

Advancing nursing education through wearable electronic devices: A scoping review

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ARTICLE INFO

Keywords:

Education
Educational technology
Nursing education
Nursing students
Nursing students
Teaching
Technology
Wearable electronic devices
Wearables

ABSTRACT

Aim: To examine the incorporation of wearable electronic devices in the education of undergraduate nursing students.

Background: The advancement of technology has influenced nursing education and will continue to do so in the future. Wearable technologies are electronic devices that can be worn as an accessory and expand the possibilities in nursing education with increased engagement in the learning process.

Design: A scoping review was conducted following JBI and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) guidelines.

Methods: The search was performed on August 25th, 2023, in the databases: MEDLINE via PubMed, ISI Web of Science, ERIC, EBSCOhost CINAHL, EBSCOhost Academic Search Premier, EBSCOhost Health Source Nursing, EMBASE, Scopus, BVShost LILACS and ProQuest. Literature that examined the application of wearable electronic devices in the education of undergraduate nursing students was included.

Results: This scoping review study included a total of 21 records published between 2014 and 2023. The analysis showed that smart glasses are the most common wearable electronic device used in nursing education, followed by smartwatches. The devices provide an opportunity for competencies development, especially when applied in the simulation environment, such as physical examination and medication administration. Wearable technologies are potentially useful and feasible as learning tools in nursing education, increasing nursing students' motivation, confidence and satisfaction.

Conclusions: In the technological revolution, educators must consider the potential of innovative teaching strategies, such as wearable electronic devices, to advance nursing education. Wearables can contribute to developing competencies required for the professionalism of undergraduate nursing students.

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<https://doi.org/10.1016/j.nepr.2024.104032>

Received 13 February 2024; Received in revised form 8 June 2024; Accepted 15 June 2024

Available online 25 June 2024

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1. Introduction

The technological revolution intensifies every day (Yang and Gu, 2021), which stimulates rethinking the status quo in nursing education. Given nurses' pivotal role in driving health outcomes, education in the use and integration of healthcare technology is essential (Barnard, 2002). With the advancement of Artificial Intelligence (AI), new intelligent systems represent a promising path for healthcare delivery (Shi et al., 2020; 2023) and these innovations will continue to shape nursing practices. As an intelligent system that requires human intelligence to perform tasks, AI must be integrated with other devices to be incorporated into nursing education effectively (Foronda and Porter, 2024), with wearables representing an emerging strategy for leveraging AI.

Wearables are electronic devices that can be worn as accessories, such as smartwatches, smart glasses and smart clothing (Wright and Keith, 2014). Among the various possibilities these devices offer, one of the most known capabilities of wearables is health monitoring, such as sleep quality, physical activity, protection in risky situations and management of personal activities (Wright and Keith, 2014; Shi et al., 2020). Historically, nurses have exercised their leadership in the adoption and implementation of the newest technologies into clinical practice, with wearables being the next step (Wilson, 2017).

The advancement of technology has influenced nursing education and will continue to do so in the future. The learning styles, preferences and needs of healthcare students change over time (Shorey et al., 2021). Generation Z, for example, clearly prefers teaching based on technological integration and digital storytelling (Hampton et al., 2020; Shorey et al., 2021). For this reason, educational experiences continually improve by implementing innovative teaching strategies (Foronda et al., 2017). Therefore, nursing curriculum revisions must be aligned with technological development to implement innovative educational strategies moving forward. For the next decades, nurse educators must be prepared to offer technological educational opportunities to enhance students' professional development (Risling, 2017; Rao, 2019).

It is essential to understand the state of the knowledge on the incorporation of wearables in nursing education, considering the learning styles and preferences of Generation Z as early adopters of technological innovation. Thus, this study aimed to examine the incorporation of wearable electronic devices in the education of undergraduate nursing students.

2. Methods

This scoping review was performed following the JBI (Peters et al., 2020) and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018) guidelines. The protocol was registered in Open Science Framework (OSF) (Araújo et al., 2023).

