International Journal of Nursing and Health Care Research
Jang A and Song CE. Int J Nurs Health Care Res 7: 1599
www.doi.org/10.29011/2688-9501.101599
www.gavinpublishers.com

Review Article

Future Direction of IoT-Based Platforms in Undergraduate Nursing Education: A Scoping Review

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Citation: Jang A and Song CE (2024) Future Direction of IoT-Based Platforms in Undergraduate Nursing Education: A Scoping Review. Int J Nurs Health Care Res 7: 1599. DOI: https://doi.org/10.29011/2688-9501.101599

Received Date: 08 October, 2024; **Accepted Date:** 12 November, 2024; **Published Date**: 15 November, 2024

Abstract

Background: An Internet of Things based platform infrastructures connected via the internet and can lay the foundation for the best learning method for future undergraduate nursing education. If we understand the current state of research on IoT platforms in undergraduate nursing education, it can be used as a reference for developing IoT platforms for undergraduate nursing education. **Objective:** This study proposes the future direction of the IoT-based platform used in undergraduate nursing education. **Design:** From January 1, 2015, to August 12, 2022, databases such as PubMed, Embase, and Cochrane Library and Cumulative Index to Nursing & Allied Health were used to identify research discussing the application IoT platforms and other scientific technologies in nursing education. **Results:** A total of 16 papers were selected out of 6,880. Technical barriers such as battery problems, integration methods, connectivity, complexity, and lack of communication were presented as barriers against using IoT platforms. In addition, there were learner-side barriers, such as difficulties in self-management, adaptation, and personal information problems, and teacher-side barriers, such as the need for a tutor, the difficulty of satisfying the requirements of interdisciplinary studies, inappropriate content, lack of participants, and lack of evaluation methods. The facilitating factors for IoT platforms included the positive implications of their role in supporting learning, environmental factors such as the adoption of various teaching strategies and problem-solving methods, and their capacity to enhance interactive communication. **Conclusions:** Developing IoT platforms for future undergraduate nursing education requires active interdisciplinary research and efforts toward establishing new teaching methods incorporating cutting-edge technologies. To this end, interdisciplinary efforts are needed to create a quality undergraduate nursing education system by considering barriers and facilitating factors discussed in this study.

Keywords: Education; Nursing; Internet of Things; Review

Strengths and Limitations of This Study

- This study systematically conducted a scoping review following a predeveloped protocol, and the search process can be highly trusted due to the keyword selection and literature search conducted by search experts.
- This study focuses on Internet of Things (IoT) platforms used in undergraduate nursing education. However, considering the global trend toward digitalized education, the future directions for the IoT platforms suggested in this study through the facilitating factors and barriers can attract international interest.
- Because the scope of this study was limited to classes within schools, excluding IoT platforms as an alternative to clinical practice, it is difficult to draw a generalized conclusion.

Introduction

Internet of Things (IoT) are everyday objects and devices connected through wireless networks [1] thus, these objects allow the uninterrupted exchange of information with a wireless internet connection, regardless of time and location. The term "platform" means "flat raised area or structure" and means various things, including a subway platform for people to get on and off, a podium for public speaking, and a specific type of computer technology that cannot be shared with other programs [2]. In education, an IoT-based platform refers to a collection of connected technologies and infrastructures that enable communication through the Internet and a set of relationships and networks that promote participation and collaboration.

In future education, IoT-based platforms serve as a collection of values and principles that determine the purpose and direction of education, influencing the content, curriculum, evaluation, and teaching methods [3]. In particular, in times of pandemics, natural disasters, and wars, IoT-based platforms provide educational access for learners who cannot physically be present in classrooms due to safety, health, or mobility issues [4]. Given that each learner has different learning styles, preferences, or requirements, IoT-based platforms not only provide various learning resources and activities to supplement and enhance face-to-face education when hybrid learning is needed but also allow learners to progress at their own pace and choose their learning paths and goals when individual learning is required, such as when learners have different prior knowledge, skills, or interest levels [5].

IoT-based platforms can be optimized for personalized learning in various situations. Therefore, understanding how IoT technology is being used in education is essential to prepare for future education.

Undergraduate nursing education has faced issues and limitations with traditional in-classroom teaching strategies, such as lack of student participation, insufficient feedback, and difficulty applying evidence-based learning in real clinical situations [6]. To overcome these problems and limitations, research is being conducted on hybrid learning, which uses online platforms or resources like IoT-based education to provide part or all of the course content [7]. However, most research has focused on literature that virtualizes simulations as alternatives to clinical education [8-11]. If students have solid and accurate theoretical knowledge for the right time before clinical practice, it will be a strong foundation for building knowledge for clinical practice. Meaningfully structured knowledge will allow them to effectively and efficiently search and apply it during clinical practice [12]. In other words, the robust knowledge structure of IoT-based platforms can be the basis for improving the quality of future undergraduate nursing education.

A scoping review is an evidence synthesis that aims to provide a comprehensive overview of the available literature on a broad topic. Its goal is to identify and map evidence organized and transparently about important concepts, sources, gaps, and issues related to the topic [13]. A scoping review increases the overall understanding of the research topic and helps gain new ideas by identifying the trends and future directions of the topic [14-16]. Therefore, conducting a scoping review on the use of IoT platforms in undergraduate nursing education can enhance the current understanding of how IoT platforms are used in nursing education, identify the direction and future trends of research and serve as a foundation for generating ideas for a new undergraduate nursing education based on IoT platforms.

Scoping reviews in nursing education have been conducted, such as a scoping review on guidelines for nursing and midwifery students [17], and a scoping review on team-based learning in nursing education [18]. There have also been studies on IoT-based platforms in undergraduate nursing education, such as researching platforms for learning nursing processes for home visits [19] and developing platforms for learning nursing processes for various cases [20]. However, a scoping review of IoT-based platforms used in undergraduate nursing education is difficult to find.

As a result, this research conducts a scoping review to propose the direction of IoT-based platforms for future undergraduate nursing education.

The following research questions were formulated:

1. What are the characteristics of the IoT platform educators and nursing students use in undergraduate nursing education?
2. What are the scientific and technological characteristics and scope of the IoT platforms used in nursing undergraduate education?

3. What are the barriers and facilitating factors of IoT platforms used in undergraduate nursing education to prepare for the future nursing education environment?

Methods and Analysis

Protocol and Registration

The protocol was drafted using the Preferred Reporting Items for Systematic Reviews and Meta-analysis Protocols (PRISMA-P) and revised by the research team and contributing members [21]. The finalized protocol was registered prospectively with the Open Science Framework (OSF) on September 7, 2021 (https://doi.org/10.17605/OSF.IO/DHZFR).

