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ORIGINAL RESEARCH

Care robot literacy: integrating AI ethics and technological literacy in contemporary healthcare

Tuuli Turja[1] · Anna-Aurora Kork[2] · Sakari Ilomäki[1] · Ingvil Hellstrand[3] · Aino-Kaisa Koistinen[4]

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Abstract

Healthcare work is guided by care ethics, and any technological changes, including the use of robots and artificial intelligence (AI), must comply with existing norms, values and work practices. By bridging technological literacy and AI ethics, this study provides a nuanced definition and an integrative conceptualization of care robot literacy (CRL) for contemporary care work. Robotized care tasks require new orientation and qualifications on the part of employees. CRL is considered as one of these new demands, which requires practitioners to have the resources, skills and understanding necessary to work with robots. This study builds on sociotechnical approach of literacy by highlighting a dynamic relationship of care robotization in which successful human–technology interaction relies on exchanges between the technological and the social. Our findings from directed content analysis and theoretical synthesis of in-demand technological literacy and AI ethics in care work emphasize competencies and situational awareness regarding both using the robot and communicating about the care robot. The initial conceptualization of CRL provides a conceptual framework for future studies, implementation and product development of care robots, drastically differing from studying, implementing and developing robots in general. In searching for technologically sound and ethically compliant solutions, the study advocates for the future significance of context-specific CRL as valuable addition to the terminology of ethical AI in healthcare.

Keywords Artificial intelligence · Care robot · Care work · Multiliteracies · Social robot · Technological changes

1 Introduction

Robots are becoming social. Alongside industrial robots, service robots, with developing interactive features, have been introduced to facilitate working life. The healthcare sector is impacted by this robotic turn. Robotic devices are no longer present or visible only in behind-the-scenes operations; rather, they share spaces with people, including both practitioners and patients. Increasingly intelligent robots can facilitate healthcare tasks by collecting data during physicians' rounds, taking responsibility for physically burdensome nursing tasks, or providing support in the context of home care recipients' daily lives [1, 2]. However, ethical concerns have been raised regarding the use of robots in the sensitive and highly regulated context of healthcare. One of the concerns lies in the perception of robots as new kinds of healthcare actors that are neither morally equipped nor responsible [3].

Care robots are autonomous or semiautonomous service robots that, at present, mostly perform instrumental tasks in healthcare [4, 5]. As Van Wynsberghe [3] affirms, service robots that perform specific interactive and social tasks must exhibit a sufficient degree of artificial intelligence (AI). Typically, care robots can be operated on the spot as they take commands from the user via tactile sensors, dialog or, for example, quick response (QR) codes. In addition to machine-readable codes, robots take cues from the social environment through touch, voice, face, gesture and proximity recognition. Knowledge about the ways to interact with robotic interfaces is the first step in the process of becoming robot literate.

✉ Tuuli Turja
tuuli.turja@tuni.fi

1 Faculty of Social Sciences, Tampere University, Kalevantie 5, 33014 Tampere, Finland

2 School of Management, University of Vaasa, Social and Health Management, Vaasa, Finland

3 Department of Caring and Ethics at the Faculty of Health Sciences, University of Stavanger, Stavanger, Norway

4 University of the Arts Helsinki Research Institute, Helsinki, Finland

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Literacy as a concept has long been associated with meanings and skills that extend beyond the ability to produce and interpret written information. In the 1990s, the New London Group [6] introduced *multiliteracies* to refer to a broad conception of literacy as the understanding of textual and visual forms of information, in which the multimodality of meaning-making and participation in culturally and linguistically diverse societies are valued. Different concepts, such as *technological literacy*, have been used to address the needs of technologically invested societies [7]. As a specific form of technological literacy, we build on the concept of *robot literacy* [8], focusing on the individual's competence and external enablement to understand and use robots.

