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Dissertations in Health Sciences

ANNDRA MARGARETH PARVIAINEN

GENOMICS-INFORMED NURSING EDUCATION

AN INTERVENTION STUDY

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Anndra Margareth Parviainen

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AN INTERVENTION STUDY

To be presented by permission of the Faculty of Health Sciences,
University of Eastern Finland for public examination in MS302
Auditorium, Kuopio on November 17th, 2023, at 12 o'clock noon

Publications of the University of Eastern Finland
Dissertations in Health Sciences
No 782

Department of Nursing Science
Faculty of Health Sciences
University of Eastern Finland, Kuopio
2023

PunaMusta, 2023
Distributor: University of Eastern Finland
Kuopio Campus Library

ISBN: 978-952-61-5004-8 (print)
ISBN: 978-952-61-5005-5 (PDF)
ISSNL: 1798-5706
ISSN: 1798-5706
ISSN: 1798-5714 (PDF)

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FINLAND

Parviainen, Anndra Margareth
Genomics-Informed Nursing Education - an intervention study
Kuopio: University of Eastern Finland
Publications of the University of Eastern Finland
Dissertations in Health Sciences 782. 2023, 118 p.
ISBN: 978-952-61-5004-8 (print)
ISSNL: 1798-5706
ISSN: 1798-5706
ISBN: 978-952-61-5005-5 (PDF)
ISSN: 1798-5714 (PDF)

ABSTRACT

The integration of genomics across the nursing education is an important component to optimize the benefits of precision medicine. The overall aim of genomics is improving the quality of care and patients' outcomes. Globally, there are knowledge gaps on genomics among nurses. There is a need of updating the nursing curriculum as practical roadmap for preparing nurses to be knowledgeable and competent in genomics concepts.

The overall purpose of this study was to develop a tailored, web-based, Genomics Nursing Educational Intervention (GNEI) and investigate the effectiveness in improving the genomics literacy among undergraduate nursing students. The research design of this dissertation is parallel randomized controlled trial (RCT), two cohort group, pre-test and repeated post-tests, single blind. This RCT study was designed to test two hypotheses at the 0.05 level of significance: HH1. If there will be significant statistical differences between the genomics scores of the intervention group (IG) and the control group (CG) in the pre-test, post-test, and repeated post-test; and HH2. If there will be significant statistical differences between the effectiveness of the newly designed, tailored, web-based, GNEI and that of standard education.

The research study was comprised of four phases during years 2017-2022: development of the study protocol; translation and linguistic validation of the research instrument; assessment of the genomics literacy of the study participants as basis for the development of a web-based GNEI; and lastly, evaluation of the effectiveness of GNEI in improving the primary outcome (increase genomics knowledge) and secondary outcome (feedback from the participants).

The translation and linguistic validation of a valid and reliable research instrument Genomics Nursing Concepts Inventory (GNCI) followed the rigorous steps of the Mandysova's decision tree algorithm from English into Finnish. Ten experts (6 nurses and 4 genetics-genomics specialists from non-nursing profession) evaluated the Finnish GNCI before it was piloted to eight nursing students. The coefficient of Cronbach's alpha showed a good alpha value of 0.816 (95% CI: 0.57–0.96).

Assessment of participants' genomics literacy was conducted through an online cross-sectional survey using the GNCI (n=245 undergraduate nursing students participated in the study). This step was vital as a basis for developing a genomics nursing education course tailored for the participants' current level of genomics knowledge. The findings confirmed knowledge gaps particularly in the basic concepts of genomics. From these results, the research team designed a tailored, web-based, GNEI.

In the RCT study, data were collected electronically from January 2020-March 2022 in the Philippines. Participants were randomly allocated to intervention group (n=114) exposed to the newly designed tailored, web-based, GNEI and the control group (n=114) was exposed to the standard genomics education intervention. The primary outcome (genomics literacy) was measured five times (pre-test 1-January 2020; pre-test 2- September 2021; post-test 1-December 2021; post-test 2- January 2022; and post-test 3- March 2022. The secondary outcomes (participants' feedback on the GNEI course) were measured after the 12 weeks intervention (post-test 1-December 2021). The intervention lasted 12 weeks and followed-up measurements after 18 weeks and 26 weeks.

Generalized Linear Mixed Models (GLMMs) was utilized in data analysis using the IBM SPSS version 27. The findings supported the first hypothesis

of this study. Significant statistical differences at 0.05 level of significance was found in the pre-test, post-test and repeated post-testing of GNCI scores among participants in the intervention arm compared with the control arm (p-value = 0.010). However, there was no any significant statistical differences in the effectiveness of the newly designed web-based GNEI compared with the standard web-based genomics nursing education (p-value = 0.476) which rejects the second hypothesis of this study.

Students who are currently taking genetics-genomics course and have taken biology course shows higher genomics literacy and the results were statistically significant respectively (p-value = 0.014; p-value = 0.024). Both the newly designed, tailored, web-based GNEI and standard genomics nursing educational interventions shows an effectiveness in increasing the genomics literacy among undergraduate nursing students.

This dissertation provides evidence of sustained learning through testing the effectiveness of an online educational intervention using RCT study design. The study has provided cohort-evidence-based findings that can facilitate in designing tailored online genomics nursing course that can bridge existing genomics knowledge gaps. Further research is recommended to investigate how genomics will be effectively integrated in the undergraduate nursing curriculum.

ClinicalTrials.gov registration number: NCT03963687
https://clinicaltrials.gov/show/NCT03963687

Keywords: education, effectiveness, genetics, genomics, nurses, nursing students, randomized controlled trial, web based

Parviainen, Anndra Margareth
Genomitieto sairaanhoitajien koulutuksessa- interventiotutkimus
Kuopio: Itä-Suomen yliopisto
Publications of the University of Eastern Finland
Dissertations in Health Sciences 782. 2023, 118 s.
ISBN: 978-952-61-5004-8 (nid.)
ISSNL: 1798-5706
ISSN: 1798-5706
ISBN: 978-952-61-5005-5 (PDF)
ISSN: 1798-5714 (PDF)

TIIVISTELMÄ

Genomiikan ja genomitiedon integrointi sairaanhoitajien koulutukseen ja työhön on tärkeä osa täsmälääketieteen hyödyn optimointia. Genomiikan yleisenä tavoitteena on parantaa hoidon laatua ja potilaiden hoidon tuloksia. Sairaanhoitajien genomitiedossa on todettu olevan puutteita kansainvälisesti.

Tämän tutkimuksen tarkoituksena oli kehittää genomiikan koulutusinterventio (GNEI) sairaanhoitajaopiskelijoille ja arvioida sen vaikutusta genomiikan lukutaitoon. Tämän väitöskirjan tutkimusasetelma on rinnakkainen satunnaistettu kontrolloitu tutkimus (RCT). Tämä RCT-tutkimus suunniteltiin testaamaan kahta hypoteesia merkitsevyystasolla 0,05: HH1. Onko interventioryhmän ja kontrolliryhmän genomiikkapisteiden välillä merkitseviä tilastollisia eroja esitestissä, jälkitestissä ja toistetussa jälkitestissä.; ja HH2. Onko suunnitellun, räätälöidyn, verkkopohjaisen GNEI:n ja vakiokoulutuksen tehokkuuden välillä on tilastollisesti merkitseviä eroja.

Tutkimus koostui neljästä vuosina 2017-2022 toteutetuista vaiheista: tutkimusprotokollan kehittäminen; aineiston keruun instrumentin validaatio; tutkimukseen osallistuneiden genomiikkalukutaidon arviointi perustana verkkopohjaisen GNEI:n kehittämiselle; ja lopuksi GNEI:n

vaikuttavuuden arviointi ensisijaisen tuloksen (genomiikan tietämyksen lisääminen) ja toissijaisen tuloksen (palaute osallistujilta) parantamisessa.

Genomics Nursing Concept (GNCI) kääntämisessä ja kielellisessä validaatiossa käytettiin Mandysovan päätöspuualgoritmia englannista suomeen. GNCI;tä pilotoinnissa käytettiin asiantuntija-arviointeja ja sitä pilotoitiin kahdeksalla opiskelijalla. Mittarin luotettavuus todettiin hyväksi. Cronbachin alfan kertoimen tulos oli alfa-arvo 0,816 (95 % CI: 0,57–0,96).

Sairaanhoitaja opiskelijoiden (n=245) genomiikan lukutaitoa arvioitiin sähköisellä kyselyllä. Tuloksia käytettiin verkkopohjaisen koulutusintervention suunnittelussa. Tulokset vahvistivat tiedon puutteita erityisesti genomiikan peruskäsitteissä. Tutkijaryhmä suunnitteli räätälöidyn, verkkopohjaisen Genomics Nursing Education Intervention (GNEI) -ohjelman.

RCT-tutkimuksessa tiedot kerättiin sähköisesti tammikuusta 2020 maaliskuuhun 2022 sairaanhoitajaopiskelijoilta Filippiineillä. Osallistujat jaettiin satunnaisesti interventioryhmään (n=114), jotka osallistuivat, verkkopohjaiselle GNEI:lle, ja kontrolliryhmä (n=114) osallistui standardiin genomiikan koulutusinterventioon. Interventio kesti 12 viikkoa. Hoitotyön opiskelijoiden genomiikan lukutaito oli päätulosmuuttuja ja sitä mitattiin viidessä vaiheessa (1. mittaus ennen interventiota tammikuu 2020;2.mittaus ennen syyskuu 2021; intervention jälkeen ensimmäinen mittaus joulukuu 2021; 2. mittaus tammikuu 2022; 3. mittaus maaliskuu 2022). Toissijainen tulos oli osallistujien palaute GNEI-kurssista 12 viikkoa intervention jälkeen.

Tulosten analysoinnissa käytettiin yleistettyjä lineaarisia sekamalleja (GLMM). Tulokset tukivat tämän tutkimuksen ensimmäistä hypoteesia. Merkitseviä tilastollisia eroja 0,05:n merkitsevyystasolla havaittiin GNCI-pisteiden esitestissä, jälkitestissä ja toistuvissa jälkitestauksissa interventioryhmän osallistujien kesken verrattuna kontrolliryhmään (p-arvo = 0,010). Verkkopohjaisen GNEI:n vaikuttavuudessa ei kuitenkaan ollut merkittäviä tilastollisia eroja verrattuna kontrolliryhmän genomiikan hoitotyön koulutukseen (p-arvo = 0,476), mikä hylkää tämän tutkimuksen toisen hypoteesin.

Tulosten mukaan genetiikka-genomiikkakurssia ja biologiakurssia suorittavilla opiskelijoilla oli parempi genomiikan lukutaito, ja tulokset olivat tilastollisesti merkitseviä (p-arvo = 0,014; p-arvo = 0,024). Sekä verkkopohjainen GNEI että standardi genomiikan hoitotyön koulutus paransivat sairaanhoitajaopiskelijoiden genomiikan osaamista. Tutkimus tuottaa tietoa verkkopohjaisten, online- genomiikan opintojakson koulutusintervention vaikuttavuudesta. Jatkotutkimuksissa on tärkeää selvittää, miten genomikkaa ja genomitietoa integroidaan parhaiten hoitotyön opetussuunnitelmiin.

ClinicalTrials.gov rekisteröintinumero: NCT03963687
https://clinicaltrials.gov/show/NCT03963687

Avainsanat: koulutus, tehokkuus, genetiikka, genomiikka, sairaanhoitajat, hoitotyö, satunnaistettu kontrolloitu tutkimus, verkkopohjainen

ACKNOWLEDGEMENTS

This Ph.D. study was conducted in the Doctoral Program in Health Sciences, Faculty of Health Sciences, University of Eastern Finland. It takes a supportive, loving, and safe community for a Ph.D. to be born. My academic and scientific journey to search for know-how in the middle of know-where would not be possible without the consistent help and support of my supervisors, colleagues, collaborators, friends, loved ones and families. The completion of my dissertation is the product of compassion, love, respect, trust, resilience, and dedication.

The flame of compassion, trust, and dedication of my supervisors have inspired me and consistently fuelled me with great motivation to take risk, be out of my comfort zone and enjoy the process of discovering new things. My supervisors were always there to guide and support me from the beginning of my Ph.D. journey until the end of the research process. I would like to express my deepest appreciation to my main supervisor, Professor Katri Vehviläinen-Julkunen, for her excellent guidance, encouragement, and empowering support. I am very thankful to my second supervisor, Professor Carsten Carlberg, for his professional expertise, patience, intensive guidance, and unconditional support. I feel humble to be mentored by two highly calibre mentors, it is my pride and honour to be trained by both of you.

Working with international experts from Australia, Czech Republic, Finland, New Zealand, Philippines, and USA, has made my whole process of learning very fruitful and exciting.

Thank you, Dr. Linda Ward, Ph.D., CNE, FNP-C, Associate Professor, Clemson University School of Nursing, Clemson, South Carolina, USA. Dr. Ward developed the Genomic Nursing Concept Inventory (GNCI), an instrument to measure knowledge of genetic and genomic concepts essential to nursing practice. Thank you for allowing us to use the GNCI tool and translate it to Finnish version. She has been very supportive in the whole process of the RCT study and generously guide us on each phase of research process.

My sincere appreciation to Dr. Petra Mandysova, Ph.D., Associate Professor, Palacky University Olomouc, Faculty of Health Sciences, Department of Nursing, Olomouc, Czech Republic. Thank you for allowing us to borrow and test the feasibility of your invented “Mandysova’s Decision Tree Algorithm” for the linguistic validation and Finnish translation of the Genomic Nursing Concept Inventory. The algorithm has help us to produce a robust, valid, and reliable Finnish GNCI tool which is essential for the data collection.

The genomics expertise of Dr. Bobbi Laing, Ph.D. and Dr. Anecita Gigi Lim, Ph.D. from University of Auckland, Faculty of Medical & Health Sciences, School of Nursing, Auckland, New Zealand and Professor Jane Maguire, Ph.D., from University of Technology Sydney, Faculty of Health, Sydney, Australia. I feel blessed and humble to meet you all through the organization International Society of Nurses in Genetics (ISONG).

My former colleagues and mentors from Philippines Dean Gabriel Bacungan, Jima Mamungay, former Dean Ofelia Valdehueza, Professor Erlinda Palaganas and Mr. James Abad, thank you very much for the support and for helping me facilitate the study in Philippines.

To my collaborators here in Finland who have played an important role to progressed smoothly in my Ph.D. journey. Thank you so much Arja Halkoaho, Adjunct Professor and Nina Smolander, Project manager, Tampere University of Applied Sciences, Tampere. Marjo Palovaara, Head of the Nursing Program in Jyväskylä University of Applied Sciences, Jyväskylä, and Hannele Sauders, Project manager, South-Eastern Finland University of Applied Sciences, Kouvola.

The statistical expertise of Matti Estola, Dr. Reijo Sund, and Santtu Mikkonen whose guidance, support and encouragement has been invaluable throughout this study.

I owe my warmest gratitude to the reviewers, for taking the time and effort necessary to review the dissertation and their constructive comments.

This research process would not have been possible without the nursing students in Finland and Philippines who voluntarily participated in this study. I am also grateful to all my colleagues in University of Eastern

Finland, Nursing Department for helping me to translate and validate our research tool.

I would like to thank the following research grants and scholarships that I have received during my Ph.D. studies: the Department of Nursing Science, Faculty of Health Sciences, University of Eastern Finland; the International Society of Nurses in Genetics (ISONG) Correspondence scholarship (2019-2021); the Marja-Terttu Korhonen Foundation (2019 scholarship); the Finnish Nursing Education Foundation (2021 scholarship); the Finnish Cultural Foundation North Savo Regional Fund (2022 and 2023 scholarship); and the Erasmus+ staff mobility training 2023.

To my family, friends, and loved ones for the unending love and support - emotionally, spiritually, and mentally. To my husband, Tero Parviainen, I feel always blessed and thankful to be your partner in life. To my parents, Mr. Arturo Dumo and Teresita Dumo, my in-laws, Mr. Raimo Parviainen and Tuula Parviainen, thank you for the love. To my aunt, Medita Bernardo-del Rosario and Gloria Bernardo-Hyttinen, thank you for your motherly love. To my brothers, Art Krisus and Art Emmanuel and to my dear sister Angielique Dumo-Hirvonen, thank you for the inspiration. To my loving and dear grandmother who was my inspiration in life and played an important role in becoming a good person, you are always in my heart and memories, thank you for the abundance of love that you have given to me when you are still alive, you are the reason why I keep on going and becoming the best version of me.

Thank you to all! Kiitos kaikkille! Maraming salamat po!

In Kuopio, November 2023
Anndra Margareth Dumo Parviainen

LIST OF ORIGINAL PUBLICATIONS

This dissertation is based on the following original publications:

I Dumo, A. M., Laing, B., Lim, A. G., Palaganas, E., Abad, P. J., Valdehueza, O., Palovaara, M., Saunders, H., Estola, M., Mandysova, P., Maguire, J., Ward, L. D., Carlberg, C., & Vehviläinen-Julkunen, K. Randomized controlled trial on the effectiveness of web-based Genomics Nursing Education Intervention for undergraduate nursing students: a study protocol. J Adv Nurs. 2020;76(11):3136–46.

II Dumo, A. M., Mandysova, P., Ward, L. D., Laing, B., Lim, A. G., Palovaara, M., Saunders, H., Maguire, J., Carlberg, C., Sund, R., & Vehviläinen-Julkunen, K. Linguistic Validation of Genomic Nursing Concept Inventory to Finnish Applying Mandysova's Decision Tree Algorithm. J Nurs Meas. 2023;31(3):1–17.

III Parviainen, A., Ward, L. D., Halkoaho, A., Laing, B., Maguire, J., Palovaara, M., Mandysova, P., Bacungan, G., Mamungay, J., Sund, R., Mikkonen, S., Carlberg, C., & Vehviläinen-Julkunen, K. Nursing students' genomics literacy: Basis for genomics nursing education course development. Teach Learn Nurs. 2023;18(1):6–11.

IV Parviainen, A., Ward, L. D., Halkoaho, A., Laing, B., Lim, A. G., Bacungan, G., Mamungay, J., Palovaara, M., Mandysova, P., Maguire, J., Sund, R., Mikkonen, S., Carlberg, C., & Vehviläinen-Julkunen, K. Effectiveness of web-based genomics nursing education intervention for undergraduate nursing students: a randomized controlled trial in the Philippines. Submitted and under review.

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ABBREVIATIONS

CG	Control group
DIT	Diffusion of Innovation Theory
DNA	Deoxyribonucleic acid
GIN	Genomics-Informed Nursing
GNCI	Genomics Nursing Concepts Inventory
GNEI	Genomics Nursing Education Intervention
GNC	Genomic Nursing Care
HGP	Human Genome Project
ISONG	International Society of Nurses in Genetics
IG	Intervention group
NIH	National Institutes of Health
NHGRI	National Human Genome Research Institute
PH	Precision Health
PM	Precision Medicine
PMI	Precision Medicine Initiative
RCT	Randomized controlled trial
WHO	World Health Organization

1 INTRODUCTION

Precision medicine (PM) is a new approach to healthcare that involves considering the genomic and genetic makeup of individuals (1,2). Guided by individual genomic variations, genomics enable precise screening, early disease detection, and personalized therapeutic approaches (3–10). Genomics is already involved in developing care options (7) by understanding the molecular-cellular mechanisms and associated pathophysiological processes of diseases like Alzheimer's disease (8), cancer (9), cardiovascular disease (10), diabetes (11), rare diseases (12), psychiatry (13), and pharmacogenomics (14).

The practice of precision medicine requires competent nurses who are knowledgeable of genomic concepts in response to the paradigm shift of the "Genomic Nursing Care Approach" (15–17). Considering this demand, there is a need to update nursing curricula and provide a practical roadmap for the integration of precision medicine across nursing. This chapter describes the scientific reasons and research gaps that this dissertation work had addressed.

Background of the study

The goals of the National Institute Research Strategic Plan Framework 2022–2026 highlighted the use of nursing science's holistic methodologies to expand precision medicine (18). This paradigm shift implies the need for genomics-informed nurses (GINs) to support the translation of genomics into clinical practice (3,14–20). Nurses have the capacity to provide patient/family education and obtain informed consent (19–21). For nurses to effectively provide genomics-based care, they need to be knowledgeable about the service pathways and the ethical, legal, and socioeconomic aspects involved (19–21).

Nurses experience knowledge gaps in genomics due to knowledge shortfalls and scant training (22–28). Research evidence has revealed that disparities in the nursing curriculum (23,29–33) limit nurses' capacity to

understand and use genomic data for delivering precision care (23,26,29,31,34–36). The existing nursing curriculum needs to be revisited and upgraded to include genomics education (24,28–30,37–39).

Diversity, inclusion, and health equity in genomic nursing were accentuated during the International Society of Nurses in Genetics (ISONG) 2021 World Congress (38) and Global Genomics Nursing Alliance (G2NA) (39). Accordingly, this dissertation attempt to contribute to the promotion of diversity, inclusiveness, and health equity in genomics nursing through research on a developed country, namely Finland, and a developing country, namely the Philippines. The overall aim of this doctoral dissertation was to develop a tailored, web-based, Genomics Nursing Educational Intervention (GNEI) and investigate the effectiveness in improving the genomics literacy among undergraduate nursing students. This is in line with UEF Faculty of Health Sciences Research Community "Effectiveness."