Eligibility Criteria

All studies focused on nursing students included in undergraduate nursing programs were incorporated in the scoping review. All literature that discusses the use of scientific technologies of IoT platforms in undergraduate nursing education was also included. This research limited the context to undergraduate nursing education programs, excluding graduate nursing aide, maternity nurse courses, and nurse training institutions. Eligible research is not limited to geographical limitations. The study design was not limited, but those without discernible content related to IoT platforms were excluded. All reports that utilized the IoT platform technology were included. Still, given the large volume of literature about VR platforms in undergraduate nursing education, the eligibility was limited to theoretical undergraduate nursing courses, excluding studies on scenario development for simulations or performance checklists. While there were no constraints on the form of literature, editorial formats and personal opinions for which the content could not be determined were excluded. As the advent of IoT was mentioned in the 2015 Davos Forum [22], research before 2015 was not considered. This study did not give particular attention to the research design, and language was restricted to English or works providing English translations. The specific eligibility criteria are outlined in Table 1.

Criterion	Inclusion	Exclusion
Population	A study involving nursing students under a nursing-related curriculum of an undergraduate nursing program	A study involving nurses, patients, and nursing graduate students
		Nursing students were used only as a control group
Concept	A platform used as an alternative to classroom education	A study evaluating the level of an online evaluation tool, such as a simple performance checklist
		Scenario development for simulation and research on effects
		Satisfaction study of web-based education without contents on IoT platform
Context	Include the educational setting of an undergraduate nursing program, and eligible research is not limited to geographic limitations.	Nonprofessional degree education
		A platform for providing simple data
		A platform for taking the national exam for nurses
		A document in the form of a personal opinion

Published period: January 1, 2015 -August 12, 2022
Language: English

Table 1: Inclusion criteria for the scoping review

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Information Sources

To search for relevant documents, databases such as PubMed (NCBI), Embase (Elsevier), Cochrane Library and Cumulative Index to Nursing & Allied Health (CINAHL) were searched during the period from January 1, 2015, to August 12, 2022.

Search

The final search strategy in Pubmed can be found in Table S1.