A premise of the study is that robot literacy is a precondition for socially sustainable, reliable human–robot interaction at workplaces. The article introduces care robot literacy (CRL) as part of a new perspective in working-life studies that considers robot literacy as an emerging occupational demand, here, in the context of healthcare. Specifically in the healthcare context, robotization is viewed as increasing both the demands of technological literacy and understanding of AI ethics. From an epistemological standpoint, CRL must be recognized as a distinct linguistic concept that highlights the unique context of care work and makes it a theoretical tool and a measurable objective. Existing robot literacy questionnaires are inadequate for accurately assessing CRL due to the essence of care work.

In comparison to other forms of technology and technological literacies care work exhibits the distinct qualities of sensitive professional practice and occupational ethics, which highlight the complexity of care robots and CRL. Healthcare is a particularly sensitive and morally complex field compared to other robotized environments, as it requires careful attention to ethical standards [3] and the occupational norms and values of practitioners [9]. Since human care largely derives from the time spent between the carer and the cared [10], its automatization is much more complicated compared to industrial processes. Robot-assisted patient care requires care workers serve as intermediaries between the robotic technology and the patients to ensure high-quality standard for human-technology interaction. Moreover, in healthcare, not all patients feel comfortable or safe with robots. The vulnerability of this particular group in a robotized environment necessitates case-specific deliberation on how or whether to utilize robotic assistance.

Suto [8] has identified robot literacy as a distinct form of technological literacy highlighting how AI systems cause robot users to face ethical dilemmas that they have not encountered while using other, more one-dimensional digital devices or interfaces. CRL is related to human–robot interaction. Care robots are physical, mobile entities and actors that must interact with people in a safe and meaningful manner [11]. However, one of the fundamental differences between the various types of robots or even among the types of intelligent service robots [8] lies in the roles they are given: In human–robot dyads working in a care context, tasks are performed with the robot as opposed to traditional scenarios where a human simply uses a robotic device.

To address the evolving needs and competencies in contemporary healthcare, this conceptual research [12, 13] introduces CRL by bridging the demands of technologically literate practitioners and the demands of ethical robotization in healthcare. To integrate perspectives of AI ethics and technological literacy into the concept of CRL, we explore how these demands are considered and justified in the literature regarding technologized healthcare work. The research question is: How can the concept of CRL bridge the existing frameworks of in-demand technological literacy and AI ethics in the context of healthcare? Here, technological literacy is viewed as the demand that care workers are adept at operating new technologies, while AI ethics is viewed as the demand of ethical considerations in the deployment of new technologies. Our sociotechnical approach examines the hypothesized interrelationship between technological literacy and AI ethics to build theoretical understanding of the concept of occupational demand of CRL.

The remainder of the article is organized as follows. Our conceptual framework is based on an understanding of the process of care robotization as a sociotechnical system in which the use of technologies is not determined to change the working life; rather, robot use is formed and negotiated in human-technology interaction. After introducing the demands of technological literacy and AI ethics in the context of care robotization, we describe our study design. The research methods include a scoping review on technological literacy in the care work domain, as the first phase of the analysis, and the theoretical synthesis that outlines the integrative conceptualization of CRL, as the second phase of the analysis. The findings section illustrates the content analysis of the scoping review and continues with the theoretical analysis between the concepts of in-demand AI ethics and technological literacy in the care work domain. In the concluding phase, we present and deliberate upon the concept of CRL.