2 REVIEW OF THE LITERATURE

In this chapter, the history of genomics, a rapid literature search into the current trends in genomics and nursing education, the minimum genomics nursing competencies, a comparison of nursing education in Finland and the Philippines, the current status of the genomics curricula in Finland and the Philippines, and the theoretical and conceptual frameworks of this study are discussed. In order to facilitate a common understanding, the definitions of the main concepts used in this dissertation are presented in Appendix 1: Glossary.

2.1 HISTORY OF GENOMICS

One of the greatest scientific accomplishments in human history is the Human Genome Project (HGP) (40), which was launched in October 1990 and completed in April 2003. The project was led by an international group of researchers seeking biological discoveries, and determining the first sequence of the human genome was one of its milestones. Genomic discoveries have since provided vital knowledge about the human blueprint, in turn accelerating and improving precision medicine (40-42). The historical landmarks of genetics and genomics research are shown in Figure 1.

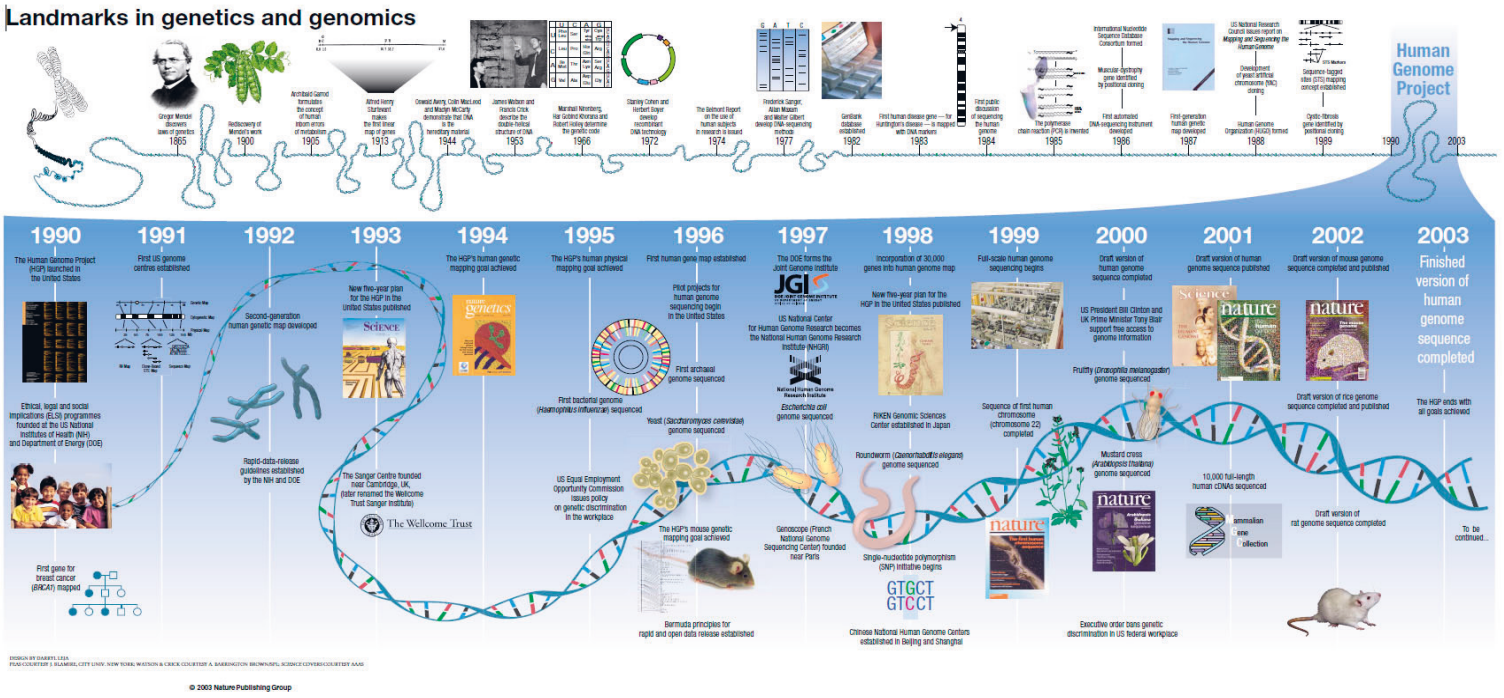

Figure 1. Landmarks in genetics and genomics history – Permission to use. Copyright National Human Genome Research Institute (40).[1]

[1] Source*:* National Human Genome Research Institute. The Human Genome Project. The Forefront of Genomics (40). https://www.genome.gov/human-genome-project, https://www.genome.gov/sites/default/files/media/files/2020-09/HGP_Timeline.pdf

Table 1. Trend of published research articles related to genomics and nursing education from the last 10 years (2013-2022)

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total
PubMed (MEDLINE)	1938	3018	3829	4343	4840	6077	7296	8429	10121	9585	59476
CINAHL (EBSCO)	46	58	41	39	44	44	54	48	53	45	472
Cochrane Library	0	2	0	2	2	4	9	11	6	17	53
Scopus	19	19	9	16	21	13	17	17	6	15	152

Table 2. The minimum nursing genomics competencies in USA

Domain	Competencies
Professional responsibilities	All registered nurses are expected to engage in professional role activities that are consistent with Nursing Scope and Standards of Practice, 2004, American Nurses Association. In addition, competent nursing practice now requires the incorporation of genetic and genomic knowledge and skills to: • Recognize when one's own attitudes and values related to genetic and genomic science may affect care provided to clients. • Advocate for client's access to desired genetic/genomic services and/or resources including support groups. • Examine competency of practice on a regular basis, identifying areas of strength, as well as areas in which professional development related to genetics and genomics would be beneficial. • Incorporate genetic and genomic technologies and information into registered nurse practice. • Demonstrate in practice the importance of tailoring genetic and genomic information and services to clients based on their culture, religion, knowledge level, literacy, and preferred language. • Advocate for the rights of all clients for autonomous, informed genetic and genomic-related decision-making and voluntary action.
Professional practice	In the application and integration of genetic and genomic knowledge in nursing assessment, the registered nurse: • Demonstrates an understanding of the relationship of genetics and genomics to health, prevention, screening, diagnostics, prognostics, selection of treatment, and monitoring of treatment effectiveness. • Demonstrates ability to elicit a minimum of three-generation family health history. • Constructs a pedigree from collected family history information using standardized symbols and terminology.

Domain	Competencies
	• Collects personal, health, and developmental histories that consider genetic, environmental, and genomic influences and risks. • Conducts comprehensive health and physical assessments which incorporate knowledge about genetic, environmental, and genomic influences and risk factors. • Critically analyzes the history and physical assessment findings for genetic, environmental, and genomic influences and risk factors. • Assesses clients' knowledge, perceptions, and responses to genetic and genomic information. • Develops a plan of care that incorporates genetic and genomic assessment information.
Professional practice	In the identification, the registered nurse: • Identifies clients who may benefit from specific genetic and genomic information and/or services based on assessment data. • Identifies credible, accurate, appropriate, and current genetic and genomic information, resources, services and/or technologies specific to given clients. • Identifies ethical, ethnic/ancestral, cultural, religious, legal, fiscal, and societal issues related to genetic and genomic information and technologies. • Defines issues that undermine the rights of all clients for autonomous, informed genetic and genomic-related decision-making and voluntary action. • In the referral activities. the registered nurse: • Facilitates referrals for specialized genetic and genomic services for clients as needed. • In the provision of education, care, and support, the registered nurse: • Provides clients with interpretation of selective genetic and genomic information or services. • Provides clients with credible, accurate, appropriate and current genetic and genomic information, resources, services, and/or technologies that facilitate decision-making. • Uses health promotion and disease prevention practices to: ○ Considers genetic and genomic influences on personal and environmental risk factors.

Domain	Competencies
	○ Incorporates knowledge of genetic and/or genomic risk factors (e.g., a client with a genetic predisposition for high cholesterol who can benefit from a change in lifestyle that will decrease the likelihood that the genetic risk will be expressed). ○ Uses genetic and genomic-based interventions and information to improve clients' outcomes. ○ Collaborates with healthcare providers in providing genetic and genomic healthcare. ○ Collaborates with insurance providers and payers to facilitate reimbursement for genetic and genomic healthcare services. ○ Performs interventions and treatments appropriate to clients' genetics and genomic healthcare needs. ○ Evaluates impact and effectiveness of genetic and genomic technology, information, interventions, and treatments on clients' outcome

Sources: Jenkins and Calzone (57), Consensus Panel on Genetic/Genomic Nursing Competencies (60)

2.2 CURRENT TRENDS IN GENOMICS AND NURSING EDUCATION

In the healthcare context, genomics involves investigating the associations between genomes, biology, health, and society (2,5,30,42–45). Nurses in the US, the UK, Canada, Japan, Australia, Hong Kong, Taiwan, China, and other countries have started providing genomics education for nurses (24,25,38,46–49), as nurses are pivotal for using genomic information to improve health outcomes (24,30,43,50).

A rapid literature review was conducted to understand the trends in genomics and nursing education over the last 10 years. Searches were performed for studies in the 2013–2022 period using the following search engine databases: PubMed, CINAHL, Cochrane Library, and Scopus. The following Boolean phrase was used as a search string: genomics AND (nursing education OR nurse education OR continuing education OR training program OR training OR nursing instruction). The literature search was done on December 9, 2022.

As shown in **Table 1** and **Figure 2**, a few research articles related to genomics and nursing education were published in 2013 (n = 2003 articles). This number doubled by 2016 (n = 4400 articles) and tripled by 2018 (n = 6138 articles). The increasing trend continued, and the highest number of publications was reached in 2021 (n = 10,186 articles). Duplicates were not omitted which gives a rough estimation of n=60,153 published research articles. Given the large number of papers, is it possible that some papers were on other topics but were identified and included because the search string was present (e.g., in an abstract) as a result of the authors making a simple reference to nurse education in genomics being required. Nevertheless, the trend is expected to continue, as many research initiatives have been launched to utilize genomics technology in maximizing the quality of care.

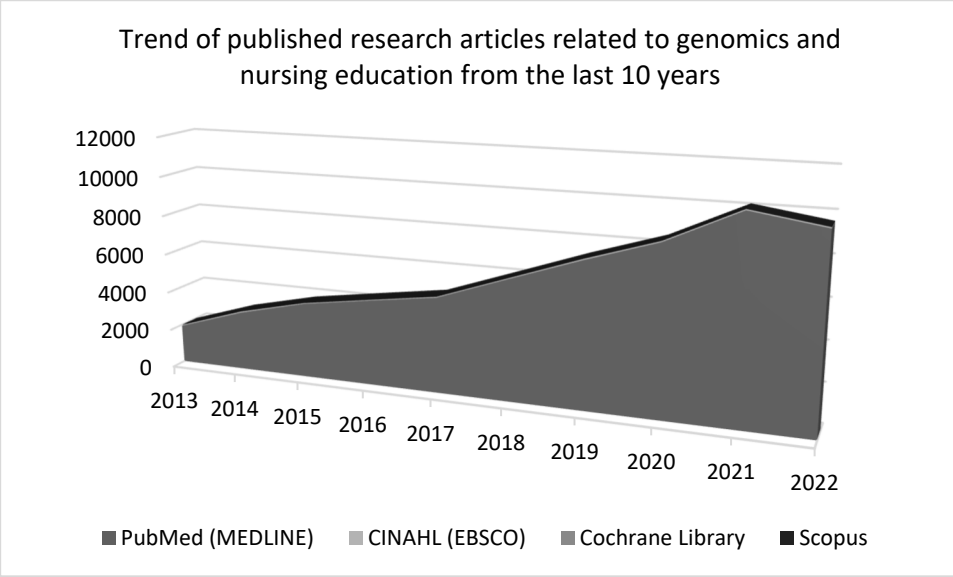

Figure 2. The trend in the number of published research articles related to genomics and nursing education from 2013 to 2022.

2.3 GENOMICS-INFORMED NURSING COMPETENCIES

"Genomics for Health" recognizes that genetics and genomics research are significant to nurses (1,3,6,39,43,51–54). Nurses can help translate genomics from basic research to clinical care (35,46,55–61). Efforts have been made to establish the minimum genetic and genomic competencies required in nursing (4,54,57-60). **Table 2** summarizes the latter.

2.4 NURSING EDUCATION IN FINLAND AND PHILIPPINES

The existing nursing education systems in Finland and the Philippines are presented in Table 3. Finland is renowned worldwide for its high-quality education (62). Finnish universities of applied sciences (UAS) offers the Bachelor of Science (BSc) degree in nursing. Nursing education lasts 3.5 years, as per the European Union (EU) Council regulations (77/452/ETY, 2001/19/EY, 2005/36/EY), and includes both theoretical learning and clinical

practice (EU Directive 2001/19/EC, 2001). In Finland (Decree on Polytechnics 352/20023), nursing students are expected to have competencies in client-centeredness, ethics, leadership, clinical nursing, evidence-based practice, education, health promotion, quality and safety of healthcare services (62,63). The training is based on the directive of the European Parliament and the Council (2005/36/EC) and the professional qualification directive (2013/55/EU), the law on healthcare professionals (559/94) and the regulation (564/94) and the professional competence descriptions that regulate the training and goals (64-69). Central to nursing education are the University of Applied Sciences Act (932/2014), the Government Decree on Universities of Applied Sciences (1129/2014) and the Government Decree on the Reference Framework for Degrees and Other Competences (120/2017), which provide the scope, structure and general goals of education in relation to the competence requirements of nurses (62-69).

In the Philippines, completing a four-year Bachelor of Science in Nursing (BSN) program and passing the national nursing license examination are mandatory to become a registered nurse (RN). The Philippine Nursing Act of 2002, RA 9173, regulates nursing practice, while the Commission on Higher Education (CHED) promulgates outcome-based nursing education policies, standards, and guidelines for nursing practice (70). National Core Competencies Standards are given in the CHED Memorandum Order No. 15, Series of 2017, with a common compulsory curriculum for undergraduate nursing study programs to prepare nurses for generalist roles (70,71).

The nursing curricula in Finland and the Philippines have many similarities and differences. A qualitative analysis of the nursing curricula showed that both countries have the same philosophy, theoretical design, and desired characteristics for nursing graduates (71). Nursing education requires 3.5–4 years of study in Finland and 4 years in the Philippines (70). Both countries emphasize the provision of holistic care for individuals, families, and communities across settings (71). They also share the goal of discovering approaches to integrating genetics and genomics know-how into the nursing curriculum (72-74).

In both Finland and the Philippines, the core nursing competencies include providing safe and high-quality nursing care and pursuing lifelong learning. However, genetics–genomics competencies have not yet been considered for either country's curricula. To date, no specific genetics–genomics competency statements have been provided in Finland (75) or the Philippines (74), and neither country offers a genomics specialty pathway for nurses.

In the Philippines, a master's program in genetic counselling offers advanced education in genetics and counselling, and students need not be nurses to enrol in the program (74). This two-year program is aimed at increasing genetic counselling services in the Philippines. There are currently 16 genetic counsellors in the Philippines; among them, 11 are nurses (75).

In Finland, a master's degree course in genetics and genomics counselling was established in 2021 offered in one University of Applied Sciences (Ylempi ammattikorkeakoulututkinto) (75). In the Finnish education system, Master's and Doctoral Degrees are not from Universities of Applied Sciences but from Universities. To date, there were no Master's and Doctoral Degree program specifically in genomics offered at Finnish university level. Some Finnish courses and modules were offered related to Genomics-Informed Nursing but the actual genomics nursing competencies is still missing.

Table 3. A comparison of nursing education in Finland and the Philippines

Bachelor of Nursing Science	**Finland**	**Philippines**
Institutions/ Nursing schools offering the program	23 Finnish universities of applied sciences (UAS)	450 registered schools and colleges of nursing
Years of education	3.5 years	4 years
Regulating bodies/ Legislations	EU Directive (2005/36/EC) and EU Professional Directive (2013/55/EU) EU Council regulations (77/452/ETY, 2001/19/EY, 2005/36/EY) Decree on Polytechnics 352/20023	Commission on Higher Education (CHED) CHED Memorandum Order No. 15, Series of 2017 Philippine Nursing Act of 2002, RA 9173
Type of education	Competency-based education	Outcomes-based education
Nature of education	Relatively flexible	Relatively rigid
Educational credits	ECTS (1 ECTS = 25–30 hours)	Credit Unit (1 unit =45 hours)
Professional Competencies	1) Professionalism and ethics, 2) Client-centred care, 3) Communication and multi-professionalism, 4) Health promotion, 5) Leadership and professional co-operation skills of the employee, 6) Information technology and documentation , 7) Guidance and education competence and supporting self-care, 8) Clinical nursing, 9) Evidence-based practice, utilization of research knowledge and decision-making, 10) Entrepreneurship and development , 11) Quality	1) Physical, social, natural, health sciences and humanities, 2) safe, holistic care, 3) evidence-based practice, 4) laws, legal, ethical, and moral principles, 5) communicate effectively and culturally appropriate, 6) Report/document accurately and comprehensively, 7) Collaborate effectively with inter-, intra-, and multi-disciplinary and multicultural teams, 8) management and leadership skills, 9) research, 10) lifelong learning, 11) responsible citizenship, 12) techno-

Bachelor of Nursing Science	Finland	Philippines
	management, 12) Service system of health care and social welfare services, 13) Patient and client safety	intelligent care, 13) nursing core values, 14) entrepreneurial skills
General education courses	46 ECTS	36 units
Supportive courses	30 ECTS	31 units
Elective courses	40 ECTS	9 units
Professional courses	180 ECTS	125 units
Clinical Practice	65 ECTS (1732 hours)	53 RLE units (2,703 hours)
Total number of credits	210 ECTS	202 units
Total number of hours	4,600 hours	5,514 hours
After graduation	General Nurse	General Nurse
Licensure examination	None Automatically registered as a professional nurse in accordance with the act (559/949), national Supervisory Authority for Welfare and Health (Valvira) grants	Yes Nurse Licensure Exam is conducted by the Philippine Regulatory Commission (PRC). To become a registered nurse, one must obtain a general average rating of at least 75%, with a rating of not below 60% for any of the five subjects.
Master's degree	2 years	2 years
Doctorate Degree	4 years (average)	4 years (average)

Sources: Finnish National Agency for Education (62), Commission on Higher Education (70), Dumo (71)
Legend: ECTS- European Credit Transfer and Accumulation System

2.5 GENOMICS IN THE HEALTHCARE SYSTEMS OF FINLAND AND THE PHILIPPINES

The Finnish healthcare system is promoting the clinical application of genomic data in response to the need for contemporary personalized healthcare (5,72). Finland's national genome strategy involves safeguarding genomic data for its effective utilization to promote health and well-being, including targeted screening, accurate diagnoses, and personalized treatment, and for increased economic benefits (72).

Meanwhile, the Philippine Genome Center (PGC) was established by the Philippine government to advance scientific knowledge and the judicious application of emerging technologies in genomics and bioinformatics for the benefit of Filipinos' health (76,77). The genetics and genomics services offered by the Philippine government and private institutions are limited (74).

2.6 THEORETICAL AND CONCEPTUAL FRAMEWORKS

To our knowledge, the present study was the first to measure actual knowledge of genomics concepts among nursing students using randomized controlled trial (RCT). This study was guided by three theoretical frameworks: Everett Mitchell Rogers' Diffusion of Innovation Theory (DIT) (78) and Jean Piaget's Cognitivism Learning Theory and Constructivist Learning Theory (79-81). Furthermore, Hickey's Transdisciplinary Nurse Scientist conceptual model (82) and Knowledge-to-Action Framework (83) were utilized. In this study, we developed the Genomic Nursing Care conceptual framework (17).

According to the DIT, people take time to adapt an innovation—in this case, genomics education for nurses. Genomics will continuously influence the field of health sciences, and the nursing discipline must adapt to these advances. Educational interventions are needed to facilitate the adaptation of genomics in nursing.

Genomics literacy is vital for ensuring the translational application of precision medicine. For this dissertation, Piaget's cognitive development

and the construction of reality theories (79-81) guided the development of the study protocol and an online genomics course tailored to nursing students. Cognitive and constructivist learning theories indicate that the acquisition of knowledge is facilitated by cognitive processes, past experiences, and active engagement (79-81,84). Accordingly, with the aim of developing genomics-informed nurses, educational materials were provided to the present study's participants to keep them actively engaged in learning. Using the cognitive learning theory, the following pedagogical teaching methodologies were incorporated when designing the course content: lectures, visual tools to facilitate memorization of learning, and the multiple-choice genomics literacy assessment. In the constructivist learning theory, pedagogical teaching methodologies such as collaborative group work and self-guided learning were incorporated in the newly develop, tailored, web-based, GNEI.