DB	No.	Search	Result	PICO
PubMed	#1	"Students, Nursing"[Mesh]	28,832	
	#2	"Students, Nursing"[TIAB] OR "Pupil Nurses"[TIAB] OR "Student, Nursing"[TIAB] OR "Nurses, Pupil"[TIAB] OR "Nurse, Pupil"[TIAB] OR "Pupil Nurse"[TIAB] OR "Nursing Student"[TIAB] OR "Nursing Students"[TIAB] OR "nurse student"[TIAB] OR "student nurse"[TIAB]	20,247	
	#3	"Nursing"[Mesh]	261,261	
	#4	"Nursing"[TIAB] OR "Nursings"[TIAB] OR "nursing service"[TIAB] OR "nursing service, hospital"[TIAB] OR "nursing services"[TIAB] OR "nursing support"[TIAB] OR "nursing, private duty"[TIAB] OR "nursing, supervisory"[TIAB] OR "office nursing"[TIAB] OR "private duty nursing"[TIAB] OR "science of nursing"[TIAB]	300,900	
	#5	"Education, Nursing"[Mesh]	87,942	
	#6	"Education, Nursing"[TIAB] OR "Nursing Education"[TIAB] OR "Educations, Nursing"[TIAB] OR "Nursing Educations"[TIAB] OR "education, nursing"[TIAB] OR "education, nursing, associate"[TIAB] OR "education, nursing, baccalaureate"[TIAB] OR "education, nursing, continuing"[TIAB] OR "education, nursing, diploma programmes"[TIAB] OR "education, nursing, diploma programs"[TIAB] OR "education, nursing, graduate"[TIAB] OR "faculty, nursing"[TIAB] OR "nurse education"[TIAB] OR "nursing education research"[TIAB] OR "nursing faculty"[TIAB] OR "nursing school"[TIAB] OR "schools, nursing"[TIAB]	23,686	
	#7	"Education, Nursing, Baccalaureate"[Mesh]	20,379	
	#8	"Education, Nursing, Baccalaureate"[TIAB] OR "External Degree Programs, Nursing"[TIAB] OR "Nursing Education, Baccalaureate"[TIAB] OR "Baccalaureate Nursing Education"[TIAB] OR "Baccalaureate Nursing Educations"[TIAB] OR "Education, Baccalaureate Nursing"[TIAB] OR "Educations, Baccalaureate Nursing"[TIAB] OR "Nursing Educations, Baccalaureate"[TIAB] OR "undergraduate education"[TIAB] OR "baccalaureate education"[TIAB] OR "bachelor degree education"[TIAB] OR "bachelor education"[TIAB] OR "bachelor's degree (BS/BA) education"[TIAB] OR "bachelor's degree education"[TIAB] OR "bachelor's education"[TIAB] OR "bachelors education"[TIAB] OR "BSc education"[TIAB] OR "undergraduate"[TIAB] OR "bachelor"[TIAB]	7,253	
	#9	#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8	504,342	P: "Students, Nursing," "Nursing"
	#10	"Internet of Things"[Mesh]	770	
	#11	"Internet of Things"[TIAB] OR "internet of thing"[TIAB] OR "internet of vehicles"[TIAB] OR "IoT"[TIAB] OR "IoT Platform"[TIAB]	6,268	
	#12	"MMORPG (game)"[TIAB] OR "Massive Multiplayer Online Role-Playing Game"[TIAB] OR "massive multi-player online role-playing game"[TIAB] OR "massive multiplayer online roleplaying game"[TIAB] OR "massively multiplayer online role playing game"[TIAB] OR "massively multiplayer online roleplaying game"[TIAB] OR "MMORPG"[TIAB]	51	
	#13	"metaverse"[TIAB] OR "zepeto"[TIAB] OR "roblox"[TIAB] OR "V-sim"[TIAB] OR "Second Life"[TIAB] OR "Digital Virtual World"[TIAB]	382	
	#14	"Cloud Computing"[Mesh]	1,164	
	#15	"Cloud Computing"[TIAB] OR "Computing, Cloud"[TIAB] OR "Cloud Processing"[TIAB] OR "Processing, Cloud"[TIAB] OR "Cloud Storage"[TIAB] OR "Cloud Storages"[TIAB] OR "Storage, Cloud"[TIAB] OR "Storages, Cloud"[TIAB] OR "Cloud Service"[TIAB] OR "Service, Cloud"[TIAB] OR "cloud"[TIAB]	17,883	
	#16	"Artificial Intelligence"[Mesh]	152,367	
	#17	"Artificial Intelligence"[TIAB] OR "Intelligence, Artificial"[TIAB] OR "Computational Intelligence"[TIAB] OR "Intelligence, Computational"[TIAB] OR "Machine Intelligence"[TIAB] OR "Intelligence, Machine"[TIAB] OR "Computer Reasoning"[TIAB] OR "Reasoning, Computer"[TIAB] OR "AI (Artificial Intelligence)"[TIAB] OR "Computer Vision Systems"[TIAB] OR "Computer Vision System"[TIAB] OR "System, Computer Vision"[TIAB] OR "Systems, Computer Vision"[TIAB] OR "Vision System, Computer"[TIAB] OR "Vision Systems, Computer"[TIAB] OR "Knowledge Acquisition (Computer)"[TIAB] OR "Acquisition, Knowledge (Computer)"[TIAB] OR "Knowledge Representation (Computer)"[TIAB] OR "Knowledge Representations (Computer)"[TIAB] OR "Representation, Knowledge (Computer)"[TIAB]	25,956	
	#18	"Virtual Reality"[Mesh]	4,714	
	#19	"Virtual Reality"[TIAB] OR "Reality, Virtual"[TIAB] OR "Virtual Reality, Educational"[TIAB] OR "Educational Virtual Realities"[TIAB] OR "Educational Virtual Reality"[TIAB] OR "Reality, Educational Virtual"[TIAB] OR "Virtual Realities, Educational"[TIAB] OR "Virtual Reality, Instructional"[TIAB] OR "Instructional Virtual Realities"[TIAB] OR "Instructional Virtual Reality"[TIAB] OR "Realities, Instructional Virtual"[TIAB] OR "Reality, Instructional Virtual"[TIAB] OR "Virtual Realities, Instructional"[TIAB] OR "VR"[TIAB]	20,196	
	#20	"Augmented Reality"[Mesh]	870	
	#21	"Augmented Reality"[TIAB] OR "Augmented Realities"[TIAB] OR "Realities, Augmented"[TIAB] OR "Reality, Augmented"[TIAB] OR "Mixed Reality"[TIAB] OR "Mixed Realities"[TIAB] OR "Realities, Mixed"[TIAB] OR "Reality, Mixed"[TIAB] OR "AR"[TIAB] OR "MR"[TIAB]	228,849	
	#22	"platform"[TIAB] OR "virtual learning environment"[TIAB] OR "e-learning environment"[TIAB] OR "e-learning platform"[TIAB] OR "electronic education platform"[TIAB] OR "electronic educational platform"[TIAB] OR "electronic learning environment"[TIAB] OR "electronic learning platform"[TIAB] OR "virtual learning platform"[TIAB]	176,629	
	#23	#10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22	599,037	I: IoT Platform
	#24	"Computing Methodologies"[Mesh]	1,147,942	
	#25	"Computing Methodologies"[TIAB] OR "Methodologies, Computing"[TIAB] OR "Computing Methodology"[TIAB] OR "Methodology, Computing"[TIAB] OR "High Performance Computing"[TIAB] OR "Computing, High Performance"[TIAB] OR "Performance Computing, High"[TIAB] OR "computer analysis"[TIAB] OR "analysis, computer"[TIAB] OR "computer assisted analysis"[TIAB] OR "computer assistance"[TIAB] OR "computer supported collaborative"[TIAB] OR "computer supported collaboration"[TIAB]	8,453	
	#26	"Electronics"[Mesh] OR "Electronics"[TIAB] OR "Electronic"[TIAB]	365,930	
	#27	"Digital Technology"[Mesh]	495	
	#28	"Digital Technology"[TIAB] OR "Digital Technologies"[TIAB] OR "Technologies, Digital"[TIAB] OR "Technology, Digital"[TIAB] OR "Digital Electronics"[TIAB] OR "Electronics, Digital"[TIAB] OR "edutech"[TIAB] OR "edu-tech"[TIAB] OR "high technology"[TIAB] OR "remote"[TIAB]	95,228	
	#29	"Technology"[Mesh]	478,776	
	#30	"Technology"[TIAB] OR "Industrial Arts"[TIAB] OR "Arts, Industrial"[TIAB] OR "high technology"[TIAB] OR "technician trainee"[TIAB] OR "technological society"[TIAB] OR "technologics"[TIAB] OR "technology transfer"[TIAB] OR "High tech"[TIAB]	409,519	
	#31	"Internet"[Mesh]	93,437	
	#32	"Internet"[TIAB] OR "Internet"[TIAB] OR "World Wide Web"[TIAB] OR "Web, World Wide"[TIAB] OR "Wide Web, World"[TIAB] OR "Cyberspace"[TIAB] OR "Cyber Space"[TIAB] OR "webinar"[TIAB] OR "internet connection"[TIAB] OR "on-line seminar"[TIAB] OR "online semina"[TIAB] OR "web seminar"[TIAB] OR "web-based seminar"[TIAB] OR "online"[TIAB] OR "on-line"[TIAB] OR "Cyber"[TIAB] OR "Online Education"[TIAB] OR "Real-Time Online Education"[TIAB] OR "Untact online education"[TIAB]	266,300	
	#33	"Internet-Based Intervention"[Mesh]	988	
	#34	"Internet-Based Intervention"[TIAB] OR "Internet Based Intervention"[TIAB] OR "Internet-Based Interventions"[TIAB] OR "Intervention, Internet-Based"[TIAB] OR "Interventions, Internet-Based"[TIAB] OR "Web-based Intervention"[TIAB] OR "Intervention, Web-based"[TIAB] OR "Interventions, Web-based"[TIAB] OR "Web based Intervention"[TIAB] OR "Web-based Interventions"[TIAB] OR "Online Intervention"[TIAB] OR "Intervention, Online"[TIAB] OR "Interventions, Online"[TIAB] OR "Online Interventions"[TIAB] OR "Internet Intervention"[TIAB] OR "Internet Interventions"[TIAB] OR "Intervention, Internet"[TIAB] OR "Interventions, Internet"[TIAB] OR "web-based intervention"[TIAB] OR "internet-intervention"[TIAB] OR "online-based intervention"[TIAB] OR "online-intervention"[TIAB] OR "web intervention"[TIAB] OR "Internet Based"[TIAB] OR "Web based"[TIAB] OR "Web based education"[TIAB] OR "Web based learning"[TIAB] OR "Web based program"[TIAB] OR "Online based education"[TIAB] OR "Online based learning"[TIAB] OR "Online based program"[TIAB] OR "Web"[TIAB] OR "untact"[TIAB] OR "Not contact"[TIAB] OR "non face to face"[TIAB] OR "Blended learning"[TIAB]	171,106	
	#35	"Education, Distance"[Mesh]	61,00	
	#36	"Education, Distance"[TIAB] OR "Distance Education"[TIAB] OR "Distance Learning"[TIAB] OR "Learning, Distance"[TIAB] OR "Online Learning"[TIAB] OR "Learning, Online"[TIAB] OR "Online Education"[TIAB] OR "Education, Online"[TIAB] OR "Online Educations"[TIAB] OR "Correspondence Courses"[TIAB] OR "Correspondence Course"[TIAB] OR "Course, Correspondence"[TIAB] OR "tele-education"[TIAB] OR "teleeducation"[TIAB] OR "virtual classroom"[TIAB] OR "virtual education"[TIAB] OR "Learning sciences"[TIAB] OR "e-learning"[TIAB] OR "e-schooling"[TIAB] OR "electronic education"[TIAB] OR "electronic educational technology"[TIAB] OR "electronic learning"[TIAB] OR "on-line education"[TIAB] OR "on-line learning"[TIAB] OR "online education"[TIAB] OR "online learning"[TIAB] OR "online schooling"[TIAB] OR "web-based nurse education"[TIAB] OR "internet-based e-learning"[TIAB]	12,036	
	#37	"Computer Communication Networks"[Mesh]	107,101	
	#38	"Computer Communication Networks"[TIAB] OR "Communication Network, Computer"[TIAB] OR "Communication Networks, Computer"[TIAB] OR "Computer Communication Network"[TIAB] OR "Network, Computer Communication"[TIAB] OR "Networks, Computer Communication"[TIAB] OR "Databases, Distributed"[TIAB] OR "Database, Distributed"[TIAB] OR "Distributed Database"[TIAB] OR "Distributed Databases"[TIAB] OR "Telecommunication Networks"[TIAB] OR "Network, Telecommunication"[TIAB] OR "Networks, Telecommunication"[TIAB] OR "Telecommunication Network"[TIAB] OR "Extranets"[TIAB] OR "Extranet"[TIAB] OR "Intranets"[TIAB] OR "Intranet"[TIAB] OR "Network Communication Protocols"[TIAB] OR "Communication Protocol, Network"[TIAB] OR "Communication Protocols, Network"[TIAB] OR "Network Communication Protocol"[TIAB] OR "Protocol, Network Communication"[TIAB] OR "Protocols, Network Communication"[TIAB] OR "Computer Network Management"[TIAB] OR "Management, Computer Network"[TIAB] OR "Network Management, Computer"[TIAB] OR "Distributed Systems"[TIAB] OR "Distributed System"[TIAB] OR "System, Distributed"[TIAB] OR "Systems, Distributed"[TIAB] OR "computer network"[TIAB] OR "computer network router"[TIAB]	2,401	
	#39	"Computer Simulation"[Mesh]	279,972	
	#40	"Computer Simulations"[TIAB] OR "Simulation, Computer"[TIAB] OR "Simulations, Computer"[TIAB] OR "Models, Computer"[TIAB] OR "In silico Simulation"[TIAB] OR "Simulation, In silico"[TIAB] OR "Computerized Models"[TIAB] OR "Computerized Model"[TIAB] OR "Model, Computerized"[TIAB] OR "Computer Models"[TIAB] OR "Computer Model"[TIAB] OR "Model, Computer"[TIAB] OR "In silico Models"[TIAB] OR "In silico Model"[TIAB] OR "Model, In silico"[TIAB] OR "Computational Modelling"[TIAB] OR "Modelling, Computational"[TIAB] OR "Computational Modeling"[TIAB] OR "Modeling, Computational"[TIAB] OR "In silico Modeling"[TIAB] OR "Modeling, In silico"[TIAB] OR "computational simulation"[TIAB] OR "computer-based simulation"[TIAB] OR "in silico simulation"[TIAB] OR "Web-based simulation"[TIAB] OR "Online Simulation"[TIAB]	36,956	
	#41	"Smartphone"[Mesh]	8,049	
	#42	"Smartphone"[TIAB] OR "Smartphones"[TIAB] OR "Smart Phones"[TIAB] OR "Smart Phone"[TIAB] OR "Phones, Smart"[TIAB] OR "smart phone"[TIAB] OR "smartphones"[TIAB] OR "Mobile"[TIAB] OR "tablet"[TIAB]	163,325	
	#43	#24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 OR #34 OR #35 OR #36 OR #37 OR #38 OR #39 OR #40 OR #41 OR #42	2,615,850	O: technology
	#44	#9 AND #23 AND #43	2280	P AND I AND O