The PCC mnemonic (Population, Concept and Context) (Peters et al., 2020) was used to develop the research question. Therefore, "undergraduate nursing students" were defined as the "P", "wearable electronic devices" as "C"; and "education" as "C", which guided the establishment of the question: "What is the state of knowledge regarding the incorporation of wearable electronic devices in the education of undergraduate nursing students?". Sub-questions were outlined as follows:

- 1) What wearable electronic devices are incorporated into the education of undergraduate nursing students?
- 2) What is the usability of wearable electronic devices in the education of undergraduate nursing students?
- 3) What are the repercussions of wearable electronic devices in the education of undergraduate nursing students?

Preliminary searches were carried out from April to July 2023 in Medical Literature Analysis and Retrieval System Online databases via

the National Library of Medicine (MEDLINE) via PubMed and ProQuest to identify the scientific literature on the topic being studied. One review study was identified on the usability and feasibility of smart glasses in nursing education (Romare and Skär, 2023). However, although smart glasses can be considered wearable devices, this scoping review aims to explore all wearable devices that could be integrated into nursing education and describe the usability and repercussions of using these devices. Also, the pilot phase included frequent meetings with the research team to discuss the scope and search terms to be adopted around exploring wearable electronic devices in nursing education. This process was important to increase the sensibility of the search strategy (Supplementary file 1).

The searches were performed on August 25th, 2023 in the following databases: Medical Literature Analysis and Retrieval System Online databases via the National Library of Medicine (MEDLINE) via PubMed, ISI Web of Science, Education Resources Information Center (ERIC), EBSCOhost Cumulative Index to Nursing and Allied Health (CINAHL), EBSCOhost Academic Search Premier, EBSCOhost Health Source Nursing, EMBASE, Scopus, BVShost Latin American Literature and the Caribbean in Health Sciences (LILACS) and ProQuest. Two reviewers with knowledge of the topic performed the data collection and screening independently.

We included literature that examined the incorporation of wearable electronic devices in the education of undergraduate nursing students. Sources of evidence eligible for this scoping review included all types of publication and no restrictions were placed on the timeframe. Sources of evidence available in English, Spanish or Portuguese (languages the authors have proficiency) were included. Sources of evidence addressing the monitoring of nursing students' vital parameters through wearables were excluded, considering that this review does not aim to map physical or psychological symptoms that may be manifested by nursing students when using wearables.

The sources of evidence identified in the databases were exported to EndNote® Web to remove duplicates. After that, the data were moved to the Rayyan web application for the selection and independent screening process among the two reviewers to improve reliability and methodological precision (Ouzzani et al., 2016). In case of any discrepancies in the analysis, a third reviewer from the research team with a background in nursing education was consulted. Hand search was performed in the reference list of the sources of evidence included.

The data extraction was performed by two reviewers independently. Each one was responsible for extracting the following information: (1) Characteristics: author, year of publication and country record development; (2) Publication: method; and sample (detailing the year of the nursing students, if possible and applicable); and (3) Wearable: device (if applicable), usability and repercussions in nursing education. A third reviewer compared each extraction and consolidated the information detailing the characteristics of the sources of evidence included. Data were analyzed by applying basic descriptive and content analysis (Peters et al., 2020) in three categories: (1) Wearable electronic devices incorporated into the education of undergraduate nursing students; (2) Usability of wearable electronic devices in nursing education; and (3) Repercussions of wearable electronic devices in nursing education.

3. Results

The identification via databases yielded 300 sources of evidence, of which 18 records were included in the sample. Additionally, a search via other methods identified three sources of evidence. The final sample was composed of 21 records. The review process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018), as shown in Fig. 1.