According to Hickey (82), nurses can build a nurse scientist career in the field of genetics–genomics through education, research, health policy contributions, genomics technology advancements, and patient and family knowledge. Nurse scientists are uniquely positioned to advance nursing science through research and evidence-based practice initiatives due to their ability to closely collaborate with other healthcare professionals in the clinical setting (85,86). This dissertation was conducted to investigate the foundational genetics–genomics knowledge of nursing students. Nurses who recognize how genes influence health (i.e., knowledgeable of foundational principles) are well positioned to provide genomics-informed care across the care continuum from assessment to evaluation of health outcomes.

The Knowledge-to-Action Framework (KTA) **(Figure 3)** provides a structured methodology for transforming knowledge into practice (83). In making an intellectual contribution, the framework was integral to knowledge translation. In this dissertation, the seven steps of KTA framework served as a backbone in the whole process of this interventional study. First was the identification of existing genomics knowledge gaps of cohort groups, and then adapting the knowledge to local context, assessing barriers to knowledge use, then selecting and

designing a tailored, web-based, GNEI. This study had monitored and evaluated the learning outcomes by comparing the results of genomics scores from pre-test, post-test and repeated post-test. The challenge was how to sustain the knowledge.

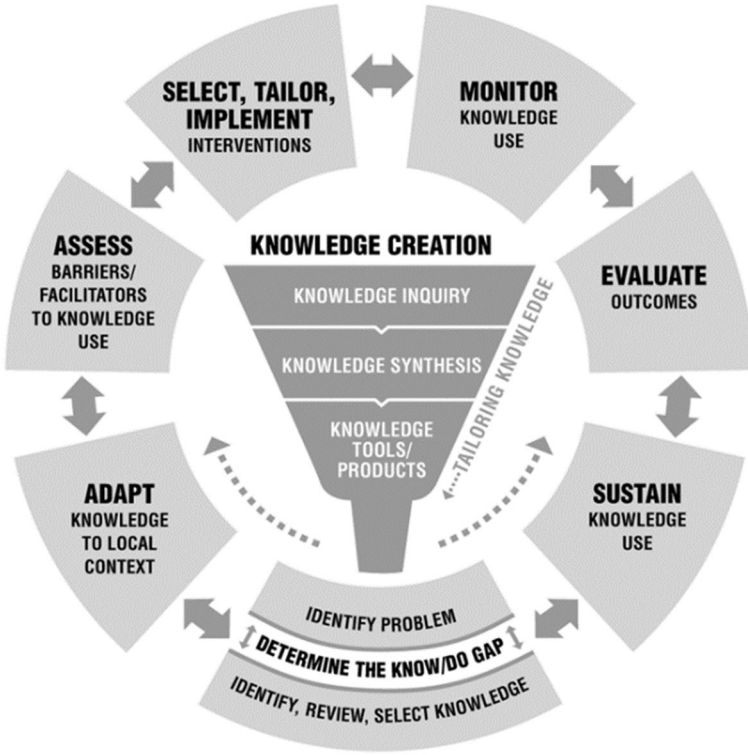

Figure 3. Knowledge-to-Action framework – Permission to use © Graham et al. (83).[2]

[2] Source: Graham ID, Logan J, Harrison MB, Straus SE, Tetroe J, Caswell W, et al. Lost in knowledge translation: time for a map? J Contin Educ Health Prof. 2006;26(1):13–24.

The mentioned theoretical and conceptual frameworks were the basis in the development of the "Genomic Nursing Care" conceptual framework formulated in this dissertation **(Figure 4).** The GNC represents the complex concepts and skills necessary for a nursing career, with education, research, and clinical practice forming the foundation for this paradigm shift. Notably, multidisciplinary teams (i.e., biomedicine sciences, biobanks, and nursing sciences) are vital to genomics-informed nursing (GIN).

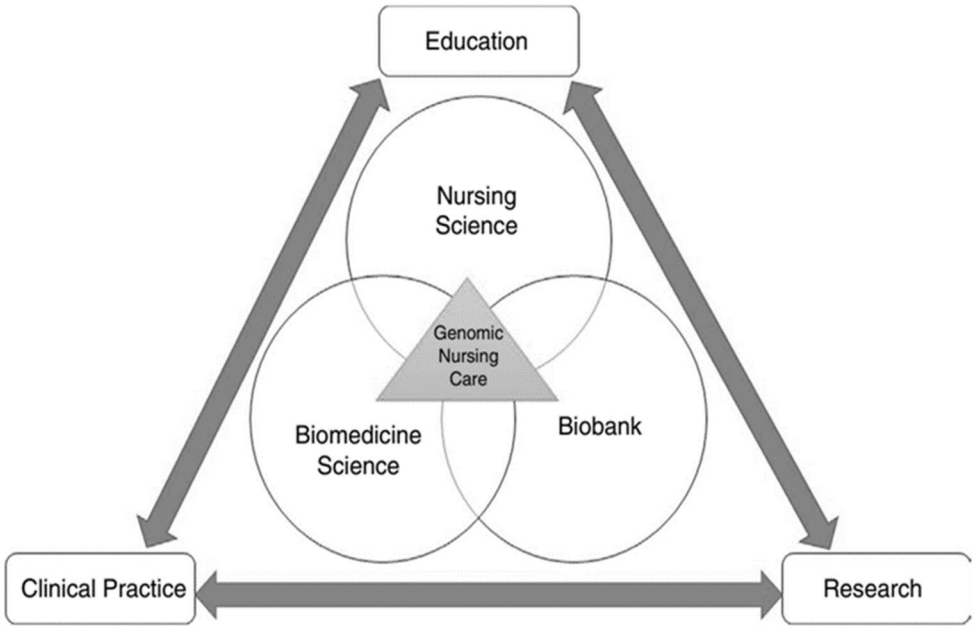

Figure 4. Genomic Nursing Care Framework – Permission to use © Dumo et al., (17).[3]

[3] Source: Dumo AM, Laing B, Lim AG, Palaganas E, Abad PJ, Valdehueza O, et al. Randomized controlled trial on the effectiveness of web-based Genomics Nursing Education Intervention for undergraduate nursing students: a study protocol. J Adv Nurs. 2020;76(11):3136–46

The paradigm shift of Genomic Nursing Care is an intersection of multidisciplinary sciences. The scientific breakthroughs of biomedicine sciences in discovering the human genomes initiated better understanding of human genetic variation, genomics, and its connection to human health (88). It is predicted that individual genome sequences will soon play a larger role in medical practice and patients or health consumers will use the information to improve their own health by taking advantage of prevention or therapeutic strategies that are suggested by their individual genome sequence (88).

Nurses, along with other healthcare professionals, will need to educate themselves on how to provide patient and family health education related to genetics and genomics. Many recent developments in the field of human genetics and genomics would not have been possible without biobanks (89). Biobanks were established to support scientific knowledge (90). Nurses play essential role in the process of collecting information by the biobanks, including comprehensive questionnaires, physical measurements, health check-ups, and data from hospital databases and national health registries (89,90).

In sum, the theoretical foundations and conceptual frameworks presented in this dissertation have been influenced by the DIT, cognitivism and constructivist learning theories, Hickey's conceptual model of transdisciplinary nurse scientist, and Knowledge-to-Action Framework. The frameworks and models were carefully selected that guided the development of the Genomic Nursing Care conceptual framework of the study. Individual frameworks have guided the research study for specific components of the dissertation work. The Rogers' Diffusion of Innovation Theory (78) and Hickey's Transdisciplinary Nurse Scientist conceptual model (82) had contributed in the beginning of the study and guided in the formulation of the study protocol (Original publication 1). Multiple frameworks had contributed across the project. Jean Piaget's Cognitivism Learning Theory and Constructivist Learning Theory (79-81) had contributed in the assessment of nursing students' genomics literacy and designing of the educational intervention GNEI (Original publication 3). Graham's Knowledge-to-Action Framework (83) and the Genomic Nursing

Care conceptual framework (Original publication 1) had contributed during the RCT study (Original Publication 4). For future work, Patricia Benner's from Novice to Expert Theory (91,92) is also relevant to guide future studies related to the sustainability of genomics nursing education.

The need for genomics-informed nurses calls for the development of effective education and training programs in this field (3,29,93-96). Collaborative work involving clients, families, and multidisciplinary healthcare professionals, including genetic counsellors, geneticists, and physicians, is crucial (6,19,20,43-46,60,61,87). Further, nursing curricula must be updated and upgraded based on the latest changes and advancements in genetics and genomics technology (1,21-3743-61,87,93-96).

3 AIMS OF THE STUDY

In this chapter, the aim of the study, phases of the study, objectives, and hypotheses are described.

The overall aim of this doctoral dissertation was to develop a tailored, web-based, Genomics Nursing Educational Intervention (GNEI) and investigate the effectiveness in improving the genomics literacy among undergraduate nursing students.

The study comprised of four phases **(Figure 5)**:

Phase I. RCT study protocol

Phase II. Translation and linguistic validation of the GNCI

Phase III. Cross-sectional survey of nursing students' genomic literacy

Phase IV. Effectiveness of the RCT

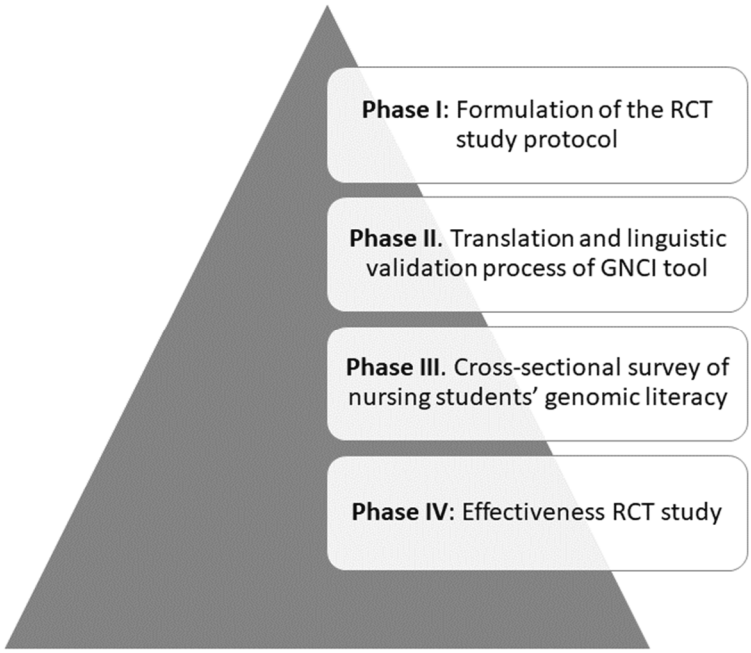

Figure 5. Phases of the study

The specific aims were the following:

1. To describe the tailored, web-based, GNEI and the characteristics of undergraduate nursing students (Original Publication 1, 3)
2. To test the validity and reliability of the translated Finnish version of the Genomic Nursing Concept Inventory (GNCI© 2017) (Original Publication 2)
3. To design tailored web-based genomics nursing education (Original Publication 3)
4. To investigate whether the GNEI has any effects on the genomics knowledge of undergraduate nursing students (Original Publication 4)

Hypothesis

This RCT study was designed to test the following two hypotheses at the 0.05 level of significance:

HH_1. There will be significant statistical differences between the GNCI scores of the intervention group (IG) and the control group (CG) in the pre-test, post-test, and repeated post-test.

HH_2. There will be significant statistical differences between the effectiveness of the newly designed, tailored, web-based, GNEI and that of standard education.

4 SUBJECTS AND METHODS

In this chapter, the research method, data collection, and data analysis were discussed.

4.1 RESEARCH METHOD

For this doctoral dissertation, a parallel-group, single-blind, randomized controlled intervention study (RCT) was conducted with two groups, a pre-test, and repeated post-tests. **Figure 6** shows the research design of the study, and **Figure 7** shows the CONSORT diagram.

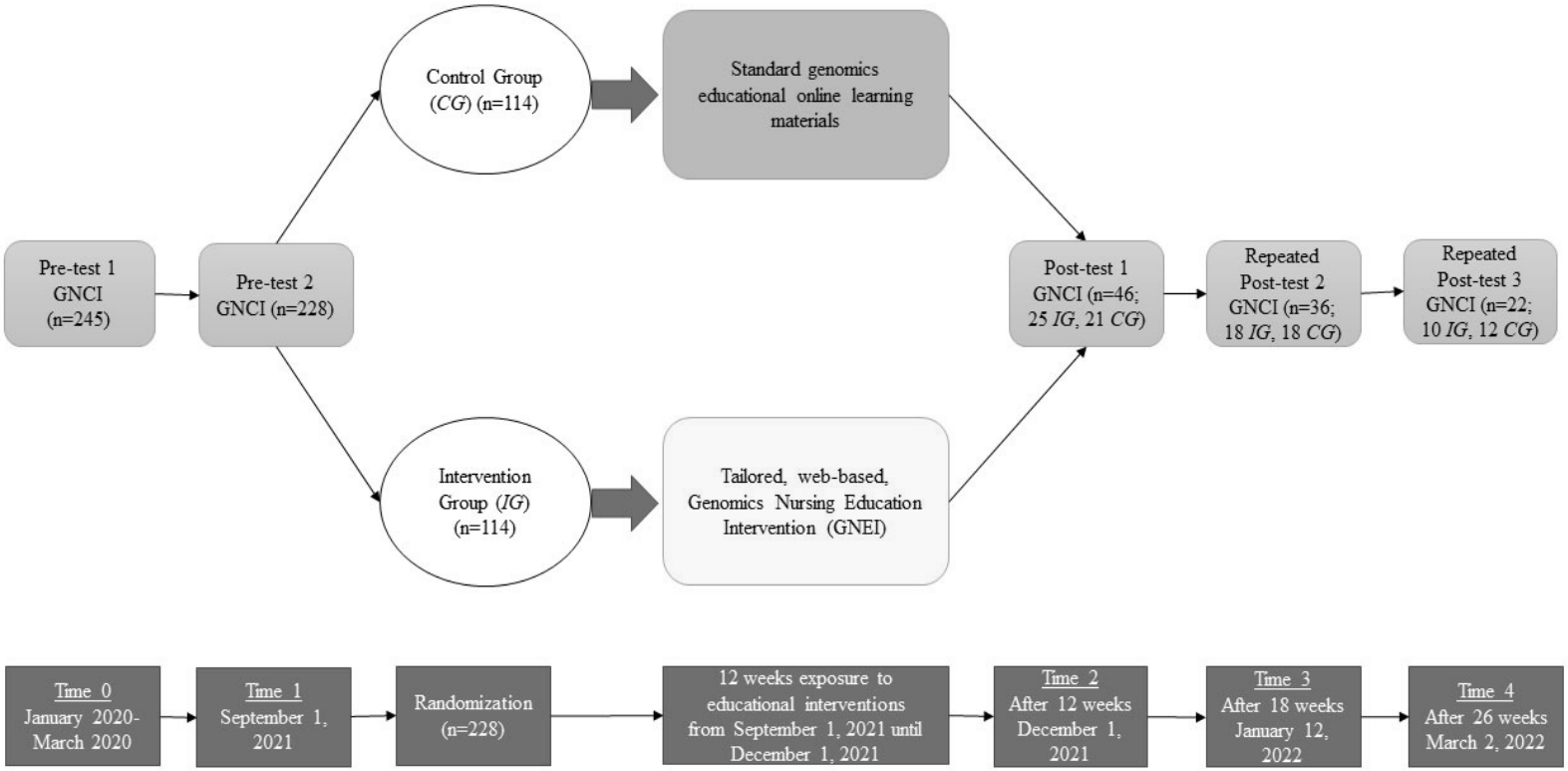

Figure 6. Research Design

Legend: GNCI = Genomic Nursing Concept Inventory; CG = Control Group; IG = Intervention Group; GNEI = Genomics Nursing Education Intervention; n = total number of participants

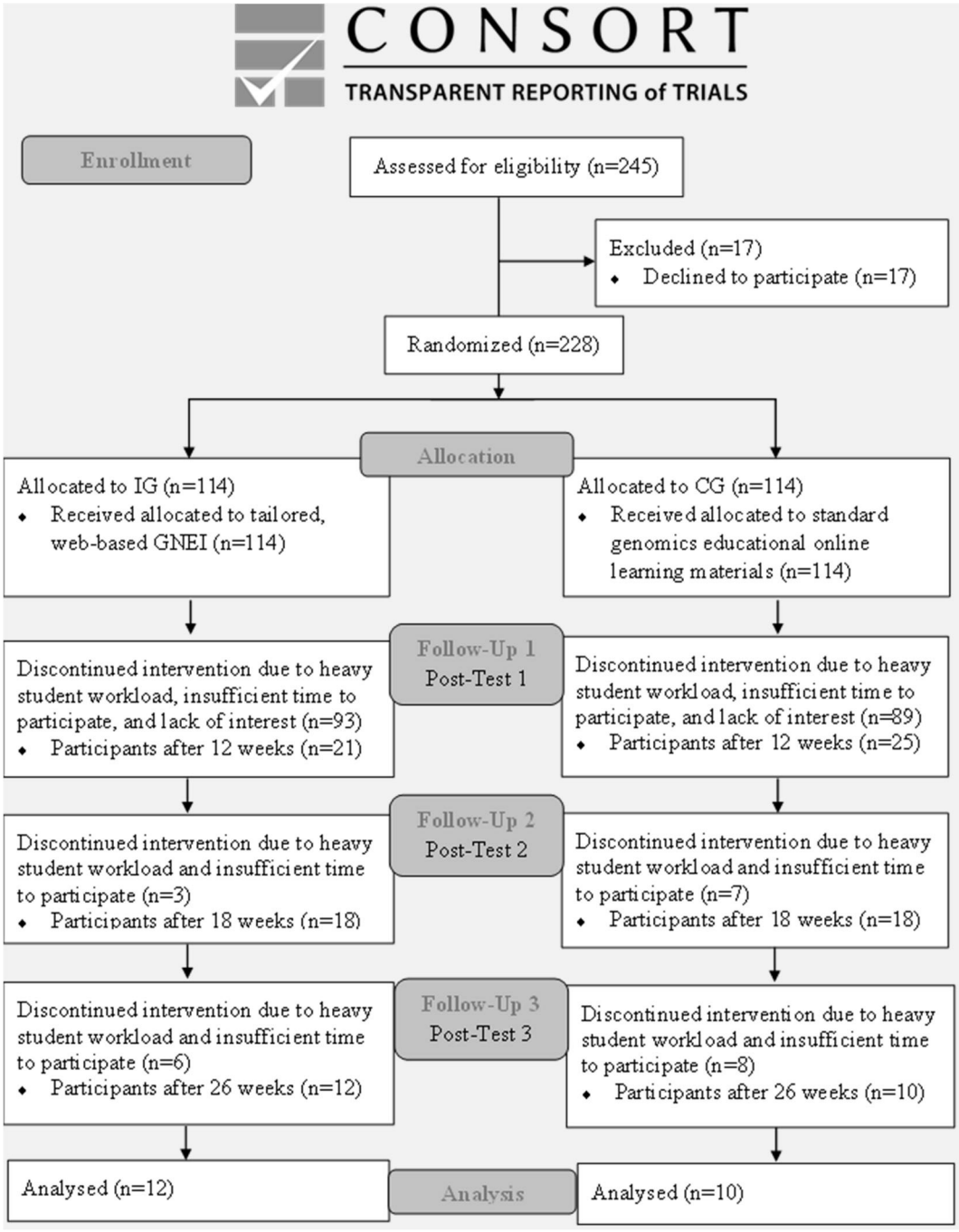

Figure 7. CONSORT Diagram
Legend: CG = Control Group; IG = Intervention Group; GNEI = Genomics Nursing Education Intervention; n = total number of participants

4.1.1 Study Design

Translation and linguistic validation of the research instrument (Original Publication 2)

The main research instrument used in this dissertation was the Genomics Nursing Concept Inventory (GNCI©), a 31-item instrument in the English language, with demonstrated validity and reliability (Cronbach's alpha values between 0.73 and 0.83) (97). The GNCI items facilitated the assessment of nurses' understanding of relevant genetics–genomics concepts and the identification of specific targets for continuing education and designing the web-based GNEI (97).

A Finnish version of the GNCI tool was not available, making the translation of the GNCI from English to Finnish a prerequisite for collecting data from a Finnish cohort. Linguistic evaluations were carried out to test the validity, reliability, and clinical usability of the translated instrument in Finland.

To this end, consent was obtained from the original developers of the translation algorithm (Mandysova's decision tree) (98) and the GNCI (97) to use their instruments in the present study. Mandysova's decision tree algorithm was developed in accordance with the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) guidelines (98,99). It comprises a flowchart for the establishment of criteria used to select forward and backward translators. It then proceeds to cover the evaluation, reconciliation, back translation, harmonization, testing, and finalization of the translation. Appropriate documentation to trace the cultural adaptation of the translated research instrument was carefully maintained in compliance with the WHO guidelines (100).

Cross-sectional survey (Original Publication 3)

An online cross-sectional survey was conducted to obtain baseline data on the genomics literacy levels and knowledge gaps among Finnish and Filipino cohorts. This phase was conducted from January 2020 to December 2021. This step was necessary to determine the type of online learning platform to be designed and developed to address the knowledge

gaps that exist. In reporting this study, the STROBE statement checklist was applied (101).