Note: PubMed is the sole source of samples

Table S1: Search strategy for the current study

Selection of Source of Evidence

References retrieved through an information search expert [23] were imported into Endnote ver. 20.0.0 (Clarivate Analytics, Pennsylvania, USA), and duplicates were removed. Final data retrieved via the information searcher based on the title and abstract were screened following the established inclusion criteria. Subsequently, full texts of relevant studies were researched and selected. In cases where there was a discrepancy in opinion, it was rediscussed. Finally, the selected pieces of full-text literature were reviewed to determine if they met the inclusion criteria. In contrast, full-text articles were examined to determine if they followed the "narrow and well-defined" inclusion criteria. In this process, ambiguous cases were discussed multiple times.

Data Charting Process

In the data charting process pilot phase, the data that were difficult to extract because detailed content was not described, such as perception equipment, access unit, access network, middleware, application, and judge server, were integrated as technology utilization. System-related aspects of learners and teachers were integrated as functions using the system. To further specify the characteristics of the study, "Content" and "Teaching method" were added to the analytical framework. Data were extracted using Excel based on the developed protocol.

Data Items

The general characteristics of the extracted studies were categorized into authors, affiliation, Publication year, country of origin, purpose, study design, and population / sample size. On the other hand, the characteristics of IoT platforms were categorized into platform type, perception equipment, access unit, access network, middleware, and technology used, considering the application. Moreover, the scientific and technological characteristics and scope of the IoT platform were categorized into scientific and technical aspects utilized by the learner and teacher sides, content and teaching method, and barriers and facilitating factors of the IoT platforms were also used for the table.

