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A digital nursing care technology at effectiveness and efficiency studies of informal and formal care technologies

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Abstract

Background: This discussion on technology as a possible solution to difficulties such as a lack of competent personnel and an increasing demand for long-term care necessitates an examination of digital technology in nursing care. We opted to conduct this research since there aren't many good empirical overviews of current technology in the literature. With this project, researchers wanted to map the field of digital technologies used in informal and formal healthcare settings that had already been studied for acceptability, effectiveness, and efficiency (AEE). They also wanted to show how widely these techniques have been applied and which populations and settings they have been used on.

Methods: A complete literature search was conducted using Medline, Scopus, CINAHL, Cochrane Library, ACM Digital Library, IEEE Xplore, the Collection of Computer Science Bibliographies, GeroLit, and CareLit. In addition, relevant articles on project websites were personally examined.

Results: During the review, 715 articles were found to be relevant. Effectiveness studies have been conducted on ICT, robots, and sensors. Studies on user adoption of EHR/EMR, robots, and ICT were common. In the past, efficiency studies were rare. Numerous studies were found to be devoid of supporting evidence. Testing acceptance and effectiveness has always relied on small-scale experiments with no controls. ICT, robots, and e-learning were the most frequent research designs with high evidence levels. A lack of technology reviews and recommendations for informal caregivers and children, as well as for official care at home or in cross-sectoral care, was noted in this study.

Conclusion: Rather than systematic reviews using low-quality research, we advocate developing high-quality assessments of current digital technologies for AEE in real-world contexts. More emphasis should be made on efficiency research. A deeper investigation of the implemented AEE assessment methodologies should be the focus of future research. Policymakers should give funds to allow large-scale, long-term assessments of technologies in clinical practise, meeting the research gaps indicated in this study for technologies, target contexts, and target populations.

Keywords: Technology, Care, Nursing, Scoping Review, Efficiency, Effectiveness, Acceptance, Evaluation, Effect, Digital

1. Introduction

We suggest generating high-quality evaluations of existing digital technologies for AEE in real-world scenarios rather than systematic reviews based on low-quality research. Efficiency studies should be given more attention. Future study should concentrate on a more thorough examination of the AEE evaluation procedures that have been deployed. Policymakers should provide funding to enable large-scale, long-term evaluations of technologies in clinical practise, addressing the research needs identified in this study for technologies, target settings, and target populations.

The Pflegeinnovationszentrum (German for "Nursing Care Innovation Center") is a collaborative research initiative funded by the Federal Ministry of Education and Research (BMBF) to establish a nursing care innovation competence centre. As well as gathering and disseminating data on digital technology's acceptance, efficacy, and efficiency in nursing care, the organisation hopes to put its findings into action. This includes the use of these technologies' capabilities in the education of nurses. There are a broad range of technologies available to aid in nursing care and education, and the AEE of these technologies will be examined as part of this evaluation. If a new technology is likely to be integrated into nursing practise, these outcome characteristics are essential to us. It's possible to learn a lot about nursing technology and nursing education from the existing literature, which covers many different themes. Scoping reviews aim to provide the full breadth of research, including AEE in both informal and formal care.

Many small-scale studies of specific technologies for informal and formal care are now available in the literature. To name just a few, they include electronic point of care wound documentation for residential long-term care, noise-sensor lights for the critical care unit and companion robots for elder care. Using electronic medical records and virtual reality technologies in nursing education, nursing institutions are able to better manage their patient data and increase their productivity. Existing review publications tend to focus on individual technologies or specialised groups, such as stroke survivors, and generally combine single outcome criteria, such as efficacy or acceptability.. Numerous comprehensive analyses in the technology and nursing care fields find that trustworthy evidence on the effectiveness and efficiency of technologies under consideration is still inadequate or insufficient. Even though there are many technologies that can aid in both formal and informal care, there is no comprehensive assessment of these technologies or studies that summarise the existing evidence for AEE in this huge field of technologies that we are aware of. A thorough examination of digital technology and nursing care, including all areas of informal and formal care and nursing education, is now possible thanks to this study. The study identifies which areas of technology may warrant further investigation and which areas of solid AEE research should be explored.

2. Objective and research question

Finally, this scoping review's ultimate goal is to identify interesting technologies for future investigation, to identify present research gaps, and to analyse how research is performed. Because of this, we want to create an AEE-based map that illustrates the breadth of the digital care technologies that have previously been investigated, as well as the intended contexts, support areas, and demographics of those technologies. Researchers may use this scoping study to discover which technologies need to be thoroughly analysed and for which technologies more research is required. As a result, a scoping study is the best approach for gathering information on technologies that have received less attention in the past but have the potential to provide more conclusive results in the future.

