of innovation theory to determine the effectiveness of integration using multiple varied instances to represent success (Collins & Stiles, 2021; Dewell et al., 2020; Dewell et al., 2021; Donnelly et al., 2017; Dumo et al., 2020; Garcia et al., 2011; Jaekel, 2012; Jenkins & Calzone, 2014, Jenkins & Calzone 2012; Parviainen, 2023). Although this measure was not felt to provide evidence of the ‘methodological quality’ of education (Lopes-Júnior et al., 2022, p12). A larger number of hours in the curriculum was not seen to guarantee quality; Israel mandates 28 hours genomics training but observes low levels of genomic literacy among registered nurses (Calzone et al., 2018, B).

Faculty were surveyed to qualitatively evaluate their chosen educational strategies in some studies despite acknowledged challenges in achieving objectivity in the data (Collins & Stiles, 2011; Jenkins & Calzone, 2014). Other core methods of measuring and enhancing the quality of higher education such as peer review of teaching (Harrison et al., 2022) were not observed in the studies reviewed. Two papers recognised a lack of strategies for evaluating teaching methods (Adejumo et al., 2021; Garcia et al., 2011) and student feedback was used to evaluate of education in five studies (Elliott, 2019; Kawasaki et al., 2021; Parviainen, 2023; Sharoff, 2015; Shuster, 2011).

Parviainen (2023) conducted a randomised controlled trial to measure the effectiveness of a new web-based 12-week genomics education programme ‘tailored to the learning needs of undergraduate nursing students’ in improving students’ (n=245) genomics literacy (p88). Learning gains were measured using the GNCI© (translated into Finnish) to measure increased understanding of key concepts. Results showed a statistically significant difference between pre- and post-education test scores for the intervention group compared to the control group (p-value = 0.010) using standard online learning materials.

Some schools reported student knowledge gains and knowledge retention as evidence to support the quality of their genomics education (Shuster, 2011) but this approach relies upon the assumption that good performance in an assessment confirms the effectiveness of teaching. Some authors felt that education was of good quality if it could be shown that students attained ‘deep learning’ or learning that could be recalled and applied in different contexts (Dewell et al., 2020; Ward et al., 2014).

Recommendations for further research included evaluating school curricula using checklists (Adejumo et al., 20210) and investigating how genomics can be more effectively integrated into nursing curricula (Parviainen, 2023).

**Discussion**

This narrative review provides a comprehensive overview and synthesis of current pre-registration genomics education literature, creating 5 broad themes from the data.

The prioritisation of genomics competencies in practice standards by nursing leadership will provide impetus for further effective inclusion of genomics in pre-registration education (Dewell et al., 2021). A lack of experiential education, however, can affect the quality of student learning and this review identified difficulty obtaining practice experiences as a central theme. Collaboration with clinical nursing specialists supported the integration of genomics into curricula in some schools (Bashore et al., 2018; Jenkins & Calzone, 2014; Williams et al., 2011) and it was thought that effective collaboration with nursing colleagues could also assist in providing clinical experiences for nursing students (Dewell et al., 2021).

Inconsistency between providers of pre-registration genomics education has led to variation in the knowledge and skills of graduates (Dumo et al., 2020; Greco & Salveson, 2009; De Jesus & Mitchel, 2016; Kirk et al., 2011, A; Munroe & Loerzel, 2016; Parviainen et al., 2023). This review also highlights that genomics has not been well-integrated into nursing education in some countries with insufficient representation of genomics content and poor levels of foundational genomics knowledge among nursing students (Adejumo et al., 2021; Dewell et al., 2020; Hsaio et al., 2011; Kirk et al., 2011, B; Majstorović et al., 2021; Munroe & Loerzel, 2016; Nicol, 2002; Parviainen et al., 2023; Prows et al., 2005). Genomics education should be linked to core professional competencies outlining required standards of proficiency upon registration, but diverse educational systems and professional leadership mean that individual countries require different proficiencies and have different standards for education (Kirk et al., 2011, B).

Some authors called for international guidance and standardisation of pre-registration genomics education in nursing programmes (Dewell et al., 2020; Majstorović et al., 2021; Parviainen et al., 2023; Rodrigues, 2016). It was thought that effective educational strategies and evaluation could contribute to guidance to reduce variation and support global efforts towards effective integration (Anderson et al., 2015). Although, we thought it judicious to consider the implications of global standardisation. Chair et al., (2019) could visualise the benefits of standardisation such as improved nurse education through coordination in countries with the same regulatory bodies. However, Adejumo et al., (2021) found that whilst students from federal institutions felt more confident following their education, in countries such as Nigeria where political influences can affect regional provision it has been difficult to standardise teaching. It is important to incorporate local community needs in nurse education because genetic risks can be related to ethnicity and environmental factors for example, the prevalence of sickle cell disease in Africa, and achondroplasia and tuberous sclerosis in Taiwan (Hsaio et al., 2011, Vandiver et al., 2022).