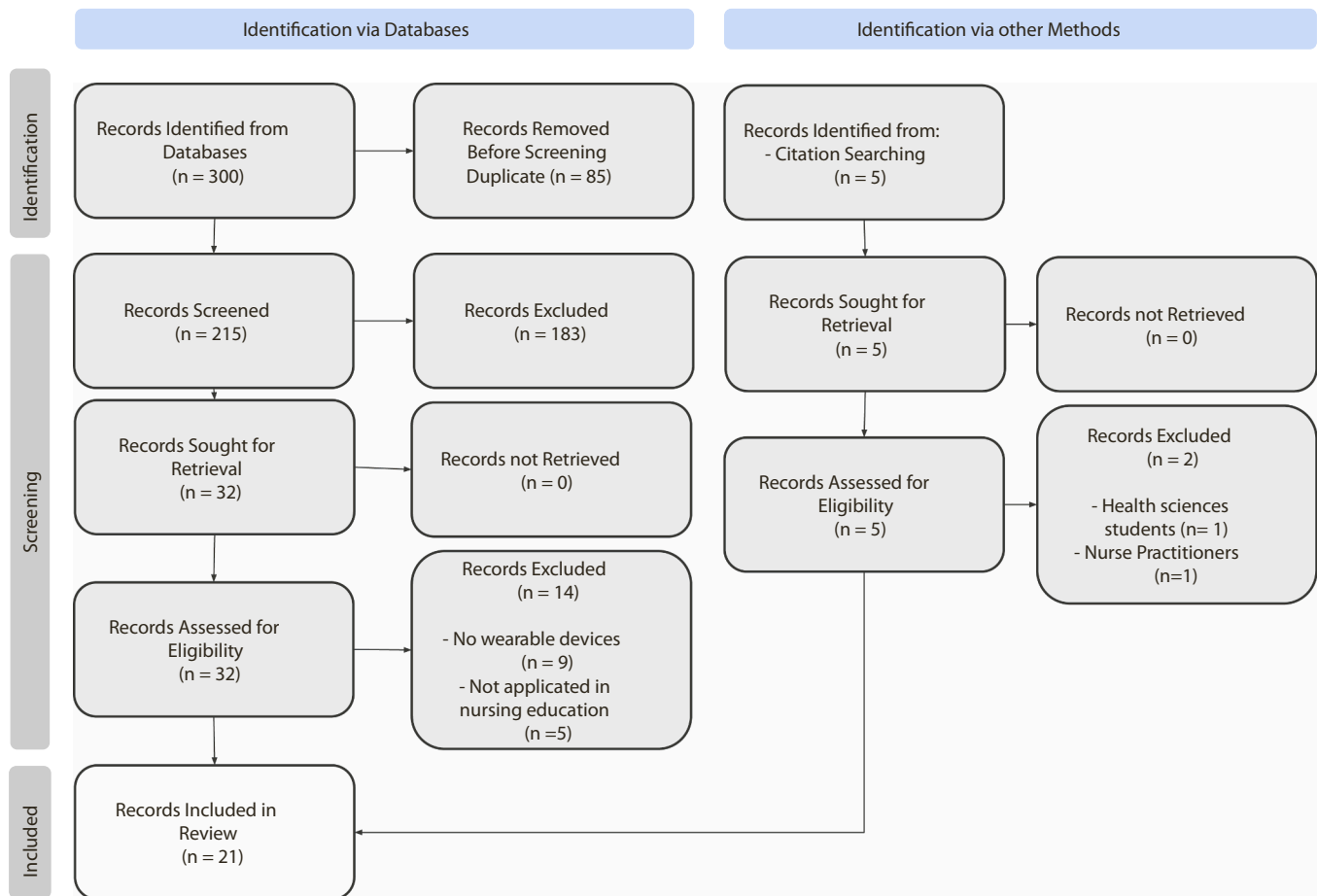


Fig. 1. PRISMA-ScR (Tricco et al., 2018).