Randomized controlled trial (Original Publications 1, 4)

A parallel-group two-arm RCT, with a pre-test and repeated post-tests, was used in this study. The parallel group design is the most common RCT design and is preferred because it reduces selection bias (102,103). This RCT was conducted from January 2020 to March 2022 in the Philippines.

The study protocol has been described in detail in Original publication 1 (17) and registered with the ClinicalTrials.gov identifier NCT03963687. The linguistic and translation validation process of the research instrument has been described in detail in Original publication 2 (104), and a preliminary assessment of genomics literacy has been done in Original publication 3 (105).

Three important changes were made to the methodology after trial commencement. Originally, the study was planned to be conducted using a crossover RCT. The complexity of the crossover RCT design was the main reason of using other types of RCT. In this dissertation, a parallel-group, two-arm RCT was most appropriate design for practicality and feasibility.

Another important change was related to the cohort groups. In the study protocol, two cohort groups were selected, Finland cohort and Philippines cohort. Due to the very low response rate of the Finland cohort during phase 3 of the study, the research group decided to proceed with only the Philippines cohort. The reason for the low response rate in Finland was because the study was conducted during the COVID-19 pandemic, at a time when European countries were highly affected. The Philippine cohort was able to continue to participate in the study during the pandemic as the education system had to shift from classroom-based to online learning, which took some time to establish. This resulted for nursing students being available to participate in the study while waiting for their regular nursing courses to commence.

Lastly, the control intervention “Genetics Education Program for Nurses” mentioned in the study protocol (Original Publication 1) was changed to another online course. The main reason was that the Genetics Education

Program for Nurses became unavailable due to some updates during the time of the RCT study phase. The research team discussed other possible online courses with similar learning outcomes and learning contents. One of the co-authors and collaborators had developed the course "Genomics in Healthcare". Permission to utilize the Genomics in Healthcare course as the control intervention was secured.

4.1.2 Participants and setting

Assessment of genomics literacy (Original Publication 3)

For this dissertation, the settings considered were Finland and the Philippines. Both countries are in the same phase of introducing genomics to the nursing curricula. The main reason for choosing these two countries, apart from practicality, was inclusivity—to highlight that no one must be left behind in advancing the integration of nursing science in the field of genomics.

Finland has a good reputation for providing high-quality education and the highly respected position of nurses in society. Likewise, the Philippines is known because the highest number of immigrant nurses working and filling out nursing shortages worldwide are Filipino. Nurses in the Philippines received a high level of education and develop skills that make them attractive to foreign countries. Therefore, it was important to include the two countries to learn from their approaches and include them equally in the genomics era.

The target population comprised of nursing students from first year to fourth year studying in government-established educational institutions. This is one cohort that has advanced in their studies during the data collection. Three educational institutions participated in the study (n = 1 university in the Philippines; n = 2 UAS in Finland). Convenience sampling was used to collect data during the 2020–2021 period.

A total of 1,570 nursing students were invited (n = 700 from the Philippines, and n = 870 from Finland). Only 16% responded, resulting in a final sample size of 245 (n = 228 from the Philippines; n = 17 from Finland).

Interventional study on the effectiveness of the GNEI (Original Publications 1,4)

Due to the very low response rate of the Finland cohort (n = 17 students; 2% response rate) in the preceding cross-sectional study, the research team decided to proceed with the Philippines cohort for the RCT. Data were collected at a government state university in South La Union, the Philippines, that offers a Bachelor of Science in Nursing degree.

A total of 245 students were assessed as eligible to participate in the RCT study; 17 of them declined to participate. Of the 228 participants included in the study, 114 were randomly allocated to the intervention group (IG) and 114 to the control group (CG). After 12 weeks of educational intervention, a total of 46 participants continued with the study (n = 25 IG, n = 21 CG). After four weeks of follow-up, only 36 participants proceeded with the study (n = 18 IG, n = 18 CG). After eight weeks of follow-up, only 22 students continued to participate in the study (n = 10 IG, n = 12 CG). **Figure 9** shows the CONSORT flow diagram.

4.1.3 Inclusion and Exclusion Criteria

Undergraduate nursing students from first year to fourth year who were willing to participate in the study were included. Participation was limited to students studying in government educational institutions. Private institutions were excluded for the purpose of comparability of nursing curriculum content. Postgraduate, employed, and unemployed nurses were also excluded.

4.1.4 Randomization and sample size calculation

G*Power and a t-test were used to measure the difference between two independent means (two groups) and to calculate the minimum sample size needed for the study. To achieve a power of 94% and a medium effect size of 0.5 with two-sided significance, 200 undergraduate nursing students had to be included (106,107).

Block randomization (block size 2) was performed using the Research Randomizer (108) in the sequence generation process on a 1:1 basis (IG or

CG). Using the single-blinding technique, specifically a central allocation web-based–controlled randomization, participants were blinded to their group allocation; only the principal investigator (AP) was aware of the participants in the IG and CG. Both groups received access to a genomics nursing intervention through the same online platform (Google Classroom) to reduce the risk of bias due to the allocated interventions. Time exposure to the online platform was controlled, and the blind outcome assessment was safeguarded to minimize any bias.

4.1.5 Description of intervention and control group

The structure of the GNEI and the standard online learning materials is presented in **Table 4**. The IG was exposed to the tailored web-based GNEI designed for this study while CG was exposed to a control educational intervention that is available online to educate healthcare professionals about “Genomics in Healthcare”.

Web-based education was utilized because it is generally cheap, flexible, and convenient for learners and teachers (22,109). Opposed to the traditional mode of learning (face to face), online learning has its advantages, such as flexibility, accessibility, and cost-effectiveness (110,111). A study conducted by Chen et al. had shown effectiveness of web-based platform in providing genomics training for health workers (112). This dissertation took advantage on the benefits of web-based learning platform.

The tailored web-based GNEI was based on the results of the GNCI pre-test, through which the genomics knowledge gaps among the research participants were identified. It was achieved by mapping the low scoring topics from the baseline assessment prioritized for teaching. The weekly topics were mapped against the GNCI questions to confirm all content was covered and to ensure that students could potentially achieve full marks without prior knowledge. The research team designed an online learning environment based on the concept of flipped learning. Moreover, the research team took advantage of a multidisciplinary teaching team to give

students the chance to learn from professionals with diverse backgrounds, such as nurses and experts in biomedicine and pharmacogenomics.

The purpose of the course was to create an overview on what is genomics, omics, precision medicine in relation to nursing profession, the role of nurses in the field of genomics era, and the challenges and possibilities in nursing and health research. The learning outcomes of the 12-week course where students will: (a) understand the genetics-genomics principles, concepts and mechanisms of how genes influence health; (b) know genomics competencies expected to nurses; (c) be aware of the practical nursing applications of genetics–genomics concepts; and (d) understand ethical, legal and social implications of genomics nursing practice. GNEI was designed as a free online course especially designed for undergraduate nursing students. The learning methods were flipped learning, video-lectures, webinars, quizzes, e-learning, self-directed learning, and small group discussions. GNEI was designed so that there will be no gateways between the different areas of content and students can move forward and backward.

The control educational intervention Genomics in Healthcare course utilized the concept of Massive Open Online Courses (MOOCs) learning platforms and tools. The Genomics in Healthcare course was developed by an Australian genomics expert. The nature of course was free and self-paced online course. The course is for professionals who want to understand the effects of genomics and its implications on public life. The learning outcomes of the course were introduction of genomic information and its implications on health across patient lifespan. The structure of the course consisted of: (a) genomics and the promise of clinical utility; (b) ethics and challenges of access to personal information; (c) actionable pharmacogenomics; and (d) risk and diagnostic testing.

The content of the newly designed, tailored, web-based, GNEI and control intervention Genomics in Healthcare were similar in their learning outcomes particularly in understanding the effects of genomics in health, and the ethical implications of genomics. The two interventions differ in some of the learning contents. GNEI was based on GNCI concepts and especially designed to improve the genomics literacy of nursing students

while the standard course was designed for healthcare professionals. Both the IG and CG were exposed in the educational interventions at the same period. Google classroom was utilized as the learning platform for both cohorts. IG cohort had 9 online meetings consisting of 1 introduction meeting, 2 online lectures, 2 online group discussions, 3 webinars and 1 closing meeting. CG cohort only had 1 meeting in the beginning of the course for introduction. In contrast to the self-paced pre-recorded, asynchronous courses (control intervention), the GNEI involved elements of interactions of students by teaching staff and peer groups.

Table 4. Structure of the tailored web-based GNEI and the standard educational materials for learning genomics

WEEK	DESIGNED WEB-BASED GENOMICS NURSING EDUCATION (IG)		STANDARD GENOMICS EDUCATIONAL ONLINE LEARNING MATERIALS (CG)	
	Teaching genomics contents	Teaching methods	Teaching genomics contents	Teaching Methods
1	Orientation phase GNCI pre-test	Online forum	Orientation lecture GNCI pre-test	Online
2	Basic concepts of genomics Essential genetic-genomics vocabulary	Short videos	Introduction to genomics	self-paced online course
3	The role nurses in genomic era	Journal article reading and reflections	History – the discovery and understanding of DNA The human genome project	
4	Family history and pedigree construction	Online lecture (1 hour)	What is DNA? Genomics health implications	
5	Practical nursing applications of genetic–genomic concepts Part 1	Groupwork	Genetic variants: deletion, insertion	
6	Practical nursing applications of genetic–genomic concepts Part 2	Group presentations and Peer-group evaluation	Genetic variants: missense, duplication	
7	Ethical, legal and social implications of genomic nursing practice	Online forum	Pre-pregnancy carrier screening	
8	Pharmacogenomics	Webinar 1	Pharmacogenomics and medication safety	
9	Cancer genomics	Webinar 2	Pharmacogenomics	

10	Genomics knowledge renews nursing competencies.	Webinar 3	The genetics of common complex diseases	
11	Summary and course feedback	Online forum	Summing up Course feedback	
12	GNCI post-test 1	Online exam	GNCI post-test 1	Online exam
16	GNCI post-test 2	Online exam	GNCI post-test 2	Online exam
20	GNCI post-test 3	Online exam	GNCI post-test 3	Online exam

Legend: IG = intervention group; CG = control group

4.1.6 Outcome measures

The primary outcome measure in this study was the undergraduate nursing students' level of genomics knowledge. The GNCI tool was utilized to evaluate the participants' genomics knowledge. To determine the effectiveness of GNEI in improving the primary outcome measure, the GNCI was administered five times online **(see Figures 8–9)**:

Pre-test was implemented twice using the same cohort groups (Pre-test 1 in January–March 2020 and Pre-test 2 in September 2021). The reason of having two different timepoints was to assess the genomics literacy baseline scores of the study participants without giving any educational learning materials related to genomics during a period of one year. This time was also utilized by the research team to formulate and design the tailored, web-based, GNEI.

The 12-weeks intervention study was implemented from September 1, 2021, until December 1, 2021. Post-test 1 was conducted immediately after the 12-weeks exposure to the educational interventions (December 1, 2021). Post-test 2 was done after 18-weeks post-intervention (January 2022) and Post-test 3 was done after 26-weeks post-intervention (March 2022). Key persons (GB and JM) in the Philippines facilitated the data collection. The participants were given up to 60 minutes to complete the GNCI. Students were followed-up twice to increase the response rate.

The secondary outcome measure in this study was the participants' feedback on the online platforms. A structured questionnaire was used to obtain feedback, and it consisted of 26 items spanning the following categories: self-assessment of learning (nine items, five-point Likert scale), evaluation of content and instruction (four items, five-point Likert scale), program evaluation (three items, five-point Likert scale), workload of the course (one item, three-point Likert scale), learning assessment (one item, five-point Likert scale), participation rate (one item, five-point Likert scale), and open-ended questions (seven items). Feedback evaluations were conducted from December 2021 to March 2022. A total of 77 participants answered the feedback questionnaire (n = 37 IC, n = 40 CG).

4.2 DATA COLLECTION

4.2.1 Data collection process and flowchart

Figure 8 illustrates the data collection process of the study, and **Figure 9** presents a flowchart of the research work done for this dissertation. Pretesting was done twice: Pre-test 1 was conducted in January–March 2020, and a repeated pre-test was conducted in September 2021. Participants joined the web-based education interventions at the same time for a period of 12 weeks, from September to December 2021, with follow-ups in the 18th week and 26th week.

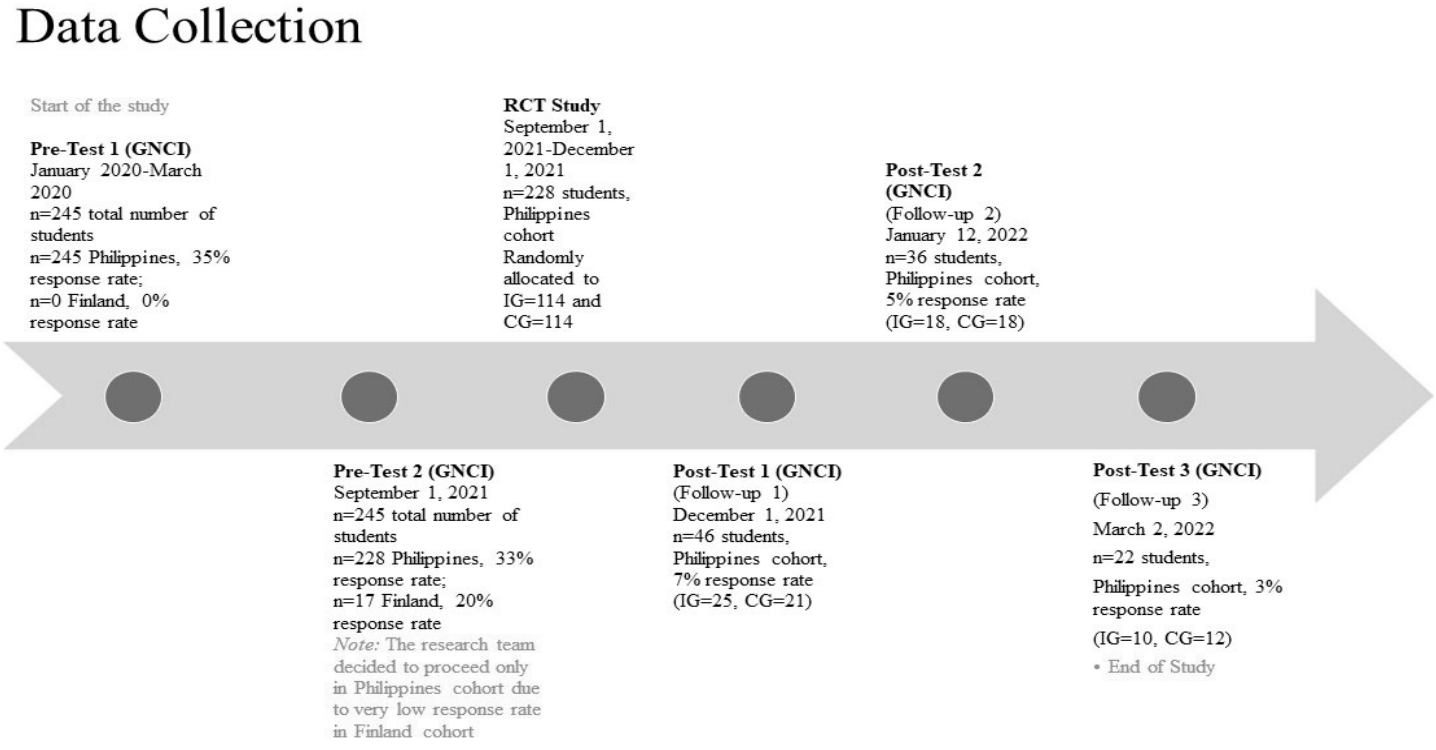

Figure 8. Data collection
Legend: GNCI = Genomic Nursing Concept Inventory; CG = Control Group; IG = Intervention Group; n = total number of participants

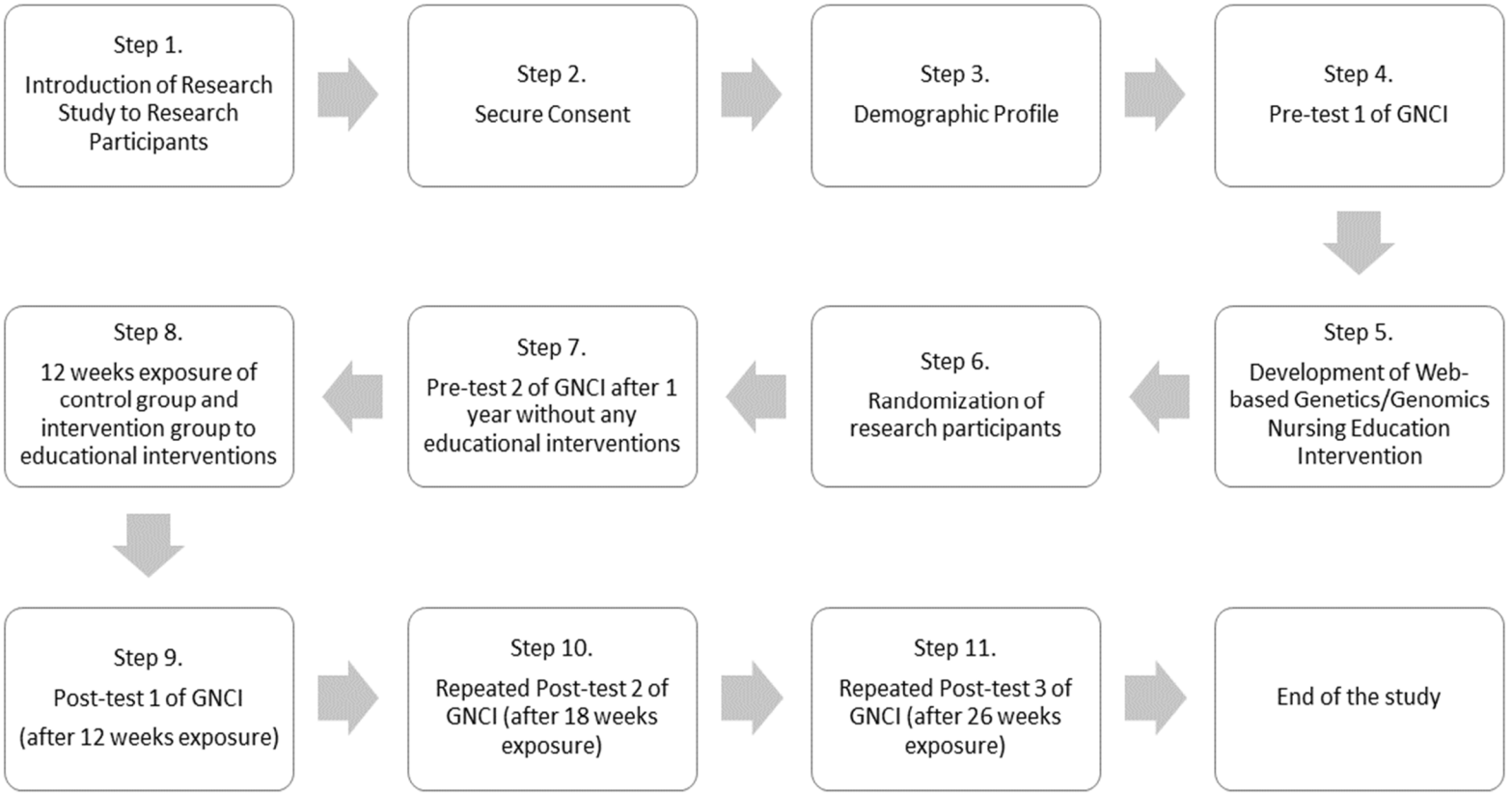

Figure 9. Research work-flowchart

4.2.2 Ethical considerations

The Committee on Research Ethics of the University of Eastern Finland issued the ethical approval statement 21/2018 in October 2018. When conducting the present study, adherence to the EU's General Data Protection Regulation (2016/679, GDPR) was observed carefully. The necessary administrative permissions from the participating institutions and universities were secured prior to data collection. Informed consent was obtained from the participants electronically. Participation in the study was voluntary, and participants could withdraw their participation at any time, with no consequences to their academic study. Participants' privacy, anonymity, and confidentiality were secured throughout the study.

4.3 DATA ANALYSIS

4.3.1 Mandysova's decision tree algorithm (Original Publication 2)

The item-content validity index (I-CVI) and modified kappa statistics (k*) were used to determine the linguistic validity of the Finnish version of the GNCI. Based on the formulas given by Polit et al. (113) and Liu et al. (114), I-CVI and k* were calculated and interpreted. An I-CVI score ≥ 0.78 for each item was considered ideal; k* values of 0.40–0.59, 0.60–0.74, and > 0.74 were interpreted as fair, good, and excellent, respectively k* values are important because I-CVI does not take into account a chance agreement, whereas k* does so.

The Cronbach alpha was used to measure the internal consistency of the instrument items (115). SPSS® (Version 28, IBM) was utilized to calculate Cronbach's alpha coefficients (with a 95% confidence interval [CI]) as measures of reliability or internal consistency of the translated Finnish GNCI (Version 4) in a small pilot study (n = 8). Intraclass correlation coefficients, the two-way mixed-effects model, consistency models, and CIs were calculated to determine related uncertainty (116).