Accordingly, the following key research questions serve as the foundation for this review:

(i) In terms of all outcome dimensions (AEE), which areas of digital technologies aimed at supporting informal or formal care are most commonly researched?
(ii) In these studies, what target settings, support domains, and target populations are addressed?
(iii) What research approaches were employed to investigate the outcome dimensions?

3. Methods Methodological basis

The format devised by Arksey and O'Malley for scoping reviews was adopted in our scoping review. Levac, Colquhoun, and others gave more processual proposals to enhance the scientific process. By combining comprehensiveness with resource feasibility and the iterativity of the

team's data selection, extraction, and charting procedure, the processual suggestions were notably effective for finding relevant research.

- **Data sources**

Electronic resources searched were Medline and Scopus; CINAHL; Cochrane Library; IEEE Xplore and Collection of Computer Science Bibliographies; GeroLit; and CareLite. A manual search of related projects from German-speaking countries supported the results. This year's literature review was finished in March. Due to the large number of publications identified, the reference lists of the included study were not examined.

- **Eligibility criteria**

Scientific publications published between 2011 and 2018 that featured empirical investigations (abstracts accessible) in German or English were included. In March 2018, all databases were checked, limiting the time period covered to January 2011 to March 2018. To keep the scope reasonable and to concentrate on the most significant advancements, the time period studied was confined to 7 years.

In order to be published, acceptance, effectiveness (including efficacy), or efficiency (including cost analysis) of digital technology in nursing care and nursing education must be documented. A caregiver's ability to respond quickly was required, as were technologies that I contributed to the person's self-reliance in a way that allowed for the waiver of direct on-site care, ii) replaced nursing assistance with technology, and iv) assisted in nurse training or education. The technology's assistance might be for the individual in need of care, for official or informal caregivers, or for organisational procedures and processes. It might imply a wide range of technical developments, depending on the situation. Residential long-term care, formal and informal care in the home, hospital care, cross-sectoral care, palliative inpatient treatment, intensive care unit (ICU) care, and day-care centre care are some of the target settings for the initiative.

We excluded studies that used only mechanical devices and aids, electrical devices that were not networked or that did not rely on sensors to detect the activity of the person in need of care or the caregiver or their immediate vicinity, biotechnology, nanotechnology, medical devices (unless they were very closely related to nursing activities), and studies that used only mechanical devices and aids, electrical devices that were not networked or that did not rely on sensors to detect the activity of the person in need of care or the caregiver or their immediate vicinity.

- **Search Terms**

The search keywords were chosen based on a preliminary literature study and the existing expertise of the project's specialists. Each phrase has been customised to fit the database's

structure. For the two German databases, equivalents have been utilised (GeroLit and CarelLit). Upon request, all search queries may be shared.

- **Data extraction**

Using an Excel data extraction form that was tested, we were able to capture the names of the authors as well as the year, title, abstract, country, research design, number of participants, technology category, result dimension, goal setting, and the targeted groups. A digital, automated data analysis, as well as prior interviews with experts and an initial literature search, were used to create an acceptable technical category system. [28, 29]. When new technologies emerged that didn't fit into any of our preexisting categories, we incrementally devised new ones. A total of sixteen technical categories were devised in order to organise the information offered in each article. The majority of the categories still include a diverse set of technology. In a final phase, an iterative team approach improved and customised the extraction form for all categories. The whole texts were examined and information retrieved by four writers. If the complete text was clearly categorised using the extraction form, it was evaluated one again. If a text was omitted, a second author investigated the cause and, if required, re-included it.

4. Results

For this review, a total of 27.339 articles were found, including 27.278 from databases and 61 through handsearch. After deleting duplicates, 19.510 titles were left to be screened. After screening the abstracts, 1.949 articles were picked, resulting in 1.044 full-texts qualified for full-text screening. For the data analysis, 715 complete texts were used (see PRISMA flow diagram in Fig. 1). The 69 studies that were included originated from all across the world. Additional file 1 contains a complete list of all studies included.