3.1. Characteristics of the sources of evidence

Wearables are viewed as an emerging topic in nursing education, considering that the oldest record was published in 2014 (Skiba, 2014). Furthermore, from 2014 to 2023, the mean of publications per year equals 2.1, with an emphasis on 2021 (Collins and Ditzel, 2021; Frederick and Van Gelderen, 2021; Kim et al., 2021; Lee et al., 2021; Yoon et al., 2021), representing ~24 % of the sample.

Globally, the evidence shows that Asia (Lee et al., 2020, 2021; Kim et al., 2021; Yoon et al., 2021; Jung and Park, 2022; Kobayashi et al., 2022) and America (Schneidereith, 2015; Vaughn et al., 2016; Byrne and Senk, 2017; Goodin, 2018; Frederick and Van Gelderen, 2021; Bradley et al., 2023) conducted the most extensive research on wearable electronic devices in nursing education, both representing more than a half (~63 %) of the sample. It is important to highlight the United States of America (Schneidereith, 2015; Vaughn et al., 2016; Byrne and Senk, 2017; Goodin, 2018; Frederick and Van Gelderen, 2021; Bradley et al., 2023) and South Korea (Lee et al., 2020, 2021; Kim et al., 2021; Yoon et al., 2021; Jung and Park, 2022) lead scientific production in those continents. Other regions, such as Europe (~21 %) (Grünerbl et al., 2015; Kopetz et al., 2019; James et al., 2020; Gruenerbl et al., 2018) and Oceania (~16 %) (Forbes et al., 2016; Collins and Ditzel, 2021; Adams et al., 2022) also researched this topic. It is important to emphasize that the analysis of the countries only considered records conducted with nursing students.

A diversity of methodological designs was applied by the authors of the records included in this scoping review. Considering that wearable electronic devices still do not have evidence synthesized in the nursing education context, some of the records are pilots (Schneidereith, 2015; Forbes et al., 2016; Vaughn et al., 2016; Byrne and Senk, 2017),

theoretical papers (Skiba, 2014; Risling, 2017), case study (Adams et al., 2022), or are conference proceedings (Goodin, 2018; James et al., 2020), showing that the knowledge is growing in the literature. Furthermore, this scoping review comprised records that used quantitative (Grünerbl et al., 2015; Gruenerbl et al., 2018; Kopetz et al., 2019; Frederick and Van Gelderen, 2021; Kim et al., 2021; Lee et al., 2021; Yoon et al., 2021; Jung and Park, 2022; Kobayashi et al., 2022; Bradley et al., 2023), qualitative (Collins and Ditzel, 2021) and mixed method (Lee et al., 2020) approaches.

Nursing students were the target population of all records included in this scoping review (Skiba, 2014; Grünerbl et al., 2015; Schneidereith, 2015; Forbes et al., 2016; Vaughn et al., 2016; Byrne and Senk, 2017; Risling, 2017; Goodin, 2018; Gruenerbl et al., 2018; Kopetz et al., 2019; James et al., 2020; Lee et al., 2020; Collins and Ditzel, 2021; Frederick and Van Gelderen, 2021; Kim et al., 2021; Lee et al., 2021; Yoon et al., 2021; Adams et al., 2022; Jung and Park, 2022; Kobayashi et al., 2022; Bradley et al., 2023). There was no consensus across studies about the demographic descriptors of nursing students, considering that the records describe this population based on the year of study (Vaughn et al., 2016; Kopetz et al., 2019; James et al., 2020; Collins and Ditzel, 2021; Jung and Park, 2022) and title - such as prelicensure (Vaughn et al., 2016; Bradley et al., 2023), junior baccalaureate (Frederick and Van Gelderen, 2021), senior baccalaureate (Byrne and Senk, 2017), mental health nursing students (James et al., 2020) and trainee and novices (Gruenerbl et al., 2018), or general (Grünerbl et al., 2015; Schneidereith, 2015; Forbes et al., 2016; Byrne and Senk, 2017; Gruenerbl et al., 2018; Kopetz et al., 2019; Lee et al., 2020; Collins and Ditzel, 2021; Kim et al., 2021; Lee et al., 2021; Yoon et al., 2021; Adams et al., 2022; Jung and Park, 2022; Kobayashi et al., 2022). Chart 1 shows the characteristics of the records included in this scoping review.