4.3.2 Assessment of the genomic literacy of undergraduate nursing students (Original Publication 3)

Descriptive and inferential statistics (117) were calculated using SPSS® (Version 27, IBM). To determine the normal distribution of the variables (age and GNCI scores), Kolmogorov–Smirnov and Shapiro–Wilk values were calculated. Moreover, the Mann–Whitney U test was used to analyse the statistical differences between dependent variables at the 0.05 level of significance. The Kruskal–Wallis test was used to compare participants' GNCI scores based on undergraduate year level and whether the respondents had completed any genetics or genomics course. Fisher's exact test was used to determine whether there were any significant differences between the two participating countries and the GNCI items. An item analysis was conducted to analyse the students' responses to the 31-item GNCI and the relationship between them (118).

4.3.3 Parallel randomized control trial interventional study (Original Publications 1,4)

A university statistician was consulted for appropriate statistical methods in data analysis. Revised Bloom's Taxonomy (119) was used to evaluate the students' learning outcomes. Item analysis was used to assess genomics knowledge gaps by mapping the wrong ideas that the students thought were true. SPSS (version 27, IBM) was used for the data analysis. Demographic variables and other pertinent participant characteristics were summarized using descriptive statistics.

To compare the outcomes of the IG and the CG, relevant statistical tests of differences were used. GLMMs were used to estimate fixed and random effects (120). They are especially useful when the dependent variable is binary, ordinal, count, or quantitative but not normally distributed. They are also useful when the dependent variable involves repeated measures, since GLMMs can model autocorrelation. The Mann–Whitney U test was used to compare the differences between the groups at a 0.1 level of significance.

Furthermore, a quantitative content analysis in an inductive approach was performed to analyse the participants' answers to the open-ended questions related to their evaluation feedback on the online educational platforms (121). The advantage of employing content analysis was it can be use with a wide variety of data sources including textual data (122). In doing so, all data were coded and formed categories directly from the text material. This was done by AP by reading and rereading the participants' feedback on the online platforms to look for emerging themes. Establishing the coding process was performed and three themes were categories as follows: learning approaches, learning process: contributing learning factors and barriers, and learning reflections and perceptions of genomics knowledge application and utilization. KVJ checked the themes for the reliability and coherence.

5 RESULTS

In this section, the results are reported in three parts in accordance with the original publications. The first subsection describes the process followed for the linguistic translation and validation of the GNCI using Mandysova's decision tree algorithm (Original Publication 2). The second subsection presents the results of the genomics literacy assessment as the foundation for the development and design of the new web-based GNEI tailored to undergraduate nursing students (Original Publication 3). The third subsection describes the study protocol for the interventional study and the effectiveness of GNEI in improving undergraduate nursing students' genomics knowledge (Original Publications 1, 4).

5.1 LINGUISTIC VALIDATION OF THE FINNISH GNCI USING MANDYSOVA'S DECISION TREE ALGORITHM (ORIGINAL PUBLICATION 2)

The Finnish GNCI was evaluated by ten experts (6 nurses and 4 genetics-genomics specialized non-nursing professionals) and piloted to eight nursing students. Computation of Cronbach's alpha coefficient resulted in a good alpha value of 0.816 (95% CI: 0.57–0.96). The CI was wide due to the small sample size (n = 8). The summary statistics showed an overall mean of 39% correct responses to the knowledge-based items. The alpha score in this study was consistent with the scores obtained in other studies (33,97) despite the small sample size. This implies that the processes outlined in Mandysova's decision tree algorithm (98) were effective for the translation and validation of the GNCI.

The findings of the cognitive review during the small pilot study revealed an average score of 12/31 (39%), with the lowest score being 5/31 (16%) and the highest score being 23/31 (74%). All students were able to answer the 31 items on the Finnish GNCI (Version 4). Only one student had a score above 50%, and seven students had scores below 50%. These results are

consistent with the pre-instruction scores reported for undergraduate nursing students in the USA (mean: 13/31 [42%]) (33).

The students' feedback was similar to that of the Panel 1 members (n=6 nurses). The students reported that they did not understand some of the technical terms used in the questions due to the newness of the concepts. In addition, they did not know the exact terms in Finnish or the answers to some of the questions.

5.2 NURSING STUDENTS' GENOMICS LITERACY: BASIS FOR GNEI DEVELOPMENT (ORIGINAL PUBLICATION 3)

5.2.1 Participants' demographic profile

A total of 245 nursing students participated in the study (n = 17 from Finland; n = 228 from the Philippines). The demographic data are presented in **Table 5.** The majority of the respondents were female, and most were first-year undergraduate nursing students, with their ages ranging from 17 to 46 years. All participants from Philippines speaks their native language, while students in Finland was comprised of both native Finnish students and internationally speaking students. Only 11% of the Filipino cohort reported that they had completed a genetics or genomics course for academic credit. Surprisingly, none of the students in the Finnish cohort had completed any genetics or genomics courses (0%). More than half of the Filipino cohorts reported not having completed any biology course (60.53%), while half of the Finnish cohort reported having completed any biology course (52.94%)

Table 5. Demographic backgrounds of the undergraduate nursing students

Demographic Background	Philippines (n = 228)		Finland (n = 17)	
Age in years				
Mean (SD)	19.66 (1.68)		28.35 (8.94)	
Range	17–34		20–46	
Sex	**n**	**%**	**n**	**%**
Male	31	13.60 %	2	11.76 %
Female	197	86.40 %	15	88.24 %
Total	228	100.00 %	17	100.00 %
Institution/University	228	100.00 %	17	100.00 %
Country	228	100.00 %	17	100.00 %
Nursing Program (BSN)	228	100.00 %	17	100.00 %
Nursing Year Level				
1st year	100	43.86 %	8	47.06 %
2nd year	14	6.14 %	9	52.94 %
3rd year	56	24.56 %	0	0.00 %
4th year	58	25.44 %	0	0.00 %
Total	228	100.00 %	17	100.00 %
Mother tongue				
Filipino/ Tagalog	228	100.00 %		
Finnish			13	76.00%
English			2	12.00%
German			1	6.00%
Silozi			1	6.00%
Total	228	100.00 %	17	100.00 %
Have completed any genetics or genomics course for academic credit.				
Yes	25	10.97 %	0	0.00 %
No	170	74.56 %	17	100.00 %
Currently taking	33	14.47 %	0	0.00 %
Total	228	100.00 %	17	100.00 %
Have completed any Biology course.				
Yes	90	39.47 %	9	52.94 %
No	138	60.53 %	8	47.06 %
Total	228	100.00%	17	100.00 %

Note: n = sample size, % = percentage, SD = standard deviation, BSN = Bachelor of Science in Nursing

5.2.2 Participants' genomics literacy

Undergraduate nursing students have low genomics literacy based on the results of Original Publication 3, a cross-sectional survey conducted in 2020. Interestingly, the average GNCI score of the Filipino cohort was statistically significantly higher than that of the Finnish cohort (mean score = 58% Philippines, 36% Finland; p-value = 0.023). **Table 6** presents the participants' mean scores of GNCI performance in comparisons with their sociodemographic data, and **Table 7** shows the respondents' performance on the GNCI per item.

Female students had statistically significantly higher GNCI scores than their male counterparts at the 0.05 level of significance (p-value = 0.022). No significant statistical differences were found between the various GNCI scores based on students' completion of a biology course (p-value = 0.188), completion of genetics or genomics courses (p-value = 0.981), and year levels (p-value = 0.509). Specifically, the following genomics concepts denote the knowledge gaps among the respondents: genome composition and organization, gene function, genotype–phenotype association, human genome homogeneity, and autosomal inheritance. The results indicated the need to develop educational interventions to bridge genomics knowledge gaps.

Table 6. Mean scores of GNCI performance in comparison with participants' sociodemographic data

Characteristics		**Total GNCI Scores**
	Mean Score (SD) Sig.	
Sex	Male	12.55 (8.74)
	Female	16.25 (9.63)
	p-value (Mann-Whitney U Test)	**0.022**
Country	Finland	9.53 (3.48)
	Philippines	16.21 (9.74)
	p-value (Mann-Whitney U Test)	**0.023**
Year Level	1st Year	14.71 (9.87)
	2nd Year	16.87 (10.51)
	3rd Year	16.77 (9.48)
	4th Year	16.33 (8.85)
	p-value (Kruskal-Wallis Test)	0.509
Have completed any Biology course?	Yes	16.48 (9.38)
	No	15.25 (9.72)
	p-value (Mann-Whitney U Test)	0.188
Have completed a genetics or genomics course for academic credit?	Yes	16.16 (8.91)
	No	15.68 (9.65)
	Currently taking a genetics or genomics course	16.03 (10.05)
	p-value (Kruskal-Wallis Test)	0.981

Note: Statistical comparisons of group differences were performed using the Mann–Whitney U test and the Kruskal–Wallis test, as indicated in the table. Boldface values indicate significant differences. SD = standard deviation, Sig. = significance, level of significance = 0.05

Table 7. GNCI total scores, subscale scores, and item scores for Filipino and Finnish nursing student cohort samples

Parameters	Filipino cohort sample (n=228)	Finnish cohort sample (n=17)	Fisher's Exact Test *p*-value (2-sided)
Total score: mean (SD, range) out of 31 possible points	16.21 (9.74, 2–31)	9.53 (3.48, 5–18)	-
Mean total score as percent correct	58%	36%	-
Subscale scores: mean score as percent correct	-	-	-
Genome basics (12 items)	56%	30%	-
Mutations (3 items)	58%	31%	-
Inheritance (8 items)	60%	41%	-
Genomic health (8 items)	60%	43%	-
Item scores: mean score as percent correct	-	-	-
Item 1: gene function	54%	41%	0.048*
Item 2: genome organization	73%	65%	0.089
Item 3: human genome homogeneity	54%	12%	<0.001*
Item 4: genome organization	46%	12%	0.001*
Item 5: genome composition	68%	59%	0.113
Item 6: gene function	61%	24%	0.005*
Item 7: genotype-phenotype association	44%	24%	0.072
Item 8: genome organization	54%	12%	<0.001*
Item 9: gene function	47%	29%	0.129
Item 10: dominance	58%	29%	0.076
Item 11: gene expression	49%	24%	0.040*
Item 12: pharmacogenomics	64%	53%	0.320

Item 13: heterozygosity	51%	24%	0.081
Item 14: genetic screening tests	66%	76%	0.606
Item 15: autosomal recessive inheritance	67%	53%	0.607
Item 16: autosomal recessive inheritance	61%	47%	0.617
Item 17: X-linked inheritance	55%	41%	0.075
Item 18: germline/somatic mutations	50%	18%	0.043*
Item 19: mutation heterogeneity	49%	29%	0.072
Item 20: cancer genotyping	52%	29%	0.042*
Item 21: how mutations cause disease	75%	47%	0.113
Item 22: carrier testing	56%	24%	0.078
Item 23: family history—red flags	52%	24%	0.044*
Item 24: inheritance of autosomal mutations	59%	18%	0.004*
Item 25: genetics of multifactorial conditions	55%	41%	0.311
Item 26: benefit of family health history	68%	65%	0.321
Item 27: pharmacogenomics	60%	29%	0.047*
Item 28: pharmacogenomics	64%	41%	0.214
Item 29: heterozygosity in autosomal dominant conditions	69%	35%	0.002*
Item 30: autosomal dominant inheritance	74%	59%	0.302
Item 31: autosomal dominant inheritance	55%	41%	0.801

Note: GNCI = Genomic Nursing Concept Inventory, SD = standard deviation, n = sample size, * = significant difference, level of significance at 0.05

5.3 EFFECTIVENESS OF THE WEB-BASED GNEI FOR UNDERGRADUATE NURSING STUDENTS: A RANDOMIZED CONTROLLED TRIAL STUDY (ORIGINAL PUBLICATIONS 1, 4)

The study protocol was published in Original Publication 1 and registered in the clinical trial registry. Research related to genomics nursing education were mostly descriptive, qualitative and generally measured perceived knowledge rather than actual knowledge. This RCT study was designed to investigate the effectiveness of the GNEI in increasing the genomics literacy levels of undergraduate nursing students in the Filipino cohort (HH_1) compared to standard web-based genomics nursing education (HH_2).

5.3.1 Demographic characteristics

The demographic characteristics of the undergraduate nursing students who participated in the RCT study (Original Publication 4) are shown in **Table 8**. The majority of participants belonged to the 21–25 age group, were female, and were in the first year to fourth year of nursing study. More than half of the participants had not completed any biology course, while 75% of the participants had not completed any genetics or genomics courses. Most students had low GNCI scores (n = 108, 44%, Pre-test 1) at the beginning of the study, with a GNCI mean score of 16.51 (SD = 9.84). At the end of the RCT study, 80% in the IG had high GNCI scores, with a mean score of 26.30 (SD = 8.22), while 84% in the CG had high GNCI scores, with a mean score of 26.42 (SD = 6.81).

Table 8. Students' demographic characteristics

Demographic data	Pre-test 1 (n=245)	Pre-test 2 (n=228)	Post-test 1 (n=46)		Post-test 2 (n =36)		Post-test 3 (n=22)	
			IG (n=25)	CG (n=21)	IG (n=18)	CG (n=18)	IG (n=10)	CG (n=12)
Age								
16–20 years, n (%)	209 (85%)	155 (68%)	14 (56%)	6 (29%)	11 (61%)	6 (33%)	4 (40%)	2 (17%)
21–25 years, n (%)	22 (9%)	72 (31%)	11 (44%)	15 (71%)	7 (39%)	12 (67%)	6 (60%)	10 (83%)
26–30 years, n (%)	11 (5%)							
31–35 years, n (%)	3 (1%)	1 (1%)						
Sex								
Female, n (%)	213 (87%)	197 (86%)	22 (88%)	20 (95%)	17 (94%)	17 (94%)	9 (90%)	11 (92%)
Male, n (%)	32 (13%)	31 (14%)	3 (12%)	1 (5%)	1 (6%)	1 (6%)	1 (10%)	1 (8%)
Year level								
1st Year, n (%)	165 (68%)	100 (44%)	5 (20%)	0 (0%)	5 (28%)	0 (0%)	1 (10%)	0 (0%)
2nd Year, n (%)	57 (22%)	14 (6%)	5 (20%)	5 (24%)	5 (28%)	5 (28%)	2 (20%)	1 (8%)
3rd Year, n (%)	21 (9%)	56 (25%)	7 (28%)	5 (24%)	2 (11%)	5 (28%)	2 (20%)	4 (34%)
4th Year, n (%)	2 (1%)	58 (25%)	8 (32%)	11 (52%)	6 (33%)	8 (44%)	5 (50%)	7 (58%)
Have completed a biology course.								
Yes, n (%)	87 (35%)	90 (39%)	8 (32%)	11 (52%)	8 (44%)	11 (61%)	5 (50%)	6 (50%)
No, n (%)	158 (65%)	138 (61%)	17 (68%)	10 (48%)	10 (56%)	7 (39%)	5 (50%)	6 (50%)
Have completed any genetics–genomics course.								
Yes, n (%)	38 (15%)	26 (11%)	2 (8%)	3 (14%)	4 (22%)	5 (28%)	3 (30%)	4 (33%)
No, n (%)	182 (75%)	169 (74%)	17 (68%)	14 (67%)	11 (61%)	9 (50%)	4 (40%)	6 (50%)

Currently taking the course, n (%)	25 (10%)	33 (15%)	6 (24%)	4 (19%)	3 (17%)	4 (22%)	3 (30%)	2 (17%)
GNCI scores								
Low score (0–10), n (%)	106 (44%)	94 (41%)	7 (28%)	4 (19%)	3 (17%)	3 (17%)	1 (10%)	1 (8%)
Average score (11–20), n (%)	42 (17%)	44 (19%)	3 (12%)	2 (10%)	2 (11%)	3 (17%)	1 (10%)	1 (8%)
High score (21-31), n (%)	97 (39%)	90 (40%)	15 (60%)	15 (71%)	13 (72%)	12 (67%)	8 (80%)	10 (84%)
Mean score (SD)	16.51 (9.84)	16.21 (9.74)	21.12 (10.52)	23.14 (9.96)	24.00 (8.99)	21.89 (8.06)	26.30 (8.22)	26.42 (6.81)

Legend**:** CG = control group; IG = intervention group; n = total number of participants, % = percentage, SD = standard deviation

5.3.2 Effectiveness of the web-based GNEI

Using the Generalized linear mixed models (GLMMs), one category of a class-type variable is set as reference category, and the coefficients of the other categories are related on that (120). Reference groups for calculating the coefficients set to zero were Group: “IG,” Time: “5,” Sex: “Female,” Genomics course: “ongoing,” Biology course: “No,” Year level: “4th year“, “CG*Time5”, “IG*Time1”, “IG*Time2”, “IG*Time3”, “IG*Time4”, and “IG*Time5”. This is a computational feature of this kind of models (120).

The results presented in **Table 9** showed statistically significant differences at the level of 0.05 between the pre-test and post-test GNCI scores of the participants (p-value = 0.010). There were no statistically significant differences between the scores when considering gender (p-value = 0.713) and year level (p-value = 0.055). However, students who had completed biology courses had statistically significantly higher GNCI scores than those who had not completed any biology courses (p-value = 0.024). Interestingly, students who were undertaking a genetics or genomics course at the time of the study had statistically significantly higher GNCI scores than those who had already completed a genetics or genomics course or had not taken any such course (p-value = 0.014). There were no statistically significant differences between the GNCI scores of the IG and CG (p-value = 0.476).

Table 9. Parameter estimates for the Generalized linear mixed models (GLMMs) statistical computation on the effect of the educational interventions in student's genomics literacy.

	Fixed Coefficients				95% Confidence Interval		p-values
Model Term	**Coefficient**	**Std. Error**	**t-value**	**Sig.**	**Lower**	**Upper**	
Intercept	3.400	0.1184	28.722	0.000	3.167	3.634	-
Control Group (CG)	-0.009	0.1289	-0.072	0.943	-0.264	0.245	0.883
Intervention Group (IG)	0[b]	-	-	-	-	-	
Pre-test and Post-test	-	-	-	-	-	-	**0.010**
Time 1	-0.238	0.1509	-1.574	0.117	-0.535	0.060	
Time 2	-0.291	0.1448	-2.011	0.046	-0.577	-0.005	
Time 3	-0.125	0.1363	-0.914	0.362	-0.394	0.144	
Time 4	-0.194	0.1267	-1.532	0.127	0-.444	0.056	
Time 5	0[b]	-	-	-	-	-	
Sex: Male	-0.046	0.1243	-0.368	0.713	-0.291	0.199	0.713
Female	0[b]	-	-	-	-	-	
Genetics-genomics course							**0.014**
Yes	-0.246	0.1174	-2.098	0.037	-0.478	-0.015	
No	-0.260	0.0892	-2.919	0.004	-0.436	-0.084	
Ongoing	0[b]	-	-	-	-	-	
Biology course: Yes	0.171	0.0751	2.273	0.024	0.022	0.319	**0.024**
Biology course: No	0[b]	-	-	-	-	-	
Year Level	-	-	-	-	-	-	0.055
1st year	-0.321	0.1221	-2.627	0.009	-0.562	0-.080	
2nd year	-0.027	0.0879	-0.306	0.760	-0.200	0.147	
3rd year	0.008	0.0809	0.104	0.917	-0.151	0.168	

4th year	0[b]	-	-	-	-	-	
Group * Pre-test and Post-test	-	-	-	-	-	-	
CG * Time 1	0.111	0.2094	0.531	0.596	-0.302	0.524	
CG * Time 2	-0.161	0.2029	-0.795	0.427	-0.562	0.239	0.476
CG * Time 3	-0.040	0.1917	-0.209	0.835	-0.418	0.338	
CG * Time 4	0.188	0.1835	1.023	0.308	-0.174	0.550	
CG * Time 5	0[b]	-	-	-	-	-	
IG * Time 1	0[b]	-	-	-	-	-	
IG * Time 2	0[b]	-	-	-	-	-	
IG * Time 3	0[b]	-	-	-	-	-	
IG * Time 4	0[b]	-	-	-	-	-	
IG * Time 5	0[b]	-	-	-	-	-	

Legend: Values in **bold** represent statistically significant differences at the 0.05 level of significance, CG=control group, IG=intervention group, GNCI = Genomic Nursing Concept Inventory, GLMMs = Generalized linear mixed models. Probability distribution: Gamma. Link function: Log[a] [a]=Target: Total GNCI Score, [b]= This coefficient is set to zero because it is redundant. Reference groups for calculating the coefficients set to zero were Group: "IG," Time: "5," Sex: "Female," Genomics course: "ongoing," Biology course: "No," Year level: "4th year", "CG*Time5", "IG*Time1", "IG*Time2", "IG*Time3", "IG*Time4", and "IG*Time5".