The results were synthesized to propose the direction of the IoT platform used in future nursing undergraduate education. The analysis results for each research question were grouped, and a wide range of results for the general literature characteristics for each question was summarized, including the characteristics of the IoT platform, scientific and technological utilization, facilitating factors, and barriers to future directions.

Result

Selection of Sources of Evidence

Out of 6,880 pieces of literature, 3,571 citations were identified from searches of electronic databases. Based on the title and the abstract, 3,331 were excluded as they did not meet the eligibility criteria, leaving 240 full-text articles retrieved and assessed for inclusion. Sixteen full-text studies were selected for inclusion in this scoping review. A PRISMA flow diagram depicts the study selection process in Figure 1.

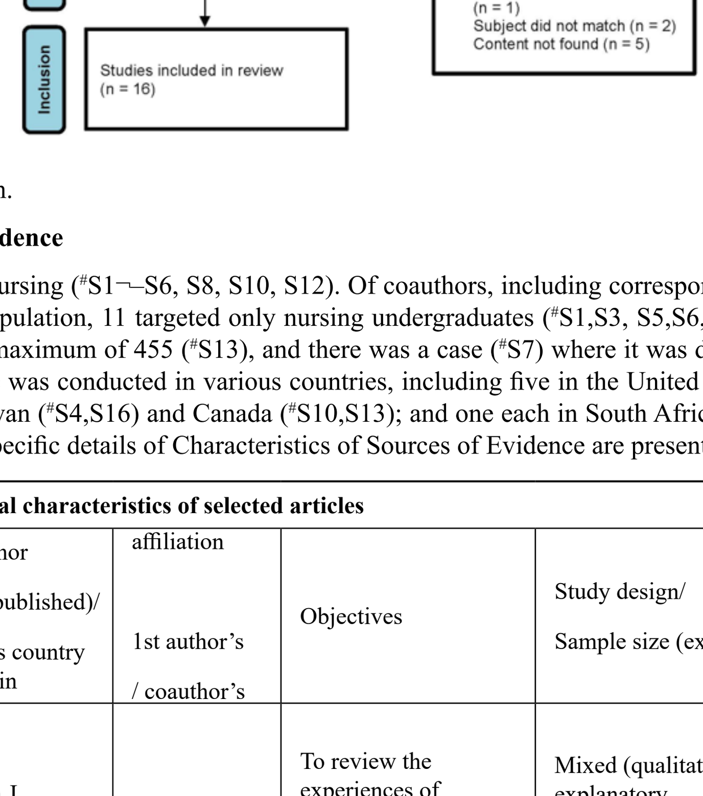

Figure 1: A PRISMA flow diagram.

Characteristics of Sources of Evidence

Of the first authors, nine were in nursing (#S1¬–S6, S8, S10, S12). Of coauthors, including corresponding authors, six were in nursing (#S3-S6, S13, S15). In terms of population, 11 targeted only nursing undergraduates (#S1,S3, S5,S6,S8-S13,S16). Sample size ranged from a minimum of 25 (#S2) to a maximum of 455 (#S13), and there was a case (#S7) where it was developed for nursing students but not applied. The selected literature was conducted in various countries, including five in the United States (#S3,S5,S6,S12,S15); three in Brazil (#S2,S7,S11); two in Taiwan (#S4,S16) and Canada (#S10,S13); and one each in South Africa, the United Kingdom, Portugal, Jordan, Sweden, and Egypt. The specific details of Characteristics of Sources of Evidence are presented in Table 2.

#	Title	General characteristics of selected articles				
		1st Author (Year published)/ Study's country of origin	affiliation 1st author's / coauthor's	Objectives	Study design/ Sample size (exp/cont)	Study population
S1	Undergraduate nurses' reflections on WhatsApp use in improving primary health care education	Juliana J. Willemse (2015)/ South Africa	Nursing / None	To review the experiences of undergraduate nurses on the improvement of primary health-care education	Mixed (qualitative, explanatory, descriptive contextual design)/ 29 (29 / N/A)	Nursing students registered for the Primary Health-Care Module
S2	Teaching-learning evaluation on the ICNP® using virtual learning environment	Carrolina Costa Valcanti Avelino (2017)/ Brazil	Nursing / Exact Sciences	To evaluate the teaching-learning process of nursing undergraduates and nursing professionals	Mixed (quantitative, qualitative)/ 51 (nursing student 25 / N/A)	Nurses; Master's degree students; and nursing student on their 4th, 6th, and 8th semesters in the classrooms and in Family Health Units
S3	Learning about end-of-life care in nursing - A global classroom educational innovation	Cara Bailey (2017)/ United States, United Kingdom	Nursing / Nursing	To develop, implement, and evaluate a joint EOL care course for nursing students	Not mentioned (identified as a single-group experimental study)/ 75 / Not mentioned	Nursing students in the United States and England taught in a "virtual classroom"
S4	Cultural competence education for health professionals from pre-graduation to licensure delivered using facebook: Twelve-month follow-up on a randomized control trial	Li-Chun Chang (2017)/ Taiwan	Nursing/ Health Promotion and Health Education, Education, Nursing Hospital	To test the effects of cultural competence education using FB as a delivery platform for knowledge, awareness, self-efficacy, and skill	Quantitative (randomized controlled trial)/ 180 (90/90 > 70/60 > 65/55)	Professional nursing, pharmacy, and nutrition programs at six medicals universities and randomly assigned them to study groups
S5	The use of a game-based learning platform to engage nursing students: A descriptive, qualitative study	Cara Gallegos (2017)/ United States	Nursing / Nursing	To describe undergraduate nursing students' reflections of their experiences	Pilot test/ 57 (57/0)	Undergraduate nursing students
S6	Student and faculty perceptions of iPad integration in a prelicensure program	Cynthia D. Rubenstein (2017). United States	Nursing / Nursing	To evaluate the satisfaction of students and faculty with the iPad platform	Quantitative (descriptive)/ 88	Undergraduate nursing students in their first semester of the program participated in the survey
S7	Plataforma PEnsinar®: a learning tool for teaching the nursing process	Erik Cristóvão Araújo de Melo (2018)/ Brazil Portugal	University / Nursing	To describe the construction and transition phases undertaken in the development of a virtual learning environment	Methodological research based on technological development (Identified as a single-group experimental study)/ N/A	As a platform development study for nursing student education, it is not applicable
S8	Student nurses' perceptions of Facebook™ as an interactive learning platform in nursing education	Ahmad Tubaishat (2018)/ Jordan	Adult Health Nursing / None	To assess students' perceptions of using Facebook™ as an educational mean to support their students	Quantitative (one group pretest–posttest design)/ 186	Nursing students enrolled on two major selected courses (Adult Health Nursing and Advanced Health Nursing) at the data collection time
S9	Evaluation of Swedish nursing students' experience of a web-based platform for drug calculation	Elisabeth Renmarker (2019)/ Sweden	Health and Society, / Health and Society	To compare the experiences of the web-based learning platform for drug calculation	Quantitative (descriptive)/ 95	All students in their first and sixth semesters
S10	Evaluating student perceptions of a multi-platform classroom response system in undergraduate nursing	Ruixi Sheng (2019)/ Canada	Nursing / Nursing	To address the research question: what are undergraduate nursing students' perceptions of Top Hat™ software	Quantitative (descriptive)/ 23	Undergraduate nursing students at Queen's University located in Kingston, Canada
S11	Students' knowledge on intestinal ostomies before and after an online educational platform intervention	Moniki de Oliveira Barbosa Campos (2021)/ Brazil	Federal University / Federal University	To evaluate undergraduate nursing students' knowledge about intestinal ostomies before and after an educational intervention via an online platform	Quantitative (before and after one-group type quasi-experimental research)/ 90	Undergraduate nursing students from two higher education institutions in Piauí
S12	Using VoiceThread to build a community of inquiry in blended RN-to-BSN education	Deborah Merriam (2021)/ United States	Nursing / Nursing	To explore the use of VoiceThread to build a community of inquiry.	Quantitative (quasi-experimental study)/ 163 (97/66)	163 students enrolled in an undergraduate nursing leadership course within an RN-BS curriculum
S13	User engagement using an etextbook: A descriptive study	Margaret Verkuyl (2021)/ Canada	Community and Health Studies, / Community and Health Studies, Nursing	To explored the level of engagement experienced by users of the e-textbook	Quantitative (descriptive)/ 455	First-year undergraduated nursing