3.2. Wearable electronic devices incorporated into the education of undergraduate nursing students

3.2.1. Smart glasses

Most records (~73 %) reported the usability of smart glasses in nursing education (Skiba, 2014; Grünerbl et al., 2015; Schneidereith, 2015; Vaughn et al., 2016; Byrne and Senk., 2017; Gruenerbl et al., 2018; Kopetz et al., 2019; James et al., 2020; Lee et al., 2020; Frederick and Van Gelderen, 2021; Kim et al., 2021; Lee et al., 2021; Yoon et al., 2021; Adams et al., 2022; Jung and Park, 2022; Kobayashi et al., 2022). The literature showed a diversity of types of smart glasses, such as Google Glass (Schneidereith, 2015; Vaughn et al., 2016; Byrne and Senk., 2017; Grünerbl et al., 2015; Yoon et al., 2021), HoloLens (Collins and Ditzel, 2021; Adams et al., 2022), Head-mounted display (Jung and Park, 2022; Kobayashi et al., 2022), Oculus Go (Lee et al., 2020), Headsets VR 3D (James et al., 2020) and Glass Enterprise Edition 2 (Lee et al., 2021). Although some models have been discontinued (such as Google Glass), some are still used in nursing education.

3.2.2. Smartwatches

Smartwatches are the most common wearable electronic devices in society. However, their use in nursing education was only reported in two records (Grünerbl et al., 2015; Gruenerbl et al., 2018) conducted by the same research team, which highlights that smartwatches are not widely recognized as educational devices in nursing education programs.

3.2.3. Other wearable electronics devices

Some wearable electronic devices have only one mention among the records included in this scoping review: A head-mounted video camera (Forbes et al., 2016) and a vest (Bradley et al., 2023). However, the findings of this study highlight its importance for nursing students' teaching and learning process, in addition to its usability and repercussions on nursing education described in the following sections.

3.3. Usability of wearable electronic devices in nursing education

Wearable electronic devices are prospective educational resources in nursing education. However, there is a significant gap between theory and practice. The synthesis of the sources of evidence showed that wearable electronic devices can be used in teaching fundamental courses for nursing students' personal and professional development, such as anatomy through smart glass (Adams et al., 2022). The evidence suggests that wearables provide an opportunity for skills development (Skiba, 2014; Schneidereith, 2015; Risling, 2017; Goodin, 2018; Kopetz et al., 2019; Kim et al., 2021; Bradley et al., 2023), including physical examinations (Bradley et al., 2023) and administration of medications (Schneidereith, 2015).

More than half of the records included in this scoping review (~59 %) highlighted the importance of the simulation environment as a site for incorporating wearable electronic devices in nursing education (Grünerbl et al., 2015; Schneidereith, 2015; Forbes et al., 2016; Vaughn et al., 2016; Byrne and Senk, 2017; Gruenerbl et al., 2018; James et al., 2020; Lee et al., 2020; Collins and Ditzel, 2021; Frederick and Van Gelderen, 2021; Yoon et al., 2021; Jung and Park, 2022; Kobayashi et al., 2022). The smart glasses (Schneidereith, 2015; Lee et al., 2020; Frederick and Van Gelderen, 2021) and the head-mounted video camera (Forbes et al., 2016) can record the activities performed by the students during simulation training. Both devices can provide a unique perspective, allowing the identification of skills that need improvement and the collection of additional information to prepare feedback on student performance from educators (Grünerbl et al., 2015; Gruenerbl et al., 2018; Vaughn et al., 2016). Additionally, the smart glasses can transmit real-time video and audio for a group of students, educators and other providers who are not directly involved in the simulation scenario (Byrne and Senk, 2017; Lee et al., 2021; Yoon et al., 2021;

Kobayashi et al., 2022).