2 Conceptual framework: care robotization as a sociotechnical system

Care robots represent a type of service robot (Fig. 1) that have been introduced to the healthcare services by a variety of pilot projects during the past two decades [9]. Care robots can perform instrumental or social tasks, effective or affective in nature [4, 5]. Indeed, both sensor technology and AI are developing toward a situation in which robots

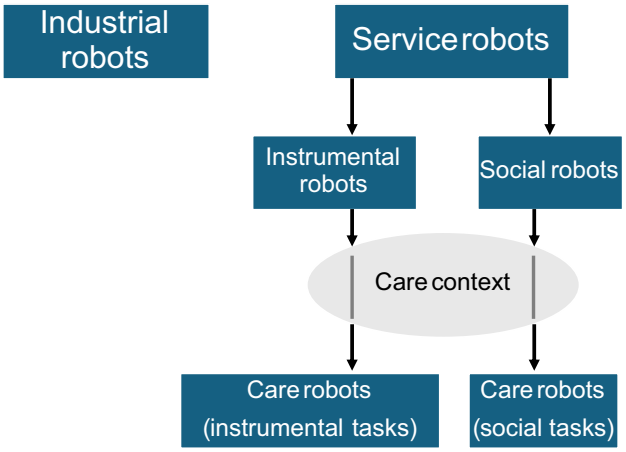

Fig. 1 Hierarchical classification of robot types

can gradually come to play more visible and active roles in social contexts.

According to the theory of sociotechnical systems [14], robotization and the corresponding expectations in the social environment exhibit a dynamic relationship in which successful human–robot interaction relies on exchanges between the technological and the social. On a principle level, human-technology interaction should be meaningful and value-compatible, and on a practical level, it should be easy and comfortable [2, 3, 9]. Sociotechnical systems fail if the robots do not find their place or take root in the social environment [15]. For example, care robots may well be abandoned on the shelf if practitioners have access to insufficient resources to learn how to use them [16] or if the robots in fact represent an unsuitable or irrelevant misinvestment in the context of daily practices [17, 18]. Robots are artifacts-in-interaction [19] and must be implemented in the care work environment through an iterative process as part of which the practices and motivations of the practitioners guide the ways in which the new technology is used.

Although many have argued that robots and robotic technologies play a part in providing good care [20, 21] tensions pertaining to the implementation of care robots remain. For example, when robots are used to support aging at home, "domestication of technology" [22] requires an awareness of the interactions between various users or actors, such as practitioners, care receivers, families, and communities [23]. To embrace robotization in care practices, we need technologically sound and ethically compliant solutions, coupled with a readiness within the care regime to integrate robots into daily practices [24]. As Salminen-Karlsson and Golay [25] note, care work is particularly vulnerable to instrumental technologies that overlook the need for relational interactions with regard to occupational care ethics.

Sociotechnical robot literacy offers practitioners the means and the agency necessary to evaluate both ethical dilemmas and the possibilities of robots being assigned tasks in a care context. Without proper robot literacy, people tend to have less understanding of the opportunities that robots can offer in the context of their work as well as poorer innovativeness with regard to how they utilize robots [26]. Furthermore, if robots are expected to be adopted in the workplace, resources for improving robot literacy are needed. This point is particularly relevant in a healthcare sector that constantly faces resource limitations but in which the drive for new technologies is nevertheless prominent [20, 27].

Among the various domains of technology use, social and ethical aspects are extremely critical in the context of sociotechnical care work. These social aspects or demands are subsequently discussed from the perspectives of in-demand technological literacy and AI ethics.

2.1 In-demand technological literacy in care work

In-demand technological literacy in the context of care work refers to the requirements of knowledge, competence, and ability to use healthcare technologies. Technological literacy encompasses all aspects ranging from competence in working with current technologies to cultural knowledge about emerging technologies [28]. Most relevant to CRL is how technological literacy extends beyond general technological skills and refers to knowledge of different interactional affordances that are integrated into a robot or other device [29]. Some social robots can be controlled through speech, while other kinds of robots require programming skills on the part of the user. Additionally, to the extent that technological literacy focuses on individual skills, it cannot be developed without access to new technologies.

A key precondition for technological literacy is access to new technologies and the facilitated opportunity to use and learn about them [30]. Workplace politics and practices control the participatory opportunities in organizational changes such as robotization [31]. Care robot pilot studies and trials in various healthcare facilities have been found to favor users in managerial positions [32]. Technological literacy can be viewed as an asset that sustains employee agency in technological changes. Neither motivation for such changes nor motivation to acquire technological literacy can be expected among the individuals who are relegated to side positions during the introduction of new technologies.