Int J Nurs Health Care Res, an open access journal
ISSN: 2688-9501

S14	Online anatomy team-based learning using Blackboard collaborate platform during COVID-19 pandemic	Ahmed Farid Al-Neklawy (2022)/ Egypt	Anatomy and Embryology of Medicine, Physiological Sciences, Medical Sciences / Medical Education	To evaluat the Blackboard collaborate platform for online team-based learning sessions	Quantitative (descriptive)/ 395 (53 first-year nursing students enrolled in the human anatomy and physiology course)	The participants were students on the MBBS Program, together with students in year one of the Nursing Program, in year two of the Doctor of Pharmacy Program, and in year two of the Medical Laboratory Sciences Program in Fakeeh College for Medical Sciences
S15	Usability of Microsoft Teams and Stream in nursing education	Michael Hebert (2022)/ United States	Nursing / Nursing and Allied Health	To report the findings of the use of online software Microsoft Office's Teams and Stream in prelicensure nursing students or baccalaureate nursing students	Quantitative/ 120 (58 BSN)	Investigators' lecture course, approximately 120 students, of which 58 were in their third- and fourth-year BSN curriculum, which included medical-surgical and women's health content
S16	Benefits of a bilingual web-based anatomy atlas for nursing students in learning anatomy	Meng-Lin Liao (2022)/ Taiwan	Anatomy and Cell Biology of Medicine / Surgery, Anatomy and Cell Biology	A bilingual National Taiwan University web-based anatomy atlas was created as a cross-platform application and its feasibility was evaluated	Quantitative (cohorts)/ 120 (54/66)	Nursing students whose native language is Chinese, who applied for the anatomy course
Note: N/A, not applicable						

Table 2: General characteristics of the selected articles.

Characteristics of the IoT Platform

The characteristics of the IoT platform were analyzed based on platform type, access, and application. Depending on the platform type, 15 cases were based on online applications, and 1 (#S6) used a separate device. As for the application, two studies focused on Facebook (#S4, S8), while another two studies focused on Moodle (#S2,S11). WhatsApp platform (#S1), Zoom (#S3), 3D Game Lab (#S5), Plataforma Pensinar (#S7), a web-based platform for drug calculation (#S9), a multiplatform–based (class response system) on Top Hat software (#S10), VoiceThread (#S12), e-textbook (#S13), Blackboard Collaborate platform (#S14), Microsoft Teams and Stream (#S15), and National Taiwan University's web-based anatomy atlas (NTU-WAA) (#S16), indicating a wide variety, were highlighted in one study each. One study (#S6) could be accessed only through a separate device like an iPad. Regarding access, in 14 cases, all devices connected to the internet could be used to access the platform (#S3-S5, S7-S16); however, there was 1 case where access was possible only through a personal mobile device (#S1); 1 case where access was possible through a notebook, smartphone, and microcomputer (#S2); and 1 case where access was possible only through an iPad (#S6). In terms of the application of platforms used in undergraduate nursing education, 6 cases provided a discussion environment (#S1-S3, S10-S12); 14 cases provided an online learning environment (#S2-S13,15,16); 3 cases provided a social network environment (#S2, S4, S11); 3 cases that provided online examinations (#S6, S7, S10, S13); 6 cases that provided homework (#S2,S7,S10,S11,S13, S14); and 5 cases that provided team activities (#S2,S3,S7,S14,S15).

Scientific and technological characteristics and scope of the IoT platform

The scientific and technological scope used in nursing education included question and answer, discussion, real-time lectures, surveys, video sharing, tests, feedback, connection to other sites, provision of learning materials, wall posts, team activities, and assignment activities. For instance, #S1 used an application that provided a discussion environment but operated the question-and-answer section separately. In the case of #S2, although it utilized online learning, scientific and technological features were used in question and answer through quizzes, discussion, real-time lectures, video sharing, tests, feedback using comments, connection to resources, and provision of learning materials through presentations and memo summaries.

Facilitation factors and barriers of the IoT platform

The barriers for the IoT platforms include technological issues, such as battery problems (#S1); issues with the integrated platform and game system (#S5); connection issues (#S6,S8-S10); complexity (#S15); and lack of communication (#S16). From the learners' perspective, barriers included self-management (#S2, S3, S8); adaptation difficulties (#S5, S11-S13,15); privacy issues (#S8); the importance of individual literacy skills (#S9); and class disruption (#S10). From the teachers' perspective, barriers included the need for tutors (#S2), the need for postmanagement (#S4), difficulties in meeting diverse multidisciplinary requirements (#S4), the need for development due to inappropriate content (#S5), lack of resources and participants (#S7), absence of evaluation and unclear standards for competence enhancement (#S9), increased time spent outside of class (#S15), lack of platform guidelines (#S15), difficulties in evaluating increases in confidence, etc., (#S16), and the need for additional education for theoretical knowledge (#S9,S16).