Sources reviewed suggested that sharing experiences, research, resources and expertise ought to improve the overall standard of genomics education (Chair et al., 2019) and faculty surveyed expressed interest in networking with other educators (Calzone et al., 2014). It is suggested that nurse educators may benefit from linking with the international nursing community and that multinational groups (such as G2NA) could support them through ‘genomic knowledge mobilization’ and resource accessibility (Dewell et al., 2020, Lopes-Junior et al., 2022, p13).

**Implications for nursing education and research**

This review highlights a shared conviction that further research is required to determine how genomics can be better integrated within nursing programmes (Greco & Salveson, 2009; Hsaio et al., 2011; Kirk et al., 2011, B; Kronk et al., 2018; Mathis, 2022; Parviainen, 2023; Rodrigues, 2016; Seibert, 2020; Sharoff, 2015). It was also felt by some that adequate funding is needed to inform the development of evidence-based genomics education and evaluation strategies (Adejumo et al., 2021, Ward, 2017).

The UK Nursing and Midwifery Council (2023) standards for education mention evaluation once with reference to assessing quality with no specific methods or guidance. The US CCNE (2024) focuses more on the evaluation of whole programmes and of student performance rather than individual teaching activities. Further investigation may prompt professional, statutory and regulatory bodies to include principles for the consistent and rigorous evaluation of key topics within their standards.

**Limitations**

Despite a systematic approach to searching and the double-screening of records, data extraction and narrative synthesis was performed by a single researcher. Much of the data reviewed relates to faculty and student self-perception of baseline or acquired knowledge which can form only part of any effective appraisal of educational interventions (Kronk et al., 2018).

Narrative reviews are flexible and practical in supporting the interpretation and synthesis of diverse literature and can highlight gaps to be addressed in future research. This approach, however, offers the interpretations of researchers within the context of the review. Narrative reviews provide general background are helpful in supporting learning about a topic but are not an evidence-based synthesis, necessary for definitive guideline statements, and a more comprehensive form of review may be required, although this may be challenging given the nature of the literature (Sukhera, 2022.) This review provides a grounding on which further exploration can be based.

Twelve studies were from 2011, representing a limitation in the currency of data. This peak may be linked to a call for relevant research within the UK Department of Health Genetics/genomics in Nursing and Midwifery Task and Finish Group report to the Nursing and Midwifery Professional Advisory Board (Kirk et al 2011, A). The group was made up of experts from the UK and the US and despite their recommendations newer data indicate little significant change.

Studies from a diverse range of countries met the inclusion criteria for review but the largest volume of research came from the US (Supplementary Table 2) and most of the information and recommendations came from North American studies. Within the US, participants involved in teaching undergraduate nurse genomics with the capacity to be involved in research are mostly women, mostly over the age of 40, mostly white and mostly holding a doctoral degree which poses a limitation in terms of diversity and the breadth of reported perspectives (Jenkins & Calzone, 2014; Mathis, 2022; Read & Ward, 2016).

**Conclusion**

The strength of this review lies in the narrative review approach which facilitated the inclusion of a range of study types to strengthen understanding using the best evidence. In response to a lack of research evidence on the effectiveness of methods of integration of genomics across pre-registration nursing curricula and of specific teaching strategies, we chose to include valuable information from commentaries and reflections on teaching practice.

This review highlights that authentic clinical experiences are important for students to develop skills in genomics but that it is difficult for faculty to obtain genomics placements. Furthermore, this review found that competency frameworks outline key content, but the lack of guidance supporting the effective integration of genomics into nursing programmes and a lack of outcome evidence underpinning effective methods of genomics education presents a global challenge. Research is needed to define successful integration of genomics particularly international research including more diverse participant demographics. Whilst effective evaluation may assist educators to improve and develop education, this review identified little meaningful evaluation of teaching and further research will support effective evaluation of genomics education. Sharing evaluations and well-evaluated teaching strategies may contribute to the standardisation of genomics education where appropriate.

The genomics literacy of the nursing workforce depends upon effective education and further research is required to establish principles to support a consistent and standardised approach to genomics integration and teaching.

**Dissemination**

This review of the literature provides information on current activity and underpinning frameworks. This will be significant in supporting the development of consistent regional, national and international approaches to genomics education. The findings will be of interest to health education regulators, health education providers and health services in relation to the development of pre-registration nursing curricula.

**Ethics**

No ethical considerations were identified, and this study did not require ethics approval.

**Conflict of interest**

None declared.

**Peer Review**

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**Appendix A: Supplementary data**

Table 2. Characteristics of included studies

Table 3. Examples of genomics skills and knowledge perceived as essential

Table 6. Supporting statements from included sources

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