Since the smart glasses are worn on the head, students have their hands free and can therefore view information through them and practice clinical skills in a simulated environment (Kopetz et al., 2019; Kim et al., 2021). Although no study has related smart glasses to any other wearable (except smartwatches), it is assumed that it would be interesting to integrate them with a vest that is effective for teaching physical examination skills (Bradley et al., 2023). These devices can be used in the simulation of sensitive scenarios or those that rarely occur in reality (Grünerbl et al., 2015; Vaughn et al., 2016; Gruenerbl et al., 2018; Lee et al., 2020; Frederick and Van Gelderen, 2021; Yoon et al., 2021), such as emergencies (Grünerbl et al., 2015; Gruenerbl et al., 2018; Yoon et al., 2021). For example, smartwatches were used to detect movements related to cardiopulmonary resuscitation (CPR) in the simulated scenario, providing information about the depth and frequency of compressions (Grünerbl et al., 2015; Gruenerbl et al., 2018).

3.4. Repercussions of wearable electronic devices in nursing education

Wearable electronic devices are a trend for the future of nursing education (Risling, 2017). Their use is reported to increase motivation (Vaughn et al., 2016; Lee et al., 2020; Adams et al., 2022), confidence (Grünerbl et al., 2015; Vaughn et al., 2016; Kopetz et al., 2019), satisfaction (Kim et al., 2021; Jung and Park, 2022), interest (Kim et al., 2021), involvement (Skiba, 2014; Adams et al., 2022), engagement (Vaughn et al., 2016; Lee et al., 2020), communication (Byrne and Senk, 2017; Kobayashi et al., 2022), decision-making (Byrne and Senk, 2017) and critical thinking (Collins and Ditzel, 2021) of nursing students. It also advances the development of competencies (Gruenerbl et al., 2018; Collins and Ditzel, 2021; Frederick and Van Gelderen, 2021; Bradley et al., 2023), such as leadership (Bradley et al., 2023). As a result, the teaching and learning process becomes more engaging, improving student retention in nursing programs.

There is little evidence of the challenges and negative repercussions of using wearables in nursing education. One study reported the ineffectiveness of head-mounted video camera technology due to the reduced quality of verbal feedback through those devices (Forbes et al., 2016) and the manifesting of physical symptoms that can affect nursing students, such as nausea, dizziness and headaches (James et al., 2020). Therefore, stronger explorations into potential barriers and solutions for incorporating wearable technology into nursing education are needed.

4. Discussion

This scoping review examined the incorporation of wearable electronic devices in nursing education. The results show smart glasses as the most explored wearable electronic devices in nursing education. However, other devices were also identified in the literature, such as smartwatches, a head-mounted video camera and a vest. Their usability is directly related to the simulation environment, enhancing students' motivation and confidence. Although the results detailed the devices, their usability and repercussions for the education of undergraduate nursing students, these devices have not been thoroughly examined in the literature.

Wearable electronic devices are part of the Fourth Industrial Revolution of the 21st century, transforming what people do, how they see themselves and how they engage in the world (Park, 2016; World Economic Forum, 2016). The advancement of Information and Communication Technology (ICT) raises a critical issue in nursing education: How nurse educators should be prepared for the future of the profession (Risling, 2017; Rao, 2019). At times, educators still adopt traditional teaching methods that do not meet evidence-based best practices. Learning approaches need to foster inspiration and support the construction of the professional identity of nursing students. Nursing teaching modalities must establish strong relationships with the demands of nurses' professionalism, which are increasingly

multidimensional and require updated and innovative actions (Shen et al., 2021; Cao et al., 2023). The idea of innovative teaching in nursing must be dissociated from one that is based on the incorporation of new technologies into the teaching-learning process. Innovation in nursing education must centre on continuously improving teaching strategies taking into account students' learning styles, preferences and needs. In this way, when incorporated as innovative educational resources, wearable electronic devices can create a positive learning environment, better preparing students for the demands of disruptive healthcare environments.