As facilitating factors for the IoT platform, positive learning–related facilitators such as increased support with learning (#S2,S4,S6,S8-S11,S13,S15,S16); level-specific learning (#S3,S8,S9,S16); improved interest (#S12); potential for curriculum integration (#S10); a paradigm shift in learning (#S7); and deep thinking (#S12) were identified. Environmental facilitators such as comfort (#S4, S8, S9, S12); reliability (#S7); enhanced participation (#S10, S13); the importance of teaching strategies (#S11); the possibility of virtual team activities (#S14); and diverse problem-solving methods (#S15) were suggested. Interactively facilitators such as anonymity (#S1); interaction (#S2,S7,S8,S14); quick feedback (#S6); the potential for diverse content development (#S11); and improvement of communication difficulties (#S16) were also identified (Table 3).

#	Facilitating factors		Barriers	
	Learning	**Environment/ Interaction**	**Technological issues**	**Learner's side/ Instructor's side**
S1	Availability of resources for test preparation Integrates theory and clinical practice	N/A/ Opportunity for clarification anonymity	The application caused the battery to discharge quickly (8 dropped out in the middle) Exclusion due to lack of an appropriate device or application	N/A/ N/A
S2	Helpful in education, support, and management Creates collaborative learning	Easy to install/ Environment for interaction	N/A	Self-commitment and responsibility are needed to manage one's own learning and complete the process./ A tutor that (motivates, answers question, disseminates information, stimulates interaction, diagnoses problems that complicate learning) is necessary
S3	Stable and supports individual learning	N/A/ N/A	N/A	Student schedules, unpredictable weather, limited time/ N/A

S4	Efficient learning possible	Comfort/ N/A	N/A	N/A/ There was difficulty in the evaluation due to a lack of postmanagement. It is challenging to meet various demands across multiple disciplines with a single education program.
S5	N/A	N/A/ N/A	The way the game platform was integrated into the course, technical barriers, and various other factors and restrictions were the causes of technical issues Several students reported frustration due to technical flaws in the platform More time was devoted to guiding the problem-solving resources available through GameLab	Students were unfamiliar with the simultaneous use of the game platform and the learning management system for assignments and grade submission. Because the game activities did not affect the course grade, there was little motivation. There was difficulty adapting due to the short period of six weeks / Inappropriateness of the course content
S6	Navigates roles of learning	N/A/ Quick feedback to assignments	When transitioning from a laptop to an iPad, Microsoft Word and Pages were so different that it was challenging It was easier to format and write assignments on a laptop than on an iPad Software malfunction When using the software application, there were delays in moving to the next question or unintentional selections were made	N/A/N/A
S7	Provides curriculum for nursing courses and categories Supports a paradigm shift to attractive and dynamic learning.	Development of reliable, accurate, and available nursing education technologies/ Enhanced relationship between students and teachers	N/A	N/A/ There was hardly any available resource, making it impossible to evaluate the platform. There was difficulty in recruiting research participants interested in the developed platform
S8	Support provided Students with various learning styles could participate	Easy to access (without distance limitations)/ Useful communication Possibility of conversational group work	Barriers due to lack of IT skills	Requires users to have special skills and does not protect privacy. It distracts attention and encourages procrastination, making students lose focus from their learning objectives/ N/A

S9	Learning support Ability to supplement traditional lectures Ability to control one's understanding Ability to calculate and test at one's own pace	Accessible anywhere, anytime/ N/A	Technical issues arise when pausing, rewinding, or fast-forwarding e-learning videos due to the use of different browser firewalls	Individual differences in students' ICT skills can cause different issues in the use of web-based lectures/ No test is provided for evaluating capability enhancement Knowledge is important because it requires 100% correct answers to pass
S10	Helps with learning Strengthens formative assessment	Strengthened participation/ N/A	Perceived limitations include practical drawbacks, such as redundant features, technical difficulties, limited access and cost	Some students felt that it did not add value to teaching as it was disruptive to classroom time/ N/A
S11	Has positive effect to learning	The importance of teaching strategies, including ICT/ Reflects various national scenarios	N/A	Difficulty in using an online education platform/ N/A
S12	Ability for deep-level thinking Increased focus and interest in content	Convenient to use/ N/A	N/A	Difficult to learn at first. Unable to understand some questions because they are unfamiliar with the terms/ N/A
S13	Strengthened knowledge and skill development When the instructors explore the textbook sections before presenting, the students' usability and understanding improve	Facilitates immersion Improves participation and technical achievement/ N/A	N/A	Not everyone likes to use online resources, and some complain that they are difficult to read/ N/A
S14	N/A	Can assign teams in a virtual space/ Challenging interactive teaching strategies possible	N/A	N/A/ N/A
S15	Recorded lectures of less than 30 minutes are effective The lecture's content is transcribed by the AI within the Stream The actual recorded lecture materials can be edited and reused every semester	Students with internet issues can solve them through streaming/ N/A	The need to reduce complexity Distraction due to the inaccuracy of the transcription Lectures should be held simultaneously for both remote and face-to-face participants	Initial prejudice of students toward face-to-face education/ Need to post the recorded version for future review, which creates more workload for instructors. Absence of guidelines for the platform

S16	Flexible learning possible Both lab learning and classroom knowledge can be enhanced Can be used as a supplementary learning tool in institutions without anatomy labs or where school learning is prohibited	N/A/ Communication difficulties can be improved through a bilingual approach	No conversational feature	N/A/ Unknown whether the confidence of nursing students increases. Theoretical knowledge is not explained
Note: AI, artificial intelligence; IT, information technology; ICT, information and communications technology; N/A, not applicable				

Table 3: Facilitating factors and barriers of selected articles.

Synthesis of Results

In this study, and authors of the selected literature were mostly in nursing, medicine, and healthcare. There was only one case, PEnsinar®, that involved the development of an IoT platform as well as content. Regarding scientific and technological utilization, there were only cases where traditional teaching methods were transformed online, and it was difficult to find evidence of advanced teaching methods. Based on this study, the identified barriers in undergraduate nursing education were technological difficulties, self-management's importance, adaptation difficulties, and privacy issues. The facilitating factors were increased support with learning and level-specific learning, comfort, anonymity, and interaction, which were positive, environmental, and interactive.