The trend in the participants' GNCI scores from the pre-tests to the post-tests was illustrated in **Figure 10**. The results showed a decrease in the GNCI scores between Pre-test 1 and Pre-test 2. The reason for the decrease in the scores during the pre-tests was the lack of educational interventions during the one-year period. After Pre-test 2, a 12-week RCT study was implemented, and participants were allocated to the IG and the CG. The IG received the newly designed, tailored, web-based GNEI, while the CG received standard online learning materials. The GNCI scores then started to increase across Post-tests 1, 2, and 3. The increase in GNCI scores was statistically significant, with a p-value of 0.010. This supports the HH_1 showing a significant statistical difference between the GNCI scores of the IG and CG in the pre-test, post-test, and repeated post-test. This implies that the newly designed, tailored, web-based, GNEI was effective in increasing the genomics literary among nursing students.

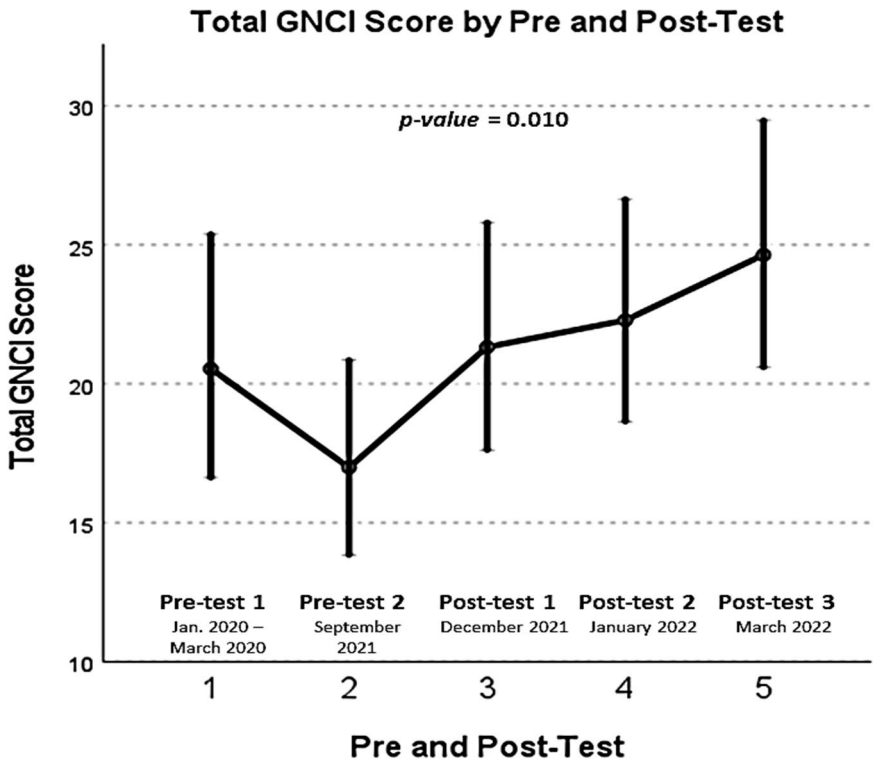

Figure 10. GNCI score trend from the pre-tests to the post-tests
Legend: 0.05 as the level of significance

HH_2 was rejected, as there were no statistically significant differences between the effectiveness of the newly designed, tailored, web-based, GNEI and that of standard education at a p-value of 0.476 (see **Figure 11**). The newly designed web-based genomics nursing education program was as effective as the standard online learning materials in increasing the primary outcome (genomics literacy). Interestingly, students who were currently taking a genetics or genomics course had statistically significantly higher GNCI scores than those who had already completed a course or had not undertaken a course (p-value = 0.014). In addition, students who had completed a biology course had statistically significantly higher GNCI scores than those who had not completed any biology courses (p-value = 0.024).

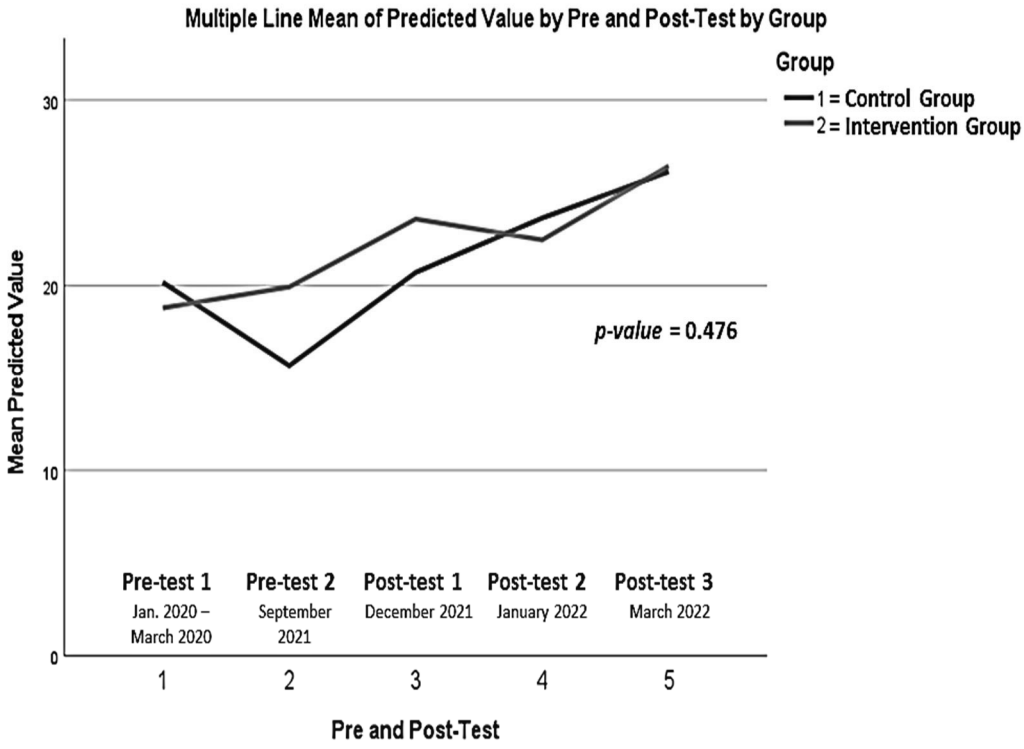

Figure 11. Comparison of the GNCI scores of the IG and CG
Legend: 0.05 as the level of significance

5.3.3 Appraisal of the online learning platforms

The participants in the IG evaluated the newly designed GNEI and reported that the teaching progressed logically, they received sufficient feedback, and the learning atmosphere was encouraging. The teaching methods were reported to be effective and the course content were relevant to genomics in nursing practice. The program enhanced the students' professional expertise, and the content presented in the program could be applied in practice.

The CG participants evaluated the standard online educational materials and reported that the content and instruction levels were appropriate for undergraduate training. Students reported that they actively worked toward reaching their course goals and the things they learned complemented to the things they had learnt earlier.

Both groups evaluated the course workload as suitable—not too low or too high. The majority of the IG participants reported that they learnt a lot from the newly designed, tailored, web-based, GNEI (73%), while 50% of the CG reported that they learnt a lot as a result of the standard online educational material. In the program evaluation, 60% of the IG reported that their learning participation rate was 75%, while nearly 50% in the CG reported that their learning participation rate was 75%. Some of the participants reported a 100% participation rate (37% in the IG, 34% in the CG).

Figure 12 shows the significant differences between the IG and the CG. The IG had a higher mean score than the CG for the content's relevance to genomics in nursing practice, and this result was statistically significant at the 0.1 level of significance (p-value = 0.086). Moreover, the IG had a statistically high evaluation rate for the web-based GNEI regarding the teaching methods' effectiveness (p-value = 0.060), as compared to the CG. Overall, the results of the content and program evaluations were statistically higher for the IG than for the CG, with p-values of 0.088 and 0.072, respectively.

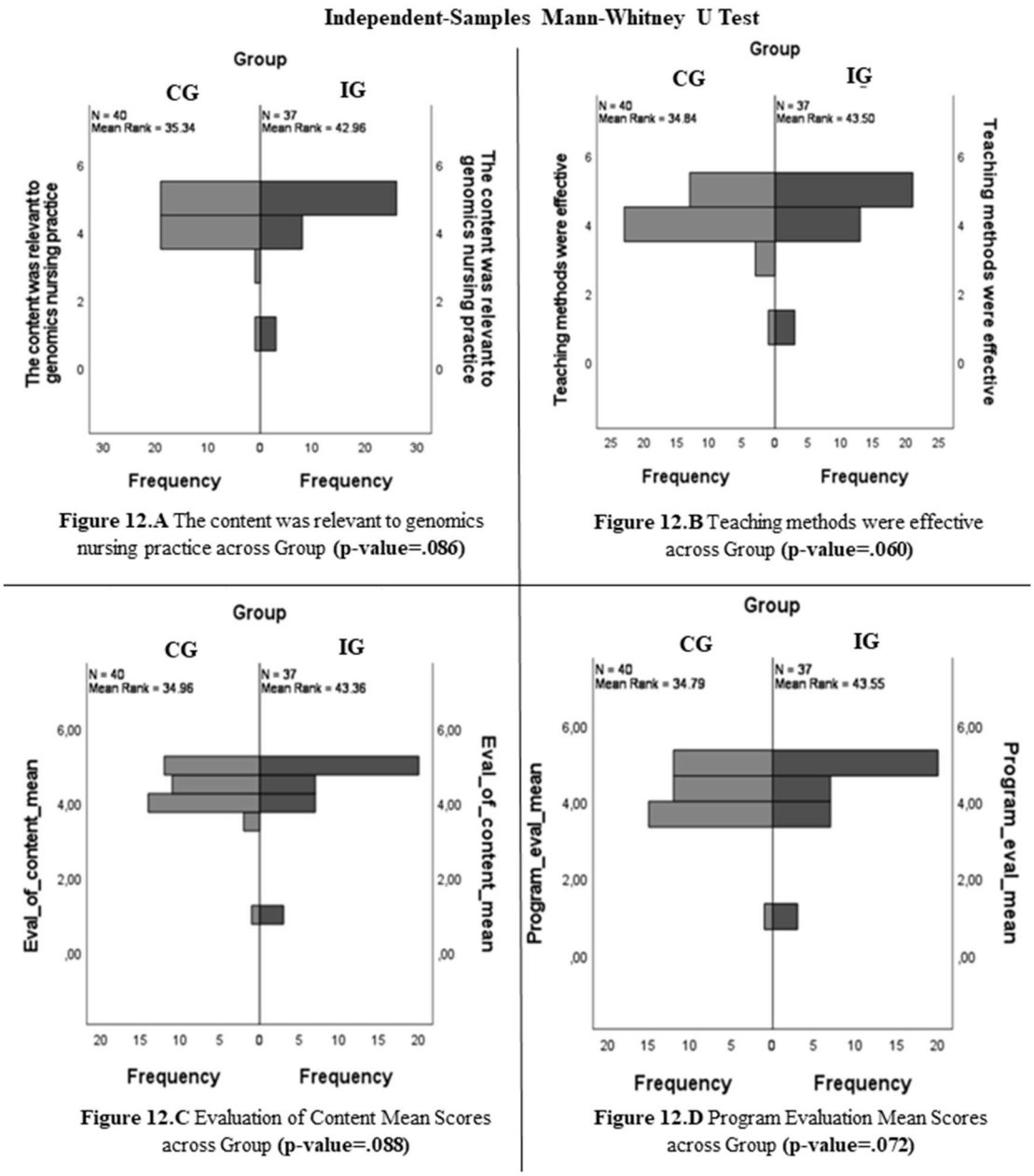

Figure 12. Computation of the Mann–Whitney U test for comparing the learning evaluations of the IG and CG students

Theme 1: Learning approaches

Learning approaches describes the contrasting ways in which students carry out learning tasks (123). The students in the IG advanced their learning during the course by listening, maintaining focus, researching additional information, fostering good attitudes and interest in reading genomics-related articles and studies, and taking advantage of available educational videos (on YouTube and Google). The students in the CG advanced their learning by reading and researching information related to the concepts that they lacked knowledge of, listening, actively participating in the course, watching documentaries, and utilizing their free time to learn genomics.

Different learning approaches had facilitated IG participants to learn about the importance of genomics. The genomics knowledge on the interconnection between the nursing process and different types of genetic disorders had resulted on the reflection on how to provide better quality of care. Meanwhile, the learning approaches of CG help them learn about the importance of genomics for understanding family history dynamics, the scope of genomics, how genetic factors and genetic disorders affect a person's health and well-being, and the impact of genomics on healthcare.

Theme 2: Learning process: contributing learning factors and barriers

Learning process can be defined as a transformation process of knowledge from teachers to students (124) and various learning factors can either contribute or hinder the process of learning (125). Participants from IG reported that the learning process made them realize that the nursing profession involves continuous learning. The students found the materials effective in helping them understand new concepts and enjoyed the group discussions. The students reported the following as contributing factors that helped them achieve their aims: sufficient information, active listening, the courage to learn new things, the help of expert speakers during webinars, and active group discussions with peers. IG participants were able to gain knowledge about genomics and understand how they could apply this knowledge in clinical nursing practice.

The participants in the CG considered genomics vital for nursing interventions, especially in the assessment and planning of care. They stated that engaging in active learning and educational activities helped them grow in their nursing careers. The students in the CG reported that sufficient online materials, time management, a sense of responsibility, and support and encouragement from the instructors that boosted their self-esteem and productivity were contributing factors that helped them achieve their aims. CG gained new information that broadened their knowledge of genomics concepts. Both groups reported the following factors as barriers to learning: lack of time management, poor internet connection, workload, other responsibilities, home environment, and the pandemic.

Theme 3: Learning reflections and perceptions of genomics knowledge application and utilization

Students' reflections and perceptions in the learning process is a tool that can support knowledge transfer (126). The students in the IG perceived that the GNEI was interactive and that the Zoom meetings were well planned, properly timed, and efficient. To improve the GNEI, they reflected and suggested having additional learning materials that are easy to understand, following a multimodal approach, using PowerPoint presentations, and having a printed copy of the learning materials. They perceived problem-solving situations to be essential to the learning process. The participants in the IG conveyed that they could apply and utilize the knowledge they gained from the newly designed, tailored, web-based, GNEI in providing nursing care and health education. They realized that genomics nursing knowledge could be utilized in the nursing process as well as in their daily lives and future careers.

The students in the CG perceived that the standard online learning materials as informative, up to date, and well organized. They reflected that to improve the standard materials, the students suggested organizing the genomics terms to make them easier to understand and highlighted the need for frequent feedback from the instructors. The students perceived that the standard online learning materials increased their

motivation and critical thinking. The students in the CG reflected and understood that genomics in nursing is essential because of its vital contributions to assessing and planning patient care. Indeed, genomics has a lot of potential for use in nursing and healthcare provision. For instance, it can be utilized to determine whether a person is at risk of a genetic condition that their family history does not reveal or disclose.

6 DISCUSSION

The overall aim of this dissertation was to investigate the effectiveness of a newly designed, tailored, web-based GNEI on undergraduate nursing students' genomics knowledge. The objectives were to translate the GNCI into Finnish using Mandysova's decision tree algorithm, to assess the genomics literacy of the respondents, and to design and investigate the effectiveness of the tailored, web-based GNEI. This chapter presents the discussion section of this dissertation.

6.1 LINGUISTIC VALIDATION OF THE FINNISH GNCI BY APPLYING MANDYSOVA'S DECISION TREE ALGORITHM (ORIGINAL PUBLICATION 2)

The use of Mandysova's decision tree algorithm for the translation and linguistic validation of the GNCI from English to Finnish has previously been described in this dissertation (104). There was an urgent need for a valid instrument in Finnish to measure nursing students' knowledge of genetics–genomics concepts. The algorithm used in the present study provided a specific, step-by-step, user-friendly approach for translating the GNCI instrument. A conceptually accurate translation of genetics–genomics concepts from English to Finnish was achieved.

The use of Mandysova's decision tree algorithm requires adherence to important ethical guidelines, such as obtaining consent from the original authors of research instruments, and it also creates opportunities for collaboration and to work closely with the original authors. This method was consistent with the recommendations of Pudas-Tähkä et al. (127) and Tsang et al. (128). However, the qualification criteria were simplified in the present study owing to difficulties in finding forward and backward translators, area/subject specialists and relevant healthcare professionals for the panels, and representative target users. The translation phase to create a Finnish version of the GNCI was essential for the assessment of

undergraduate nursing students' genomics knowledge in the Finnish cohort.

6.2 NURSING STUDENTS' GENOMIC LITERACY: THE BASIS FOR GNEI DEVELOPMENT (ORIGINAL PUBLICATION 3)

A cross-sectional online method was adopted in this study to investigate the genomics literacy levels of Finnish and Filipino cohort groups. This phase of the dissertation project laid the foundation for designing the tailored, web-based, GNEI.

The evidence-based findings of this study highlighted the need to design and develop an intervention to overcome nurses' knowledge shortfalls. The findings were consistent with those of other international studies demonstrating low genomic literacy among nursing students, nurse educators and clinical nurses (23-37,129).

Multifactorial educational barriers, including a lack of genomics knowledge among nursing educators, crowded curricula, inadequate time, and a lack of regulatory legislation for genomics competency (19,27-31), have contributed to low literacy in this area. These obstacles impede nurses' professional growth in advancing genomics in clinical practice (27).

Educational interventions can empower nurses to engage patients, families, and communities in promoting healthy behaviours (22-37,43-61,130-137). To accelerate the integration of genomics into nursing healthcare, it is important that nurses acquire sufficient knowledge of genomics (18-37,43-61,130-137).

Standalone or elective genomics courses should be included in nursing curricula to overcome curriculum implementation challenges (43-46,52-61,132-137). Novice nurse educators are encourage to use learning assessment tools (such as GNCI) in mapping students' knowledge gaps. Further, it is important to use available educational resources in designing suitable genomics courses and ensuring the sustainability of the learning process (38,132-136).

6.3 EFFECTIVENESS OF THE WEB-BASED GNEI FOR UNDERGRADUATE NURSING STUDENTS: A RANDOMIZED CONTROLLED TRIAL STUDY (ORIGINAL PUBLICATIONS 1, 4)

6.3.1 GNEI improves the genomics literacy of nursing students

To our knowledge, this was the first RCT to use the GNCI to evaluate the genomic literacy of undergraduate nursing students during a longitudinal period (2020–2022). A significant and increasing trend in GNCI scores was detected after the completion of the educational interventions. The completion of biology and genomic courses significantly contributed to the GNCI scores. The results showed that the GNEI significantly increased the genomics literacy of nursing students from the pre-test stage to the post-test stage. The newly designed, tailored, web-based, GNEI was expected to show higher educational effectiveness compared to standard online learning materials. However, there were no significant differences between the knowledge levels of the IG and the CG. Considering these results, HH_1 was accepted and HH_2 rejected. It could be that the number of participants were not sufficient to show significant differences between the GNEI and the standard genomics educational intervention. Another interpretation of the data was that the Genomics in Healthcare was able to meet the same learning/knowledge needs in the control group as the GNEI did for the IG resulting in similar benefit and changes in GNCI scores. This implies the need of replicating the study in larger cohort.

Notably, this study provided evidence-based that educational interventions can improve the genomics literacy of undergraduate nursing students. This study was limited to the short-term effects of educational interventions. Nevertheless, the findings were supported by those of other studies that tested the effectiveness of online educational interventions (112,138–140).

Zureigat et al. (52) conducted a scoping review and found that online or remote interventions ranging from hours to days or months were associated with increased genomics knowledge (138-140). For example, a web-based genomics training provided evidence of significant effectiveness

in improving the attitudes, knowledge, intention, and self-efficacy of health educators in Texas immediately post-training and after 3 months (112). The 45-minute interactive, web-based pharmacogenomics developed by Dodson (138) provided evidence of improving the knowledge and attitudes among oncology nurses. An 18-week web-based educational intervention developed by Prows et al. (139) resulted in significant knowledge improvements among nursing faculty in the areas of molecular genetics, clinical genetics, and ethical concepts. An increase in the genomics knowledge of nurse practitioners was reported after their use of a mobile health technology app designed by Smania (140) for less than 20 minutes.

6.3.2 The research methodology facilitated a robust evaluation of the effectiveness of the web-based GNEI

The newly designed, web-based, GNEI was cohort-based or tailored to the learning needs of undergraduate nursing students. In this RCT study, the GNEI was proven to be as effective as the standard educational tool. The study showed that the standard education tool was effective in educating the nursing students about genomics concepts. To our knowledge, no previous research has been conducted to evaluate the effectiveness of the standard educational tool.

The study participants reported that they benefited from the educational interventions and had increased motivation to continue learning genomics. The12-week educational intervention of this dissertation study provided evidence-based for effectiveness of GNEI in increasing the genomics literacy of nursing students after one-month and three-month follow-ups. These findings were similar to those reported by Chen et al. (112) and Smania (140).