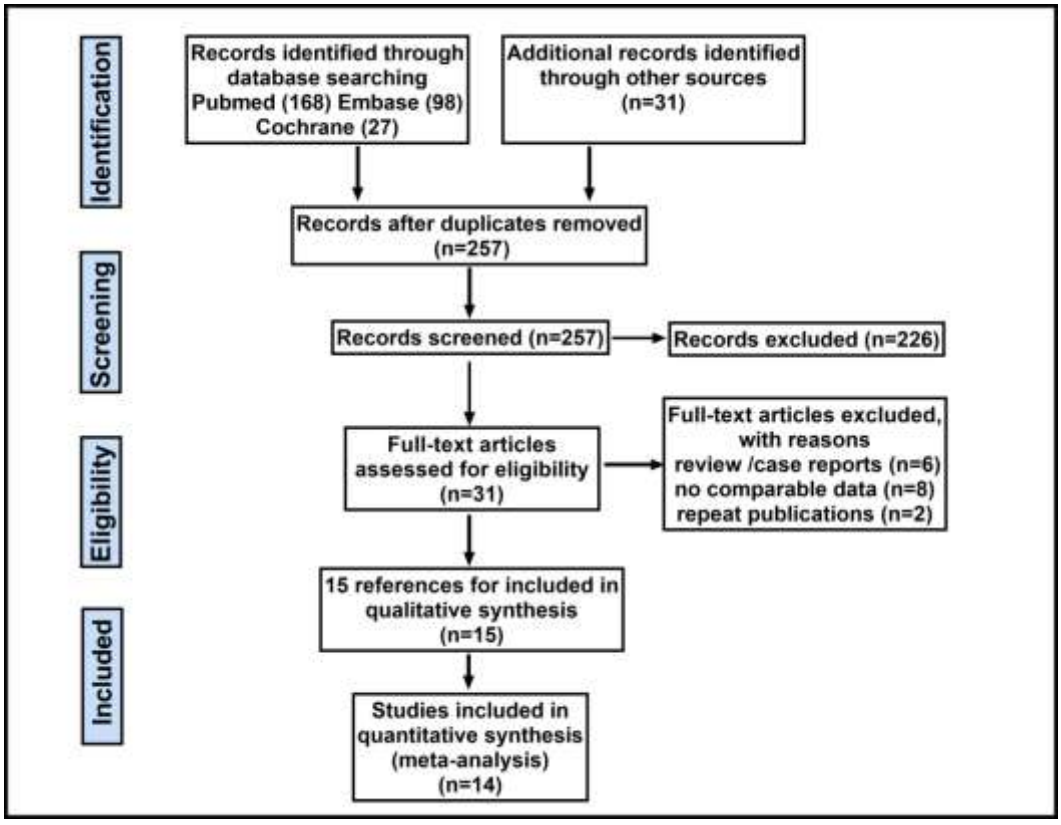

Figure. 1 Flowchart of the study selection and search results

- **Technology categories**

We looked at the amount of studies that were included in each technological area to see which ones were most often investigated in terms of all outcome dimensions (AEE) and which ones were least. Table 1 gives an overview of the distribution of included research in terms of technological categories. The table is arranged in order of frequency. During the analysis of the research, it became obvious that there were no common definitions for distinct technological categories. Table 1 contains the definitions we created to distinguish the technologies in this study. Information and Communication Technologies (ICT) (n = 147) is the most investigated technological category. ICT is a broad term that refers to a variety of technologies. In general, information and communication technologies (ICT) are technologies that offer or record significant information with a major emphasis on improving interpersonal interactions. Table 1 lists the technologies that are included. ICT might also include electronic health records (EHR)/ electronic medical records (EMR), hospital/care institution information systems (HIS), or monitoring technology. We opted to showcase these subjects individually since they represent huge areas of study. Robots (n = 102) are the second most investigated category. We discovered that the robots under investigation had a wide range of focus. They provide assistance on a variety of levels, including physical, psychological, social, organisational, security, educational,

and therapeutic. This category contains all sorts of robots that were referred to as "robot" throughout the article.

This type of technology is the third most commonly investigated in terms of research (n = 83). It's possible to use these sensors to monitor and control other equipment, such as pumps and alarm systems, as well as to monitor and track behaviour. A wide range of technologies (n = 80) are examined in several research, rather than just one. Most of the evaluations are focused on a certain demographic or a specific nursing issue. Many of these studies are acceptability studies, which look at a wide selection of technologies before making a final conclusion. Only a small number of studies truly investigate the efficacy or efficiency of technological systems that include a variety of technologies. Technology that has not been extensively studied includes virtual reality technology and tracking technologies, which may be used to find people or items, as well as serious games that are utilised for educational or personal development objectives. Personal medical records (PMR), unlike electronic medical records (EMR), enable the patient to view all of their data. In certain categorization systems, however, research on PMR might be considered secondary to those on EMR. The significance of this research should not be elevated as a result. Robotics and sensors are the most commonly researched technologies in terms of all result aspects, according to ICT, robots, and sensors (AEE). The least studied technologies include virtual reality, tracking, and serious gaming.