Discussion

In this scoping review, 16 studies on the use of IoT platforms in undergraduate nursing education were analyzed. Of these 16, the first authors of 14 studies were in the fields of nursing, medicine, and health, and the coauthors, including the corresponding authors, of 15 studies were also from the fields of nursing, medicine, and health, with only one from exact science. Many studies have already been conducted on the need for convergence between nursing and other fields. For instance, research calls for converging nursing and other disciplines for improved caring [24], emphasizing professional socialization in nursing [25]. However, finding convergence with fields such as engineering, sociology, and business studies was challenging in researching IoT platforms in nursing education. Active integration with other fields is needed to prepare for future nursing education.

Three studies developed IoT platforms solely for nursing education, and five developed both the platform and content. The three studies that only developed a platform focused on nursing processes, student response systems, and response systems at the level of social media and the platform dedicated to undergraduate nursing education can only be found in PEnsinar®,#S7. The five studies that developed both a platform and content concerned using a game application and Facebook for adult health nursing and advanced health nursing subjects and developing drug calculations, digital textbooks, and anatomy textbooks developed in two languages, usually auxiliary means in undergraduate education. The only case where the developed platform is dedicated to the purpose of undergraduate nursing education was the case of S8 using Facebook. Some examples include interactive screens, voice-to-text technology, webcams in classrooms, electronic bracelets, head sensors, and smart classrooms. There is a wide range of IoT applications in the educational sector, such as video projectors, sensors, and facial recognition algorithms [26]. However, the use of IoT in undergraduate nursing education, as identified in this study, has not yet been integrated with the scientific technologies used in these research results. Therefore, future researchers would have to try to understand the level of the latest scientific technologies and actively incorporate these technologies into undergraduate nursing education.

The platform type was application-based in 15 cases, and one involved the use of separate devices, with 14 cases being able to connect with any electronic device connected to the internet. In addition, the teaching methods used with these platforms were not so much appropriate for the IoT platform but rather applied existing teaching methods. However, an existing scoping review on the impact of artificial intelligence on nursing education [27] has already called for curriculum reform and new teaching methods in nursing education for the AI era, integrating knowledge and technology. This observation indicates that the actual trend in undergraduate nursing education is not keeping pace with the trend demanded by society. Therefore, it is imperative to develop innovative AI-based educational curriculums in undergraduate nursing education and a platform to integrate such curriculums in Korean and global nursing education.

The scientific and technological characteristics used in undergraduate nursing education were diverse. However, these

were not necessarily related to IoT-based education but were mostly seen in traditional face-to-face lectures, video sharing, tests, and feedback. In a systematic literature review on digital technology and nursing care, studies on ICT, robots, sensors, and e-learning have already been carried out [28]. However, most of these studies targeted nurses or patients, and no studies were specifically for undergraduate nursing education. As mentioned in the discussion of the authors' affiliations in the general characteristics of the research, the field of nursing education has yet to significantly step further for a convergence with the scientific and technological fields. Therefore, a proactive challenge is required to move beyond traditional face-to-face teaching methods and develop new teaching methods by actively integrating with experts in the field of science, applying and converging with advanced scientific technologies.

This scoping review identified technological difficulties, the importance of self-management, difficulties in adaptation, and privacy concerns as personal barriers to the future development of IoT platforms in undergraduate nursing education. In addition, the teachers' perspective confirmed the need for tutors, continuous post-management, and the lack of content to meet interdisciplinary requirements. These results are consistent with the studies suggesting the need for technical support in digital education, the potential for student distraction [29], and the need for human rights protection and continuous assistance for development [30]. The facilitating factors of IoT development showed that the IoT platform can serve as a learning aid and induce interest-based learning, which are educational advantages. In addition, it offers environmental advantages like comfort, reliability, and enhanced participation. Moreover, there are interactional advantages such as anonymity, interaction, quick feedback, improvement of communication difficulties, and the possibility of developing various contents. These results align with the studies suggesting the advantages of digital learning as a learning plarform [31]. Thus, keeping these barriers and facilitators in mind while developing an IoT platform for future nursing undergraduate education creates a more quality-based system for undergraduate nursing education.

Limitations

This study excluded research on virtual simulation, which is used as an alternative to clinical practice. Therefore, it did not consider the IoT platforms that could have been utilized for theoretical knowledge in clinical practice learning, making it difficult to generalize this study's results. In addition, this study aimed to present the future direction by understanding the overall situation of the research on IoT platforms in undergraduate nursing education. As it is not a study that evaluates the level of evidence through a critical review, individual studies could have been either under- or overestimated. Finally, this study analyzed only 16 of the total searched literature, which is a small number. It is unlikely that the duplicated or excluded literature significantly impacts the research results, but it is still important to recognize the significance of the excluded literature.

Conclusion

The IoT platforms used in undergraduate nursing education are diverse, but there is a lack of convergence with other disciplines or integrated IoT platforms for nursing education. Therefore, IoT platforms for future nursing education should take the following directions

- The development of IoT platforms for future undergraduate nursing education should move in an integrated direction through active convergence research with other fields.
- IoT platforms for future undergraduate nursing education should attempt to develop new teaching methods that move away from traditional teaching methods and incorporate cutting-edge scientific technologies, such as artificial intelligence.
- IoT platforms for future undergraduate nursing education should consider the barriers and facilitators identified in this study and require multidisciplinary efforts to create a higher-quality undergraduate nursing education system.

Based on these findings, the following suggestions are made for future research

- Nursing educators and researchers should continue to find intersections between nursing and other fields, such as engineering, sociology, and business management.
- Research should actively be conducted to develop digital literacy skills for nursing educators and students.
- In preparation for a future where nursing education will mostly be on IoT platforms, there needs to be much discussion about what should be taught by nursing educators.

Registration

The data presented in this study are openly available on Open Science Framework (OSF) on September 7, 2021 (https://doi.org/10.17605/OSF.IO/DHZFR).

Contribution

C.E.S: AJ acquired financial support for this study, collected and analyzed the data, and wrote the manuscript. CES also performed data analysis and wrote the manuscript.

Source of Funding

This study was supported by the National Research Foundation

of Korea (2021R1I1A3046198)]. However, they had and will not have a role in study design, data collection, analysis, the decision to publish, or manuscript preparation.

Conflicts of Interest

The authors of this study declare no competing interest of any form.

Ethics and dissemination

The Institutional Review Board of Nambu University, South Korea, approved the exemption of this study for IRB review (1041475-2021-HR-030). Study results will be disseminated through peer-reviewed journals.

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