The participants' recent exposure to learning materials positively contributed to their gaining genomics knowledge. It is unclear whether there will be a decrease in genomics knowledge improvements or a return to baseline knowledge years after the educational intervention. Similarly, investment of time and cost to develop high quality learning online is required and the involvement and interaction by teaching staff may still be

needed for some online formats in contrast to self-paced pre-recorded or asynchronous courses was not explored. This could be particularly relevant given what is known about knowledge levels (23-34) and confidence to teach genomics of many nurse educators currently (32-37). Targeted genomics education and training of professionals are core components of strategic planning for sustainable, ethical, and appropriate use of genomics in health care (141). It is evident that tailoring sessions have resulted to positive learning outcomes, nonetheless, practicalities of revising content of cohort-based educational intervention built on baseline assessment data is necessary. Consequently, there is a need for the continuation of genomics education alongside with nursing education for the sustainability of genomics literacy and the appropriate integration of genomics into clinical practice.

6.3.3 Students' learning experiences

The evaluation feedback provided by the students in this study revealed the different factors that contributed to learning and motivation. It also provided evidence of different challenges and barriers to learning, which need to be acknowledged by educators facilitating the learning process. The findings were congruent with those of Dagan et al.'s study about the factors associated with the attitudes and genomic professional skills and competencies of Israeli nurses and nursing students (27). Although the present study did not investigate these particular issues, the students' feedback reflected similar learning barriers.

The inclusiveness of nursing in the decision-making systems therein impact the diversity of participation in genomics research (38-40, 43-48,61). With respect to the present study, the inclusion of participants from the Philippines, a developing country, facilitated diverse participation in genomics research.

6.3.4 Integration of genomics into the undergraduate nursing curriculum

The scope of nursing science is extremely wide and includes understanding health at the genomic level (93,132-136,142). The National Institute Research Strategic Plan Framework for 2022–2026 highlighted the use of holistic approaches from nursing science to advance precision health across the human lifespan (18).

Educational strategies to integrate genomics frameworks into nursing education pathways at all levels of practice are needed (93-95, 132-137). A reconstruction of the current nursing undergraduate curriculum and continuing education in genomics are needed to improve and sustain genomics literacy (52-61). The interventions in this study had initiated students' interest in utilizing genomics concepts to provide patient care and improve the quality of life and well-being of their clients.

The influence of the nurse educators was a motivating factor for the students to continue participating in and subsequently complete the genomics courses. This indicates that influential nursing leadership was necessary to motivate nurses and help them develop confidence and core competencies in genomics.

6.3.5 Suitability of online education

The study findings revealed the appropriateness of online education in ensuring that students have sufficient knowledge about the latest trends and advancements in genomics technology. This intervention study contributed to increasing the knowledge and cognitive abilities of nursing students. This step is important to initiate the development of genomics competencies required for nurses. It is also important to reflect on how nurses can translate this knowledge into practice.

6.3.6 Theoretical and conceptual frameworks relevant to the study

The process of adaptation to genomics innovations takes time (78). The uptake of genomics technologies depends on the genomics knowledge

nurses have acquired during their undergraduate studies. The cognitivist and constructivist learning approach adopted in the present study helped increased students' understanding of the fundamental genomics concepts (79-81). As the students are now equipped with a foundation in genomics, it is expected that they will develop genomics competencies in the real world.

Supportive career pathways are essential to further the use of genomics in the nursing profession (82,142). In line with the Knowledge-to-Action Framework, the knowledge creation process in the RCT was initiated by identifying students' knowledge gaps, designing an appropriate educational intervention, and evaluating outcomes (83).

6.4 STUDY STRENGTHS AND WEAKNESSES

6.4.1 The study protocol and RCT research on the effectiveness of the GNEI (Original Publications 1, 4)

This interventional study provided evidence of the effectiveness of a web-based educational intervention. Evidence of sustainable learning and career advancement in genomics was the added value of this RCT. This dissertation thus provides direction for the enrichment of nursing education in response to the demand for genomics-informed nursing.

This dissertation has led to the initiation of an international collaborative research network between Finland, the Philippines, the USA, New Zealand, Australia, the Czech Republic, and the UK. The study protocol was carefully determined by a multidisciplinary team of international genomics experts. The RCT protocol can be tested in other healthcare disciplines, clinical settings, and other countries in the future.

It was not possible to use two blinding techniques, so participants were blinded, while researchers were aware of who belonged to the IG and CG. The risk of between-group contamination and biased findings was minimized by not providing either group with the correct answers to the 31-item GNCI. However, it was not possible to control for the possibility of students using search engines to find the correct GNCI concepts and

answers. The risk of researcher bias was minimized by adhering to the protocol-based implementation of the intervention.

The complex nature of the study protocol affected the research timeframe. Considering the updated Medical Research Council Framework, including a theory-based evaluation of nursing interventions promotes better understanding on how and what makes an intervention effective and had led to change (143). Flexibility must be carefully considered in the future.

Securing the necessary institutional permissions and ethical approval and registering the study protocol were time-consuming processes. It was also challenging to recruit participants in a timely manner. The intervention was implemented in only one university in the Philippines, so the results of this study cannot be generalized.

It was not possible to proceed with the data from Finland due to a lack of respondents and a high dropout rate, which posed major challenges in conducting an RCT. Data collection during the pandemic, heavy student workload, insufficient time to participate, exhaustion, and lack of interest were the reasons for the high dropout rate.

6.4.2 The translation process of the Finnish GNCI (Original Publication 2)

The key strength of adopting the selected systematic decision tree algorithm (98,104) was that it added rigor to the translation process and was useful in verifying the validity and usability of the translated instrument. The Finnish version of the GNCI was used to assess the knowledge levels of nursing students in Finland and can be used as a guide when updating Finnish nursing education curricula.

There were several challenges when applying the selected decision tree algorithm. The project required considerable resources (98) (i.e., time, linguists, healthcare professionals and specialists with area/subject expertise, and financial support). Certain criteria of panel of experts needed to be adjusted and simplified. According to Wild et al. (99), translators and subject specialists should meet certain criteria. Difficulties

in recruiting nurses and translators who met the predetermined selection criteria were encountered which made the translation and linguistic validation processes demanding and time-consuming.

The student nurses were required to be enrolled in an undergraduate nursing program, and they were tasked with evaluating the usability of the Finnish GNCI, which meant that they had to be relatively proficient in Finnish (i.e., intermediate level), although they did not need to be native Finnish speakers. Another challenge was the participants' unfamiliarity with genetics–genomics terminologies. The registered nurses in Panel 1 and the nursing students in the pilot study recognized that they lacked knowledge of specific translated genetics and genomics concepts. Furthermore, the nurses did not know the correct terms/concepts to be used in Finnish for certain English terms. It was challenging to determine how to resolve these issues without changing the intent of the original instrument.

The main limitation of utilizing the selected decision tree algorithm (98,104) was the time it took to follow the recommended procedures (16 months: October 2018 to February 2020). Factors that affected the speed of the process included difficulties in finding qualified forward and backward translators, the length and complexity of the GNCI tool, and the learning curve faced by the research team members who had not previously used the algorithm. The translation services were also costly. Finally, the small size of the sample used to represent the target population (n = 8) may affect the validity of the results.

6.4.3 Cross-sectional study of genomics literacy (Original Publication 3)

The study findings in this phase of the dissertation revealed the genomics literacy levels of the undergraduate nursing students. Tracing genomics knowledge gaps provided a solid starting point for the development of an appropriate educational intervention (i.e., GNEI). The teaching pedagogies of the designed GNEI need to be constantly improved for the integration of theory and practice.

The intervention was complex and required students' cooperation until the completion of the study. Students' commitment to answering the GNCI during two pre-tests and three repeated post-tests was crucial for the completion of the interventional study. It was challenging to get a high response rate due to COVID-19 restrictions. Barriers such as students' workload, lack of interest in the topic, and lack of time to participate resulted in a low response rate. Further, the research team did not have control over the possibility of respondents using internet searches to answer the GNCI questions. Nonetheless, the research team managed to get enough responses to conduct the analyses, although there may be selection bias due to convenience sampling.

6.5 RESEARCH IMPACT

Integrating genetics and genomics into nursing science is the added scientific impact of this research project. As for societal impact, the methodology of this research can be tested in other countries to improve the genomics education of undergraduate nursing students.

The adapted Finnish GNCI version was an important and relevant tool in Finnish nursing education to upgrade and upskill nurses' genomics knowledge. The Finnish GNCI can be used as a pre-instruction test to measure students' knowledge and identify incorrect perceptions to be targeted in subsequent teaching sessions. The GNCI can be used to measure short-term or sustained learning gains and teaching effectiveness. It can also be used to determine the need for additional training for nursing educators. Nursing leaders can utilize the inventory to provide credentials to nurses who wish to specialize in the field of genomics in nursing. This instrument may enable further research related to the applicability of genomics in clinical practice.

This dissertation was relevant to the enrichment of current nursing curricula. This research project was an attempt at providing solutions to address the existing genomics knowledge gaps. Notably, it initiated nursing students' interest in emerging advancements in genetics–genomics and precision medicine.

7 CONCLUSIONS

The following conclusions were drawn from the results:

1. Testing the effectiveness of a web-based GNEI using an RCT provided evidence-based findings that can guide the design of online genomics courses and sustained learning of emerging topics in nursing science, such as genomics.
2. Mandysova's decision tree algorithm had provided a clear and rigorous direction to the translation and validation of the Finnish GNCI. It enabled the application of genetics and genomics concepts in evaluating the genomics literacy among Finnish nursing students.
3. In-depth understanding of the existing genomics knowledge gaps among nursing students can be leveraged to inform evidence-based education.
4. The newly designed, tailored, web-based, GNEI has proven its effectiveness in improving the genomic knowledge of nursing students in a small cohort group.

7.1 RECOMMENDATIONS FOR EDUCATION AND CLINICAL PRACTICE

- The preparation of genomics-informed nurses requires research-based educational interventions and the integration of genomics concepts into nursing curricula.
- Multidisciplinary and professional collaboration is important in developing lifelong learning pathways for the sustainability of genomics literacy and the appropriate integration of genomics concepts into clinical practice is essential.
- Leadership support and legislations are needed to the advancement of genomics in the nursing education.

7.2 RECOMMENDATIONS FOR FURTHER RESEARCH

- New research directions emerged from our research findings, such as exploring the educational effectiveness of genomics-related educational interventions in a wider population cohort, including clinical nurses, nurse educators, and researchers, to advance the nursing profession in the field of genomics.
- Research to appraise the long-term effects of educational interventions is recommended. Evidence on the application of genomics knowledge within clinical practice is limited. Further investigations in this area is needed.
- A larger study needs to be conducted to further evaluate the Finnish GNCI.
- Research needs to be conducted in other settings and with an appropriate sample size to appraise the long-term effects of educational interventions using reliable evaluation methods for nurses.
- Further research is recommended to investigate how genomics can be effectively integrated into undergraduate nursing curricula.

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APPENDICES

APPENDIX 1. GLOSSARY

DNA is composed of four chemical building blocks: adenine (A), thymine (T), cytosine (C), and guanine (G). Variations in the order of these codes allow DNA to function in distinct ways, making each individual unique (40).

Gene is a segment of DNA that provides the cell with instructions for making a specific protein to carry out a specific function in the body (40).

Genetics has a narrower scope. It is defined as the study of heredity and focuses on the function and composition of individual genes (42).

Genomes are large molecules that look like long, twisted ladders of deoxyribonucleic acid (DNA) (40).

Genomics is the study of molecular mechanisms and the interplay between molecular information, health interventions, and environmental factors in disease (42).

Genomics-Informed Nursing is a complex field that encompasses all areas of health care. It is defined as a platform to educate nurses in terms of current advances and possibilities of genomics in nursing education, research, and clinical practice (43).

Genomic nursing is often viewed as a specialty within the nursing profession more closely aligned with genetic counselling while **genomics-informed nursing care** can be provided by all nurses (44).

Nurse scientists are uniquely positioned to advance nursing science through research and evidence-based practice initiatives due to their

ability to closely collaborate with other healthcare professionals in the clinical setting (85,86).

Precision health (PH) is a broad science that involves disease prevention and health promotion approaches, including precision medicine, and it is also called “precision public health” (40).

Precision medicine (PM) is also called personalized medicine and involves identifying which approaches will be effective for patients based on genetic, environmental, and lifestyle factors (40). The National Research Council prefers the term “precision medicine” over “personalized medicine” because of misinterpretations of the word “personalized” (41). Accordingly, we have utilized the term “precision medicine” in this dissertation.

Precision Medicine Initiative (PMI) is a long-term research endeavor involving the National Institutes of Health (NIH) and multiple other research centres. The aim of the PMI is to understand how a person’s genetics, environment, and lifestyle can help determine the best approach to prevent or treat disease (41).

APPENDIX 2. THE PERMISSION LETTER FROM THE ORIGINAL AUTHOR OF THE GNCI TOOL

CLEMSON
School of NURSING

July 16, 2021

Anndra Dumo
University of Eastern Finland
Kuopio Campus

Dear Ms. Dumo,

Thank you for your interest in translating the Genomic Nursing Concept Inventory (GNCI© 2017) into Finnish in connection with your work to support genomic nursing education in Finland. I understand that you plan to translate the current version of the GNCI (which was most recently revised in 2017) into Finnish using a robust approach, Mandysova's decision tree algorithm, that involves multiple steps including direct translation, expert consultation, back translation, review and harmonization of the back translation, and initial testing to measure psychometric properties. I further understand that you wish to use the translated GNCI to measure genomic knowledge among nursing students in your country.

Your proposal aligns well with the purposes for which the GNCI was designed. As you know, we have a good deal of evidence to support the use of GNCI items to measure genomic literacy among nursing students and nursing faculty.

You have my permission to translate the 31 GNCI items into Finnish for the purposes described above. You may adapt items to better fit the Finnish culture or health system as you see fit. I will be happy to contribute to the review of the back translation for conceptual congruency or other purposes as you wish. No fee or data-sharing requirements are required. Of course, I ask that you provide appropriate citations in any presentations or publications related to your project.

The GNCI is protected under US copyright law. Under that law, any translated version of the GNCI constitutes a "derivative work." My understanding is that you may use your translated GNCI as you wish, without requiring further permissions. I agree to your unrestricted use of your derivative work.

As you may know, the content domain for the GNCI was drawn from essential nursing genetic-genomic competencies developed in the United States for all registered nurses. Item distractors (incorrect answers) reflect misconceptions shared by US nursing students around each concept. Validation testing with more than 8,000 nursing students, 500 nursing faculty, and a smaller number of practicing nurses indicated mean pre-instructional difficulty to fall between 41%-48% correct, with Cronbach's alpha values between .73 and .85. We do not expect higher alpha values because the GNCI content domain is broad. Because each item maps to a particular concept (or in some cases a few concepts), results provide useful measures of understanding of individual genetic-genomic concepts. Furthermore, because item distractors reflect misunderstandings

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shared by many nursing students, analysis of response data identifies specific targets for education.

Please be aware that we continue to improve the GNCI, revising and retesting underperforming items. Also, please keep in mind that the initial content domain for the GNCI was developed a decade ago. As genome science has advanced, the content domain has begun to seem a bit dated. For example, no items address epigenetic mechanisms or the use of nucleic acid vaccines, while items about inheritance patterns are likely over-represented. You may wish to develop new questions and, if that is the case, you should be aware that item development for concept inventories traditionally applies a particular process that is well described in the literature. As your work proceeds, please feel free to contact me and ask if we have made any changes.

I have attached the beta-revised (current) version of the GNCI© as a Word file with correct responses highlighted. I also attached a table that maps GNCI items to the concept each was developed to test. **As we continue to develop the GNCI as a standardized measure of genomic knowledge among nurses, it is important to protect inventory security**. For that reason, please do not share the English GNCI with anyone not directly involved with your project. Please ensure that team members understand that you do not have permission to share the English inventory or individual inventory items beyond the conduct of this particular project. Please control test distribution to prevent participants from acquiring the English GNCI. Finally, please do not reproduce inventory items in English in any publications without my express permission. As I mentioned above, you may manage your translated instrument as you see fit.

Best wishes with your work! Much work is needed to develop a genomic-informed health professional work force and I am honored that you wish to use the GNCI for that purpose. Please do not hesitate to contact me if I can provide any further information.

Sincerely,

Linda D Ward

Linda D. Ward, PhD, CNE, FNP-C
Associate Professor
Clemson University School of Nursing
411 Edwards Hall
Clemson, SC 29634
(864) 656-5528
ldward@clemson.edu
attached: GNCI beta revised version 2017 with answers
GNCI item-concept table

APPENDIX 3. THE PERMISSION LETTER FROM THE ORIGINAL AUTHOR OF THE MANDYSOVA'S DECISION TREE ALGORITHM

Palacký University
Olomouc

July 16, 2021

Letter of Permission to use the Mandysova's Decision Tree Algorithm

Anndra Dumo
University of Eastern Finland, Kuopio Campus

Dear Ms. Dumo,

This letter is a proof that you have my permission to use the **Mandysova's Decision Tree Algorithm** for the purpose of translating the original English version of Genomic Nursing Concept Inventory (GNCI) to Finnish GNCI version.

Sincerely,

Petra Mandysova, PhD, MSN
Associate Professor
Palacky University Olomouc
Faculty of Health Sciences
Department of Nursing
Hněvotínská 976/3, Olomouc 775 15, Czech Republic
email: petra.mandysova@upol.cz

APPENDIX 4. THE CLINICALTRIALS.GOV REGISTRATION OF THE RCT STUDY PROTOCOL

ClinicalTrials.gov PRS
Protocol Registration and Results System

ClinicalTrials.gov Protocol Registration and Results System (PRS) Receipt
Release Date: October 4, 2021

ClinicalTrials.gov ID: NCT03963687

Study Identification

Unique Protocol ID:	Genomics Nursing Education
Brief Title:	Effectiveness of Web-based Genomic Nursing Education Intervention
Official Title:	A Randomized Controlled Trial of the Effectiveness of a Web-based Genomic Nursing Education Intervention on Outcomes of Increasing the Level of Knowledge of Undergraduate Nursing Students in Genetics-genomics Concepts: Study Protocol
Secondary IDs:	

Study Status

Record Verification:	October 2021
Overall Status:	Enrolling by invitation
Study Start:	January 20, 2020 [Actual]
Primary Completion:	December 31, 2021 [Anticipated]
Study Completion:	December 31, 2022 [Anticipated]

Sponsor/Collaborators

Sponsor:	University of Eastern Finland
Responsible Party:	Principal Investigator Investigator: Anndra Dumo [adumo] Official Title: Researcher Affiliation: University of Eastern Finland
Collaborators:	

Oversight

U.S. FDA-regulated Drug:	No
U.S. FDA-regulated Device:	No
U.S. FDA IND/IDE:	No
Human Subjects Review:	Board Status: Approved Approval Number: STATEMENT 21/2018 Board Name: Committee on Research Ethics Board Affiliation: University of Eastern Finland Phone: Email: tuetto@uef.fi Address:

ORIGINAL PUBLICATIONS (I – III)

I

Randomized controlled trial on the effectiveness of web-based Genomics Nursing Education Intervention for undergraduate nursing students: a study protocol

Dumo A, Laing B, Lim A, Palaganas E, Abad P, Valdehueza O, Palovaara M, Saunders H, Estola M, Mandysova P, Maguire J, Ward L, Carlberg C, and Vehviläinen-Julkunen K

Journal of Advanced Nursing 76: 3136–3146, 2020

II

Linguistic Validation of Genomic Nursing Concept Inventory to Finnish Applying Mandysova's Decision Tree Algorithm

Dumo A, Mandysova P, Ward L, Laing B, Lim A, Palovaara M, Saunders H, Maguire J, Carlberg C, Sund R, and Vehviläinen-Julkunen K

Journal of Nursing Measurement 31(3): 1-18, 2023

III

Nursing students' genomics literacy: Basis for genomics nursing education course development

Parviainen A, Ward L, Halkoaho A, Laing B, Maguire J, Palovaara M, Mandysova P, Bacungan G, Mamungay J, Sund R, Mikkonen S, Carlberg C, and Vehviläinen-Julkunen K

Teaching and Learning in Nursing 18: 6-11, 2023

Teaching and Learning in Nursing 18 (2023) 6–11

Contents lists available at ScienceDirect

Teaching and Learning in Nursing

journal homepage: www.sciencedirect.com/journal/teaching-and-learning-in-nursing

Nursing students' genomics literacy: Basis for genomics nursing education course development

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ARTICLE INFO

Article History:
Accepted 29 November 2022

Keywords:
Course
Development
Education
Genomics
Learning
Literacy
Nursing
Teaching

ABSTRACT

This study aimed to investigate the genomics literacy of Finnish and Filipino nursing students as a basis for developing a genomics nursing education course. This is a cross-sectional online survey using the 31-item Genomic Nursing Concept Inventory, IBM SPSS version 27, and item-analysis. A total of 245 nursing students participated in the study; 75% reported that they had not completed any genetics-genomics courses. The GNCI scores ranged from 2 to 31 total correct answers out of a total possible score of 31. The GNCI mean score of the Finnish cohort (9.53; SD = 3.48; 36% correct) was significantly lower compared to the Filipino cohort (16.21; SD = 9.74, 58% correct). These results show that the genomics literacy of nursing students in Finland and the Philippines is weak, particularly in human genome homogeneity and genotype-phenotype association concepts. We recommend designing effective genetic and genomic educational programs and updating the nursing curricula.