A great deal of terminology is included under the umbrella term "technology literacy" and different terms focus on its various dimensions. AI literacy tends to emphasize the individual's understanding of what is to be learned about the AI systems and the potential ethical consequences due to the use of them [33]. Also, data literacy focuses on in-depth knowledge about the system. Data-literate users are understood as being aware of algorithmic decision-making and being able to apply this process safely and

reliably in their jobs [34]. Robot literacy is a concept that closely resembles those of AI literacy and data literacy and that exhibits links to digital literacy, information technology literacy, device literacy, algorithm literacy, or media literacy [35–37]. To date, robot literacy is the only term that encompasses the comprehensive essence of robots as a combination of online, digital programmable systems and mechatronic, physically mobile machines.

As in the case of digital literacy, which entails the ability to find, evaluate, and generate information on digital platforms [35, 38], robot literacy refers to an individual's ability to use, understand, and critically evaluate a robot's actions [8, 39]. In contrast to mere digital platforms, robots involve both digital and mechanical affordances that entail particular ways of understanding and using them [40]. Additionally, the more intelligent a robot is, the more dynamic affordances it exhibits and the more proactively it interacts with its environment and user [41].

The Digital Health Literacy Model proposed by Yoon serves as an important foundational framework for initiating research of CRL. In the model, digital health literacy consists of functional, communicative and critical literacy domains [42]. Functionally literate individuals have the ability to find and understand information in digital formats. Functional literacy includes skills, such as navigating websites or using mobile applications. Communicative literacy involves more interactive skills, allowing individuals to actively engage with digital tools and produce information to digital platforms. Critical literacy encompasses the ability to critically analyze and evaluate digital information, discerning the reliability and relevance of online health resources and discussions.

Although robot literacy as an occupational demand is still a marginal research topic, it is predicted to receive more attention in the future [43]. The concept of robot literacy has been used almost exclusively in the context of education for children [44], even though robots have been an essential part of working life for decades. Work-related robot literacy studies would contribute to the literature of general technological literacy as a future objective of working life. In several studies, technological literacy has been shown to play an increasingly key role in employee empowerment, employment, career prospects and lifelong learning [45, 46].

Occupational differences have led researchers to view technological literacy as an ability that varies in terms of demand. According to Curtarelli [47], the basic level of technological literacy represents the individual's general readiness to use digital platforms. The second level is related to the specific requirements of any occupation or workplace. The third level includes the technological literacy of an information technology professional and adds the specific, vocational ability to create digital services to the two lower-level competencies [45, 47]. A competing perspective posits that all work in the contemporary world is developing in a direction that will require every employee to develop professional-level digital competence [48]. This view of a more universal demand for technological literacy emphasizes the importance of informal, continuous workplace learning with regard to every occupation, age group and career stage [46].

Focusing on the digital competence specifically in healthcare, Koivisto et al. [49] has introduced their model, in which competence consists of digital customer service, skills needed for using digital tools, knowledge management, professional ethics, and technological development orientation. This model emphasizes the specific context of professional healthcare and how digital competence has distinct demands in sensitive, human-centered service work.

The perspectives on occupational demands also hold true in the context of robot literacy. When robots are introduced to new sectors of work, employees need competence, educational resources and facilitation to utilize the new technology. Robot-literate individuals have the skills necessary to use robotic equipment as well as knowledge of the norms and practices involved in using these tools appropriately in a given context [46]. Emphasizing a future in which robots are more than a curiosity in society, Suto [8] has furthermore described robot literacy as a factor that will evolve when new generations become robo-native, just as contemporary youth can be called digi-native (see also [50] for a critical perspective on the idea of digi-nativity).