- **Outcome dimensions and technologies**

Acceptance, efficacy, and efficiency are all considered in this study's inclusion criteria. There are many different ways of describing and measuring these outcomes in the included research, which is mirrored in their wide range of conceptualizations. The quantitative assessment of acceptance in line with a broad variety of theoretical acceptance models as well as qualitatively stated acceptance outcomes are included in acceptance studies. Personal health or care-related outcomes, organisational or learning outcomes, and technology-related outcomes are all included in the definition of effectiveness. Many research labelled as efficiency-studies incorporate rudimentary cost assessments with a few complete economic evaluations since there are only a few studies focused on the prices of technologies at all.

Table 1 Classification of Technology Adoption Studies

Category	Percentage of Papers in Category	Description	Time of Influence	Example Technologies
Stand-Alone Desktop Technology	24.95%	Software for personal computers; the primary functionality of these applications exists without network connections.	Late Eighties to early Nineties	Personal productivity Suites; word processing, spreadsheet software
Client-Server Technology	25.08%	Software relying on a networked environment for main functionality.	Early to late Nineties	CRM systems; email systems; distributed databases
Internet-Based Technology	49.95%	Technologies which require an internet (IP) connection.	Mid Nineties to present	Web sites; Ecommerce portals; online classes

Only 5,8% (n = 42) of the included studies examined efficiency or at least included a cost analysis when it came to the specific outcome dimensions (AEE). Sixty percent of the included studies (n = 427) examined aspects of the effectiveness of care technologies, 59 percent (n = 424) examined acceptance. There are several counts of studies since some research include various outcome aspects, which means the percentage shares sum up to more than 100%. According to Table 2, which breaks down acceptance studies by outcome dimension, ICT (n = 93), robotics (n = 64), and EMR/EHR (n = 48) are the most commonly studied technologies. ICT has been the subject of the most efficacy studies (n = 94). The second- and third-largest groups are sensor and robotic technologies (n = 68 and 57, respectively). All technologies have only been evaluated for efficiency a few times. For this category, ICT (n = 9) may be emphasised. Only 6% of all ICT studies focus on efficiency or cost evaluations, despite the fact that the total number of studies is far more than that. Summarizing, we discovered a high number of research on ICT, robots and sensors that concentrate on efficacy and a big number of studies on ICT, robots and EHR/EMR that focus on acceptability. There is extremely little research on efficiency.

Table 2 Important Life Domains and Technology

Technology functions	Life domains				
	Physical and mental health	Mobility	Social connectedness	Safety	Everyday activities and leisure
Monitoring/ measurement (person, environment)	Physiological functioning (e.g., heart rate, blood pressure, and oxymetry), affect, health behaviors	Speed and variability of gait, distance covered, vestibular functioning, driving behavior, daily exercise	Frequency and duration of mobile and fixed communication device uses; frequency and duration of time in direct communication with other humans; frequency and time spent in social settings	Frequency of falls, location, driving ability	Frequency, accuracy, and speed of daily task performance; frequency and duration of leisure activities
Diagnosis, screening	Clinical conditions, risk status for clinical conditions	Risk for falling; ambulatory ability, adequacy of daily physical exercise	Social isolation, social integration	Emergency situation, being lost, at risk for driving accidents	Critical cognitive functioning, critical ADL/IADL status
Treatment, intervention (compensation, prevention, enhancement)	Remote behavioral treatment, chronic disease management, prevention and wellness interventions, clinical decision support	Guidance assistance, risk mitigation (e.g., risk of falling), encouragement and support for exercise	Enhanced social integration, connectivity through computers/communication technologies	Emergency response systems, computerized driving assistance, alert systems	Task assistance or training, entertainment, education

Note: ADL = activities of daily living; IADL = instrumental activities of daily living.