Background

The advancing science of genetics and genomics is remarkably transforming the way nurses deliver care (Beery et al., 2018; Bhavnani et al., 2017; Finnish Institute for Health and Welfare, 2019; World Health Organization, 2020). Genomics as a discipline is becoming mainstream in this genomic era and nurses needs to be aware of it; hence upgrading the current nursing curriculum is essential (Anderson et al., 2015; Campion et al., 2019). The paradigm shift of precision healthcare requires nurses to be prepared to provide genomics-informed nursing care (Aiello, 2017; Dumo et al., 2020). This transformation in global nursing knowledge to increase literacy in genomics is required to advance nursing's role in the genomics discipline (Buaki-Sogo & Percival, 2022; Bueser et al., 2022; Calzone et al., 2018). The need to maintain competent practice standards with the changes in science is essential, and thus knowledge of genetics-genomics is also essential. A primary reason for implementing genetics-genomics into a nursing curriculum is that new discoveries in genetics-genomics are revolutionizing medical approaches to the diagnosis, management, and treatment of disease (Calzone et al., 2018; Finnish Institute for Health and Welfare, 2019; Majstorović et al., 2021; Tonkin et al., 2020; World Health Organization, 2020).

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https://doi.org/10.1016/j.teln.2022.11.013
1557-3087/

Validating the genetics/genomics literacy of students is important to ensure that appropriate genomic content is added to curricular integration (Abad & Sur, 2022; Dewell et al., 2020). Internationally, numerous studies have assessed the genomics literacy of nurses (Dagan et al., 2021; McCabe et al., 2016; Wright et al., 2019), nursing students (Dewell et al., 2020; Ward et al., 2016), and nursing faculty (Dewell et al., 2020; Read & Ward, 2016); however, the literacy of Finnish and Filipino nursing students has not been investigated to date. The identification of knowledge gaps by regions indicates a need to improve knowledge. In addition, an understanding of where genetics content exists in the curriculum is also necessary.

No one must be left behind in advancing genomics knowledge, regardless of whether a country's economic profile is highly developed or still developing. The International Society of Nurses in Genetics 2021 World Congress highlighted the importance of promoting diversity, inclusion, and health equity in genomic nursing (ISONG, 2022). Assessing the genetics and genomics literacy of nursing students across the world is important to strengthen genomics nursing education, practice, and research internationally (Calzone et al., 2018). Understanding the literacy in genetics and genomics between a developed country, such as Finland, and a developing country, such as the Philippines, is a stepping-stone in promoting diversity, inclusion, and health equity in genomic nursing worldwide.

Genomics in Finland and the Philippines

Finland is promoting the incorporation of genomic data to provide a distinctive opportunity for contemporary personalized health care (Finnish Institute for Health and Welfare, 2019; Ministry of Social Affairs and Health, 2022). The Finnish health care system has prepared for this by acknowledging that the clinical application and sharing of genetic information involves risk so a national genome strategy to safeguard genomic data has been developed so that it can be effectively and safely utilized in health promotion and well-being (Ministry of Social Affairs and Health, 2022). This judicious application of genomic data will provide more effective targeted screening, more accurate diagnoses, personalized treatment, and increased economic benefits (Finnish Institute for Health and Welfare, 2019). Moreover, limited genetics and genomics services are now offered by the Philippine government and private institutions (Abad & Sur, 2022). Recently, the Philippines has established the Philippine Genome Center (PGC) in 2019 as a national strategy to facilitate genomics application to public health promotion (Padilla & Cutiongco-de la Paz, 2016). The nursing educational systems in Finland and the Philippines are presented in Supplementary Material Table 1.

Health care professionals with genetic and genomic knowledge are needed. Training nurses in genetics and genomics would enable them to provide these services in their care to patients and add to their skills in the assessment, management, and evaluation of care (Bhavnani et al., 2017; Buaki-Sogo & Percival, 2022; Bueser et al., 2022; Calzone et al., 2018). Appropriate genetic-genomic education will enhance nurses' collaborative work with multidisciplinary health care professionals, including genetic counselors, geneticists, physicians, clients, and families (National Academies of Sciences Engineering and Medicine, 2021; Tonkin et al., 2020). There is an urgent need to improve genetic and genomic nursing education worldwide by updating and upgrading the nursing curriculum to reflect advances in genetic and genomic technology (Calzone et al., 2018; Campion et al., 2019; Chair et al., 2019).

Learning Theories

The learning theories of cognitivism and constructivism guided this study. According to cognitivism, learning relies on both external and internal factors (Michela, 2018); the learner as an information-processor can acquire knowledge by undertaking cognitive operations, absorbing information, and storing it in memory. According to constructivism, the learners build meaning based on previous experiences, creating new knowledge through active engagement such as real-world problem solving (Tam, 2000). The need to measure deep understanding of foundational genetic-genomic knowledge is supported by both learning theories. Nurses who understand how genes influence health (i.e., understand foundational principles) are well positioned to deliver genomics-informed care (Abad & Sur, 2022; Aiello, 2017; Buaki-Sogo & Percival, 2022; Campion et al., 2019; Laaksonen et al., 2022; Majstorović et al., 2021; Ward et al., 2016; Zureigat et al., 2022). Genomics literacy is important to nurses so that they can deliver and explain precision healthcare across the care continuum, from assessment to evaluation of health outcomes. The Genomic Nursing Concept Inventory (GNCI) was designed to measure that foundational understanding that nurses are expected to recall and apply in practice.

Research Aim

This study aimed to investigate the genomics literacy of Finnish and Filipino nursing students as a basis for developing a genomics nursing education course. These findings can be used to inform nursing education, enable the design of evidence-based educational programs, and update nursing curricula.

The following research questions guided the study:

- What is the level of genomic literacy among Finnish and Filipino undergraduate nursing students?
- Are there any statistically significant differences in genomics literacy between Finnish and Filipino cohorts?

Method

Study Design

The study design was an online cross-sectional survey of Finnish and Filipino nursing students. The STROBE statement checklist of cross-sectional studies was used in reporting this study.

Samples and Setting

Baccalaureate nursing students (years 1-4) studying in a government-established educational institution were the target population of this study. Finland and Philippines were chosen as the study setting because both are comparably new to including genomics in their nursing education. A convenience sample was taken from one university in the Philippines and two universities of applied sciences (UAS) in Finland from 2020-2021. A total of 1,570 nursing students were invited from participating universities (n = 700 from the Philippines, and n = 870 from Finland), and 245 nursing students responded (n = 228 from the Philippines, and n = 17 from Finland), with an overall response rate of 16% (33% response rate from the Philippines, and 2% response rate from Finland). The main reason for the low response rate was that the data were collected during the COVID-19 pandemic time. Other reasons were lack of interest in the topic, lack of time, and student workloads.

Inclusion and Exclusion Criteria

Participants were included if they were (a) undergraduate nursing students of any year level; (b) studying in government institutions; and (c) willing to participate voluntarily. Participants were excluded

if they were (a) graduate nursing students; (b) studying in private institutes; or (c) employed and unemployed nurses.

Data Collection

The data were collected electronically using an electronic platform from Finnish and Filipino nursing students. The use of a convenience sample was appropriate in this study, as screening was first undertaken to identify whether the student had taken any genetics-genomics or biology courses.

The English version of the Genomic Nursing Concept Inventory (GNCI© 2017) was used in the Philippines, because English is used in teaching and represents the country's second official language. In Finland, both the English and Finnish versions of the GNCI were used to assist local and international students. Recruitment of undergraduate students was facilitated via email with the help of Finnish and Filipino department heads, deans and directors, and other individuals in leadership positions. Postings targeted to specific students were placed on their learning management system. The postings described the study and how to participate, and were placed there by the first author (A.P.). In Finland, both face-to-face and online recruitment were conducted. In the Philippines, a 30-minute online webinar was arranged to describe the study and recruit participants. The key people recontacted the students twice to increase the response rate. To facilitate the accuracy of the collected data, the students were instructed not to use any resources when answering the GNCI.

Instrument

We obtained permission from the author of the GNCI© to use the instrument in Finland and the Philippines. The GNCI© 2017 is a 31-item English-language scale with demonstrated validity and reliability (Cronbach's alpha values between 0.73 and 0.83) (Ward et al., 2014). The Finnish version of the GNCI demonstrated a Cronbach's alpha value of "good" ($\alpha = 0.816$; 95% confidence interval: 0.567-0.956) (Dumo et al., 2022). The GNCI was used to determine the participants' level of genetic-genomic knowledge. The GNCI items assess the understanding of genetic-genomic concepts relevant to nursing practice and identify specific targets for education (Ward et al., 2014). The following demographic data were also collected: age, sex, institution, year level, native language, and whether they have completed any genetic-genomics courses or any biology courses. The latter data point was important in data collection, as it will provide insight into the effectiveness of existing genetics and biology course content in the nursing curricula.

Data Analysis

IBM SPSS Statistics version 27 was used to calculate descriptive and inferential statistics. Kolmogorov–Smirnov and Shapiro-Wilk were used to test the normal distribution of the variables of age and total GNCI score. The Mann–Whitney U test—level of significance 0.05—was used to calculate the difference in the dependent variable (total GNCI scores) for independent groups: sex, country, and completion of a biology course. The independent samples Kruskal–Wallis test was used to compare total GNCI scores to participants' year level and whether respondents had completed a genetics–genomics course for academic credit. Fisher's exact test was used to determine if there were significant differences between the two participating countries and GNCI items. Item-analysis was used to analyze the student's responses on the 31-item GNCI and the relationship between them (Rezigalla, 2022).

Results

The Participants' Background

A total of 245 nursing students participated in the study (n = 17 from Finland, and n = 228 from the Philippines). The demographic data are presented in Supplementary Material Table 2. The age of the respondents ranged from 17 to 46 years; Filipino students' mean age was lower (20 years) than that in Finland (28 years). The majority of the respondents were female (88.24% in Finland, and 86.40% in the Philippines), and approximately half of the respondents were at the first-year level (47.06% in Finland, and 43.86% in the Philippines). Few of the respondents from the Philippines had completed any genetics or genomics courses for academic credit (25% in the Filipino cohort), while none of the respondents from Finland had completed any (0% in the Finnish cohort). Sixty percent of respondents from the Filipino cohort reported having completed a biology course, as did 53% of Finnish students.

Literacy in Genomics and Genetics

Overall, scores on the GNCI were low to high, ranging from 2 to 31 (out of a possible 31). In this study, scores among the Filipino cohort were higher compared to the Finnish cohort (58% mean score in the Filipino cohort, and 36% mean score in the Finnish cohort), with a mean score of 16.21 correct in the Filipino cohort and 9.53 correct in the Finnish cohort (95% confidence intervals). Supplementary Material Table 3 shows that the results of the Mann-Whitney U test reveals statistically significant differences between the nursing students from the Filipino cohort and the Finnish cohort (p-value = .023). Our study found statistically significant differences between male and female respondents in relation to their genomic knowledge (p-value = .022): females had better GNCI scores than their male counterparts.

There were no significant statistical differences between the genomics knowledge scores and completion of biology (p-value = .188) or genetics-genomics courses (p-value = .981). This means that regardless of whether students had completed a previous biology course or a previous genetics and genomics course, the GNCI scores were the same. In addition, the independent samples Kruskal–Wallis test showed no statistically significant differences between GNCI scores and students' year levels (p-value = .509). This means that regardless of whether students were in the first, second, third, or fourth year in their studies, the GNCI scores were the same. Our study results indicate an existing lack of genomics knowledge, and this implies that the current nursing curriculum requires reconstruction, which should include discussions with nursing leaders and national accrediting organizations that mandate essentials within the curriculum. In Finland, the national regulations derive from European Union directives (2013/55/EY), EU Council regulations (77/452/ETY, 2001/19/EY, 2005/36/EY), the Decree on Polytechnics 352/20023, and national Supervisory Authority for Welfare and Health (Valvira). In the Philippines, the Commission on Higher Education, the Philippine Nursing Act of 2002, RA 9173, and the Philippine Regulatory Commission determine the national regulations.

Supplementary Material Table 4 shows the respondents' performance on the GNCI©. Respondents from the Filipino cohort performed better in their responses to the question about "Mutations and disease" (Question 21, 75% answered correctly), the concept "Autosomal dominant" (Question 30, 74% answered correctly), and the topical category "Genome basics" (Question 2, 73% answered correctly). Respondents from the Finnish cohort performed better in their responses to the question about "Genetic testing" (Question 14, 76% answered correctly), the concept "Genome basics" (Question 2, 65% answered correctly), and the concept "Family history" (Question 26, 65% answered correctly). In contrast, respondents from the

Filipino cohort performed least well in response to the question about genotype-phenotype association. As an example, this question asked students to distinguish genotype from phenotype. Students who answered (b) had them reversed; 46% of students knew that all cells contain the same genes, while 47% could correctly describe the function of a gene. Respondents from the Finnish cohort performed least well in response to the question about "Human genome homogeneity" (Question 3, 12% answered correctly), the concept "Genome composition and organization" (Questions 4 and 8, 12% answered correctly), and the concept "Autosomal inheritance" (Question 24, 18% answered correctly). For five items, the mean correct response percentage was $< 50\%$ among respondents from the Filipino cohort compared to 24 items with $< 50\%$ correct responses in the Finnish cohort. Fisher's exact test showed statistically significant differences on 12 items with a p-value (two-sided) lower than 0.05 level of significance. Respondents from the Filipino cohort performed higher in GNCI items specifically in gene function (Items 1 and 6, p-value = .048; .005 respectively), human genome homogeneity (Item 3, p-value $<$ .001), genome organization (Items 4 and 8, p-value = .001; $<$.001 respectively), gene expression (Item 11, p-value = .040), germline/somatic mutations (Item 18, p-value = .043), cancer genotyping (Item 20, p-value = .042), family history/red flags (Item 23, p-value = .044), inheritance of autosomal mutations (Item 24, p-value = .004), pharmacogenomics (Item 27, p-value = .047), and heterozygosity in autosomal dominant conditions (Item 29, p-value = 0.002) compared to respondents from the Finnish cohort. The scale reliability measure showed a Cronbach's α of 0.949, indicating a high internal reliability of the whole GNCI.

Discussion

Our study evaluated the genetic and genomic literacy in Finnish and Filipino nursing students. Our findings demonstrate the need to bridge these students' knowledge gaps. Acquiring adequate levels of genetic and genomic literacy is important to achieve genomics competency in nursing practice (Majstorović et al., 2021). Genomics knowledge acquisition is important to accelerate genomics integration into healthcare and improve patient outcomes (Calzone et al., 2018). Our findings are consistent with those of other international studies demonstrating the lack of nurses' genomic literacy (Dewell et al., 2020; Majstorović et al., 2021; McCabe et al., 2016; Read & Ward, 2016; Ward et al., 2016; Wright et al., 2019). Finnish and Filipino nursing students' genomic literacy was weakest in basic genomic concepts, particularly in the areas of human genome homogeneity and genotype-phenotype association, similar to the results from Europe, Australia, Canada, and the USA. Majstorović et al. (2021) identified low genomic literacy in Croatian undergraduate students; Dewell et al. (2020) found low GNCI scores among nursing students and faculty in Canada; Wright et al. (2019) reported a low mean GNCI score in Australia among registered nurses and midwives; McCabe et al. (2016), Read and Ward (2016), and Ward et al. (2016) highlighted low genomic literacy among practicing nurses, nursing students, and nursing faculty in the USA. Our results are similar to those of a large cohort study by Dagan et al. (2021) among Israeli nurses. They found that, compared to male nurses, female nurses had more genomic knowledge and performed more genomic practices. In contrast, Dewell et al. (2020) found that male nurses achieve better GNCI scores in a Canadian cohort. This implies that it is important for nurse educators to conduct an initial genomics literacy assessment using a validated tool on the target population of learners to have an overview of existing knowledge gaps. This step is essential when developing and designing genomics nursing courses to facilitate efficient learning processes and evidenced-based teaching.

A genomic literacy assessment must precede the curriculum development to overcome knowledge shortfalls. As an example of how measuring literacy can inform curricular development, using the GNCI tool, nurse educators can recognize where student knowledge is very weak, and this can help an educator in designing a course and creating learning activities to rectify the knowledge deficit in the curriculum. In our study, we found that students have misconceptions regarding a person's genotype; 49% answered incorrectly that genotype is the traits and characteristics determined by their genes. A nurse educator can then use this information to formulate appropriate genomics nursing courses and learning materials such as web-based courses, video clips, online resources, flipped learning approaches, and so on.

Low nursing genomic literacy is due to multifactorial educational barriers. These obstacles include deficient genomic knowledge among educators, crowded curricula, inadequate time, and lack of regulatory legislation requiring genomic competency (Calzone et al., 2018; Majstorović et al., 2021). Two factors are crucial, one of which is the lack of nursing leaders in designing curricula; the other is nurse trainers' reluctance to consider alternative approaches that facilitate integrating new knowledge and clinical advances (Calzone et al., 2018). Similarly, Abad and Sur (2022) reported various other issues that impede the expansion of nurses' roles in genetics and genomic competency in clinical practice.

Although, we cannot generalize the Finnish results with such a small sample and further research is needed using larger cohort groups. The value of our study is that our methodology and results can help nurse educators to design tailored genetics and genomics nursing education based on evidence. Our findings could inform the development of any educational interventions. We suggest that genomics nursing education be included in the nursing curriculum as a stand-alone or elective course to overcome curriculum implementation challenges. Our suggestion is supported by Fangonil-Gagalang and Schultz (2021); Fater (2014); the International Society of Nurses in Genetics (2022); and Zureigat et al. (2022). We suggest that nurse educators, especially those who are novices in genomics concepts, use the available genomics education resources repository published by the International Society of Nurses in Genetics (ISONG) global membership and education committees (Fater, 2014; International Society of Nurses in Genetics, 2022). Our results make an important scientific contribution by expanding our understanding of the magnitude of the knowledge problem of the lack of genetics and genomics literacy among nurses.

When incorporating genomics knowledge into nursing curricula, basic principles of genomics, omics, precision medicine, precision health, nurses' role, practical nursing applications, and the ethical, legal, and social implications of genetic-genomic concepts need to be addressed. Educational nursing preparation to integrate genomics empowers nurses to engage patients, families, and communities to promote healthier behaviors (Campion et al., 2019; Laaksonen et al., 2022; Majstorović et al., 2021; Saleh et al., 2019). For example, nurses who are knowledgeable about cancer genomics could provide better support in patient education and family counselling. Nurses who are knowledgeable about the genetics and genomics of Alzheimer's disease could provide a better understanding of the disease process, which can help in creating personalized nursing care. Nurses who are knowledgeable about pharmacogenomics and medication safety could better ensure patient safety. Nurses who are knowledgeable about the genomics of diabetes could provide better quality of nursing care. Ultimately, nurses who are educated and knowledgeable about genomics-informed nursing care can facilitate evidence-based practices to improve patient outcomes.

Limitations and Recommendations

The large difference between participants by country (n = 17 for Finland, n = 228 for the Philippines) makes comparisons inaccurate

and difficult. Results cannot be generalized. The results from Finland should be interpreted carefully because the research did not examine how much the nursing curriculum relies on biology taught in other courses.

In this study, researchers did not have control over the possibility of respondents using internet searches while answering the GNCI tool. The response rate was low and based on a convenience sample. The COVID-19 restrictions and other factors, such as students' workload, lack of interest in the topic, and lack of time to participate, explained the low response rate in general. Nonetheless, although the survey response rate was lower than expected, we still had enough responses to conduct some analyses, although there may be a selection bias. Our study findings provide a valuable snapshot of genomic literacy among undergraduate nursing students, and a solid starting point for the development of a nationally and internationally adapted curriculum.

Conclusion

The literacy in genetic and genomics knowledge and its application to the clinical situation in a cohort of nursing students from Finland and the Philippines is low to moderate. The understanding of genomic and genetic basic concepts was weakest particularly in the areas of the human genome homogeneity and genotype-phenotype associations. The study findings provide specific information about the concepts nursing students do and do not understand, which can be leveraged to inform evidence-based education. Designing effective and targeted educational programs and updating nursing curricula is necessary to ensure that the next generation of nurses are prepared in advanced genomics, as well as in personalized health care, in order for them to practice evidence-based clinical care.

Funding

This research was funded by the Department of Nursing Science, Faculty of Health Sciences, University of Eastern Finland; the Marja-Terttu Korhonen Foundation (2019 scholarship); the Finnish Nursing Education Foundation (2021 scholarship); and the Finnish Cultural Foundation North Savo Regional Fund (2022 scholarship).

Declaration of Competing Interest

None.

Acknowledgments

The authors wish to thank the nursing students who voluntarily participated in the study.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.teln.2022.11.013.

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The integration of genomics across the nursing education is an important component to optimize the benefits of precision medicine. This dissertation provides evidence of sustained learning through testing the effectiveness of an online educational intervention using RCT study design. The study has provided cohort-evidence-based findings that can facilitate in designing tailored online genomics nursing course that can bridge existing genomics knowledge gaps.

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**PUBLICATIONS OF
THE UNIVERSITY OF EASTERN FINLAND**
Dissertations in Health Sciences

ISBN 978-952-61-5004-8
ISSN 1798-5706