2.2 In-demand AI ethics in care work

In-demand AI ethics in care work refers to the requirement that all changes and reorganizations must respect the ethical norms to which practitioners are committed, whether in utilizing AI or automating some of the work tasks [51]. In general, intelligent systems are ethically assessed based on transparency, privacy, safety, accountability, fairness, justice, and autonomy [52]. In the context of working life, ethical dilemmas related to AI include a variety of situations ranging from algorithmic biases affecting the delegation of decision-making to machines to the employment crises that emerge when entire professions are replaced by robots [43].

Complying with general AI ethics is a key element in all contemporary robot development, but in healthcare, this approach must be combined with a focus on additional, vocational ethics emphasizing the relations between practitioners and care receivers [53, 54]. The international code of ethics for nurses prioritizes social responsibility and advocacy for patients and their human rights. The values associated with maintaining patients' dignity and respect are expected from all practitioners. This requirement refers to a trusting relationship in which patients are respected and heard [55]. Incorporating this code of ethics into the idea of care robotics immediately leads to a contradiction because

while a robot may have voice recognition capabilities, it does not have listening skills. Robots are therefore capable of only quasilistening, quasirespecting and quasicaring [56].

Among the ethical norms involved in care work, patient safety is emphasized. Thus, robots should be deployed in scenarios in which they contribute to the enhancement of patient safety [17]. Although robot safety mostly refers to protecting people from misfunctioning robots, human–robot interaction also involve a dimension of psychological safety. Despite the fact that robots merely simulate feelings and motivation, in ethical use of care robots, robots are expected to act as if they recognize human emotions, experiences and needs and to treat people with dignity [57].

In care robotization, AI ethics and care work ethics are understood to be linked together in existing guidelines concerning the use of robots. The ethical deployment of care robots involves two phases. First, in product development, intelligent robots are developed following the guidelines of AI ethics [58]; second, in practice, robots are implemented in response to context-specific demands, norms and expectations [39]. With regard to care robots, the first phase can be viewed as focusing on general AI ethics, while the second phase raises concerning ethical considerations that are specific to care work robotization. The convergence of these phases is evident as AI development is already characterized by its pursuit of fairness, trustworthiness and empowerment of users [59].

In light of the objectives of AI ethics in the robotization of care work, a review of social robots conducted by Boarda et al. [60], identified ethical dilemmas resulting from both technological and social aspects. In addition to the technological particularities associated with the process of implementing robots in novel working sectors, social dilemmas regarding the division of roles between humans and robots emerge. The most frequent ethical concerns expressed in AI ethics research have included issues related to privacy and data control, deceptive presentations, and human autonomy [60].

Adapting this categorization to the care work context, the term *privacy and data control* mostly refers to the need to protect the patient's right to be informed about the data being collected. From a technical perspective, this process includes questions regarding the locations of cameras and sensors and their activation in living spaces [60]. From a social perspective, the most important issue pertains to decision-making: The patient, such as a home care recipient, should be aware of and able to impact which data are being collected, how long the data are to be stored and how the collected information is handled [61, 62].For example, an ethical dilemma related to privacy arises when a telepresence robot is deployed in a care facility without a clear protocol specifying acceptable times and locations for video connections [63].

In a reality featuring conflicts, robotic monitoring may provide safety while simultaneously raising challenges pertaining to privacy. A primary concern that emerges with regard to the collection private information focuses on informing the patient about what and when such data are being collected. In a nonideal scenario, the actions and decisions of a care robot remain incomprehensible to both the practitioner and the patient. Situations in which robots' functions remain unknown to their users are known as black-boxing: the algorithms underlying the robots' functions are not revealed or understandable to people but are rather kept in a "black box" [64].