- **Study design and outcome dimensions**

The study designs have a significant impact on the quality and extent of evidence provided in investigations of acceptability, efficacy, and efficiency. In assessing the evidence level of diverse research designs, we use mainstream evidence-based nursing and evidence-based medical recommendations The highest level of evidence is meta-analysis, systematic reviews (Ia), RCTs (Ib) and quasi-experiments (II), while the medium level of evidence is evidence from well-designed cohort or case-control studies (III) and evidence from single descriptive, qualitative (IVa) or uncontrolled interventional studies (IVb) Study design has an effect on the outcome dimensions. There were a total of 22% of research on acceptability and 32% of studies on efficacy included in this review, both of which fall under the category of "experimental no control (n.c.)" study designs. Consequently, this research design accounts for the vast majority of investigations on both outcomes. Technical performance and correctness (regardless of efficacy) as well as acceptability under laboratory circumstances or initial effects with no control groups are covered in this category of investigations (mostly under laboratory conditions as well). An "experiment" in this context is used in a technical sense that varies from the methodological definition of "experimental research" in the social sciences. Small groups of people who "test" the technology in controlled environments to obtain accurate measurements and/or answers to questions about the technology are frequently used in engineering to conduct experimental testing with user studies to better understand acceptance, usability, feasibility, and technical effects. Our study's usage of the word "experimental (n.c.)" characterises these user studies and

links them to other frequently utilized research in the social sciences. Experiment. To put it another way, nursing technologies are somewhere in between the social and technological sciences, making this a common problem for researchers. A low level of evidence (IVb) is assigned to this research design per the cited recommendations.

In addition to these studies, mixed methods designs are used in 20% of acceptance research (n = 83). Case studies account for 16% of all methodologies, as do qualitative methods, cross-sectional analyses, and qualitative methods in general. Cross-sectional studies of technologies already in use, like as EMR/EHR, have frequently been conducted. Most of the studies included in this study were conducted at a low level of evidence design. However, we have just a few quasi-experiments and RCTs that studied acceptance (n = 14 and 8 respectively), but we discovered 24 systematic reviews. These meta-analyses included studies with a medium level of evidence (qualitative and quantitative).

5. Discussion

Digital technologies for informal and formal care that have previously been studied in terms of AEE were mapped out in this research to provide a systematic overview of the employed methodologies, target settings, domains of support (and the target groups) for these technologies. No previous research has attempted a quantitative review of all aspects of digital technology and nursing care, including formal and informal care as well as nursing education, to the best of our knowledge.

In terms of all possible outcomes, it's safe to say that ICT, robots, and sensor technology are the most often investigated technological topics (AEE). Virtual reality, monitoring, and serious gaming are some of the technological areas with the least amount of study. For the last several years, academics and research funders have likely focused their attention on the most commonly explored technology. With no further information, it is reasonable to conclude that this research interest has either been fueled by high expectations for these technologies in terms of supporting nursing care from the perspective of care research and nursing science, or that nursing contexts are application areas of high interest to those developing these technologies. Technology that is infrequently studied might be a fruitful study subject in the future.

For example, there are a huge number of effectiveness studies concentrating on ICT, robotics, and sensors, as well as several acceptability studies focusing on ICT and robots. However, as will be discussed further below, a huge percentage of these studies have just a poor level of evidence. In general, efficiency studies are quite uncommon. A lack of attention to the link between the advantages and costs of a new technology is evident in this example. Several factors might be at play here. There may be insufficient high-quality research that enables a comparison of the benefits and costs of a technology via a health economic assessment as one potential explanation. Many technologies are still under research or have never been put into practise. As a result, they may not be able to effectively predict future expenditures since they haven't had time

to conduct high-quality research in the actual world. This might be due to the fact that it is impossible to estimate the long-term costs of a technology that is still in development, as it is reasonable to believe that long-term costs will be much lower than present ones are. We discovered that the majority of the technologies featured in this collection are aimed at providing care in the hospital, at home, or in a long-term care facility. In addition, a great number of technologies are still without a clear setting. When developing a new technology, we don't believe it is necessary to leave the technology's goal setting up in the air. This hampers the development of the technology. Research limitations were discovered in relation to target locations for formal home care and cross-sectoral care. 'According to our findings, the vast majority of the technologies we examined are geared at persons in need of care as well as the professionals who provide it. For this reason, technology connected to informal home care is meant for those who need it, not for those who provide it. Due to the fact that these technologies are typically aimed at enhancing the freedom of those who need care, we believe that this is a primary factor in this. Even Nevertheless, this analysis points out that informal carers are an under-represented group when it comes to exploring digital technology. There has also been relatively little research done on technology that may aid youngsters in need of care.