In 1962, Everett Rogers proposed the Diffusion of Innovation (DOI) Theory, which outlines how an idea gains momentum and diffuses, or spreads, throughout a particular population or social system over time. Innovation does not happen simultaneously in a social environment (Rogers, 1962), but occurs based on a series of proposals and actions implemented practically. In the light of DOI theory, wearable electronic devices are social innovations that revolutionized practices and customs worldwide. However, the incorporation into nursing education is still restricted, as educators are unaware of the potential of these devices.

Technologies are fundamental for nursing students to satisfactorily achieve critical thinking, decision-making, professional self-efficacy and a better definition of professional role and professionalism (Shen et al., 2021; Cao et al., 2023). Similarly, records included in this review cite similar competencies and others (Skiba, 2014; Grünerbl et al., 2015; Vaughn et al., 2016; Byrne and Senk, 2017; Gruenerbl et al., 2018; Kopetz et al., 2019; Lee et al., 2020; Collins and Ditzel, 2021; Frederick and Van Gelderen, 2021; Kim et al., 2021; Adams et al., 2022; Jung and Park, 2022; Kobayashi et al., 2022; Bradley et al., 2023). Further research in the area of wearables and students' learning outcomes is needed. Furthermore, it is important to consider students' evolving perception of nursing as their competencies develop throughout their academic journey (Rudberg et al., 2022). When implemented in simulation environments (Grünerbl et al., 2015; Schneidereith, 2015; Forbes et al., 2016; Vaughn et al., 2016; Byrne and Senk, 2017; Gruenerbl et al., 2018; James et al., 2020; Lee et al., 2020; Collins and Ditzel, 2021; Frederick and Van Gelderen, 2021; Yoon et al., 2021; Jung and Park, 2022; Kobayashi et al., 2022), wearables can prospectively reduce the gap between theory and practice during the educational process. New studies could also explore the physical and psychological aspects that emerge from the application of wearable electronic devices in nursing education.

Finally, this study has some limitations. A limited number of records were identified in this scoping review. This may be attributed to the lack of standardization of the concept of wearable electronic devices in the literature. Consequently, some authors may classify certain electronic devices as "wearable," whereas others may not.

5. Conclusion

Educators must consider the potential of innovative teaching strategies, such as wearable electronic devices, to advance nursing education in the technological revolution. Wearables can contribute to developing competencies required for the professionalism of undergraduate nursing students. When applied alongside other strategies, wearables enhance learning experiences, meeting the learning styles expected by future generations of digital native students.

Funding

National Council for Scientific and Technological Development (CNPq), Brazil; Visiting Scholar Grant, Global Nursing Office at Faculty of Nursing, University of Alberta, Canada

CRediT authorship contribution statement

Isabel Amélia Costa Mendes: Writing – review & editing, Writing –

original draft, Visualization, Validation, Supervision, Project administration, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Ítalo Rodolfo Silva:** Writing – review & editing, Writing – original draft, Visualization, Validation, Investigation, Formal analysis, Data curation, Conceptualization. **Simone de Godoy:** Writing – review & editing, Writing – original draft, Visualization, Validation, Investigation, Formal analysis, Conceptualization. **Agostinho A. C. Araújo:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Tracey Stephen:** Writing – review & editing, Writing – original draft, Visualization, Validation, Investigation, Formal analysis. **Sara Soares dos Santos:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Investigation, Formal analysis, Data curation, Conceptualization. **Lucas Gardim:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jordana Salma:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors acknowledge Adriana Sayuri Ota, Librarian from the University of São Paulo, for technical assistance in establishing the search strategy.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.nepr.2024.104032.

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