For ICT, robotics, and elearning, the most rigorous studies were discovered (metaanalysis, systematic reviews, RCTs, quasi-experiments). It is critical to differentiate between systematic reviews and meta-analyses and RCTs and quasi-experiments on the one hand and on the other hand. If it is based on research with strong evidence, a systematic review will have a high level of evidence. Little-quality studies with low evidence in a systematic review contribute little insight into the efficacy or adoption of a technological innovation. As a consequence, it will be necessary to examine the quality and outcomes of the systematic reviews and meta-analyses included in this study in more depth before making a final judgement on their quality. This is particularly true when dealing with a variety of different technology. Although there are numerous RCTs and quasiexperiments in the fields of ICT, robots, and e-learning, systematic reviews on a high level of evidence may be anticipated in these areas of study. A quick glance at the systematic reviews featured in this article indicates that many of them actually find that there are not enough high-evidence studies and that additional high-quality research are required. Additionally, it seems that this holds true for subfields within ICT, such as robot e-learning, AAL, and assistive technology. Although the methodologies utilised in each study are similar, the assessed outcomes for each technology category are extremely varied, which might have an impact on the comparability of the findings of the research when it comes to AEE, as well.

6. Limitations

It is important to point out that our scoping review was done in accordance with the methodology's requirements. We've entered an area with a lot of potential. It was difficult to provide a succinct collection, systematisation, and summary of all the information due to the vast area and the high number of potentially relevant technology. In order to keep the scope modest, the study was confined to a time span of seven years. This has to be labelled as a restriction since

there is no way to represent a longer period of time. Due to the intricacy of the technologies, it was not feasible to organise all of the new developments in a way that avoided any duplication. An iterative collaborative method was used to generate the best feasible quality requirements for categorization, although any overlaps should be considered when evaluating the reported findings All 715 studies included in this evaluation were found to explain their techniques and outcomes in an unsatisfactory manner. This complicated the process of identifying, classifying, and evaluating relevant data. The higher the quality of the research design, the better the study description. As a result of this, the notion evolved that research writers often labelled their study designs with a greater degree of evidence than they really employed.

Propose systematic sacrifices owing to limited resources, we were still able to preserve the quality of the review by using the four-eye concept to all exclusion phases and employing a unique sequencing mechanism we devised for this study. Another weakness of this study is the publication bias. Rather than relying on unpublished research, we solely evaluated peer-reviewed articles. There are fewer papers with negative or neutral results in this review. As a result, it's reasonable to conclude that emerging technologies have an advantage.

The inclusion of both systematic reviews and direct research may have resulted in an over-representation of certain technological areas. Systematic reviews contain data from primary research as well. In order to acquire an overview of the various evidence levels employed to investigate distinct technological domains, we have acknowledged this constraint. Due to the large number of prospective publications discovered at this stage, we did not thoroughly review the reference lists of all research listed in the databases. Since there are no published studies involving real users, we cannot include technologies that are in the early stages of development. Nevertheless, our extensive search of nine databases, spanning the important disciplines of health and nursing research as well as computer science, has produced a complete overview of the spectrum of relevant literature.

7. Conclusion

Research in the area of digital technology and nursing care may benefit from the findings of this scoping study. Using AEE, we compiled a comprehensive analysis of the existing literature on the use of technology in informal and formal care settings and identified prospective areas for future research. We also compiled a database of promising technologies for further study. In light of the wide range of important technology, it was a challenge to summarise, organise, and synthesise all the information.

Because of a dearth of high-quality research, we urge that the scientific community refrain from performing systematic evaluations of digital technologies in nursing care for the time being. As a result, we advocate conducting high-quality studies of current technologies in terms of their acceptability, efficacy, and efficiency in real-world situations. As of this writing, there is a low percentage of studies focusing on efficiency, which should be a priority. It is also recommended

that future study examine the methodologies used to evaluate AEE more closely and determine whether or not new methods are required to achieve an optimum assessment of AEE. We observed that formal care at home and cross-sectoral care technologies are under-explored in terms of AEE when analysing the target locations and target categories. In addition, there are a number of technologies that do not have a specified setting. If you're working on health-care technology, we strongly suggest establishing an application context first. Informal caregivers and children in need of care have gotten little attention in the world of technology. To close the research gaps in the areas we focused on (technologies, target contexts, and target populations), policymakers should provide resources to support large-scale long-term assessments of how digital technologies are being used in the delivery of healthcare.

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