In addition to technical black boxes, 'social white lies' that can mislead robot users are also a relevant issue. For example, *deception,* as a second ethical concern in Boarda et al. [60], can manifest in situations where AI may appear to be more lively or capable than it actually is (e.g., simulating vs. feeling empathy). In a form of white lies, caregivers may also embellish and exaggerate robots' attributes to patients [65]. In these cases, such deception is typically rationalized by reference to consequentialist values related to the aim of benefitting the patient. That is, if patients suffering from dementia receive emotional benefits from a plush robot that is introduced to them as a living and affectionate entity, this outcome justifies the deception—the white lie—of presenting the robot as such [57]. However, deceiving a patient can be viewed as an ethical concern, particularly in situations featuring highly vulnerable patient groups [60].

The third ethical concern, *patient autonomy,* is another ambivalent ethical value related to the robotization of care work. Generally, robotic devices can either promote or obstruct the autonomy of patients [60]. New technology can support aging at home while simultaneously decreasing autonomy when living spaces are equipped with automated systems. With respect to ethical concerns pertaining to privacy and data control, autonomy is also relevant when the patient has the right to object to the use of a robot in their care. Healthcare practitioners must be able to read individual situations to identify tasks that are suitable for delegation to a robot without compromising patient autonomy.

Any other ethical concerns arising from the use of care robots that involve conflicts with the foundational principles and ethical norms of healthcare must be duly recognized, too [1, 66–68]. These concerns include the risk of increasing social isolation and loneliness associated with the replacement of human contacts by robotic contacts. Ambivalence prevails here, as well. Social robots, such as artificial pets and companions, hold the power to elevate social interactions; yet, at times, they may stand as poignant symbols of loneliness.

3 Methods

Through a scoping review of the extant research literature on both in-demand technological literacy and AI ethics we introduce and conceptualize in-demand CRL. Figure 2 illustrates CRL integrated from technological literature and AI ethics in healthcare.

3.1 Study design

To transform the general notion of technological literacy into a sociotechnical context- and AI-ethics-specific definition of CRL, this study assimilated, combined, and interpreted existing research literature [69–73] across three domains: technological literacy in the context of care work, AI ethics in the context of care robotization, and sociotechnical systems.

In the first phase of this process, aspects of and justifications for in-demand technological literacy were collected through a scoping review. The database consulted as part of this research was Academic Search Ultimate (EBSCO). The search focused on peer-reviewed journal articles in the English language (all content) based on the following search terms: ("care" OR "health") AND ("work*" OR "professional" OR "nurs*" OR "practitioner") AND ("literac") AND ("digital*" OR technolog* OR "ai" OR "artificial intelligence"). A total of 76 search results were revealed, and any duplicates, reviews or irrelevant studies concerning, for example, literacies other than those pertaining to practitioners (typically patients) were excluded. This process resulted in a total of 10 studies, which are described in Table 1.

3.2 Data analysis

To explore the aspects of and justifications for in-demand technological literacy, the review data were analyzed using directed content analysis [78, 79]. We used two conceptual frameworks to guide the reading of the included studies: first, the conceptualization of three domains of digital health technology literacy (functional, communicative and critical), developed by Yoon et al. [42], and second, the model of practitioners' digital competence in the context of healthcare work [49].

Based on these conceptual guiding tools, we formed a matrix where we extracted the information on the articles. The literacy domain of each article was coded as functional, communicative, critical literacy or a combination of two of the three. This was followed by two independent authors collecting quotations from the articles that related to the digital competences. An example of the coding scheme for practitioners' digital competence is presented in Table 2. The included articles were read repeatedly to identify how technological literacy was discussed and how the need for digital competences of healthcare practitioners were justified. To accompany the directed content analysis and to secure the inclusion of potential demands that have not been recognized earlier, the category "Others" was included in the coding scheme to allow inclusion of unanticipated themes competencies, interprofessional interactions and the establishment of a professional identity and image being identified). The analysis was based on the verbatim content of whole text of the included articles. The categorizations of the data (Table 1) were determined by two authors, after which any conflicts were resolved through consensus.

In the subsequent phase of the analysis, the findings from the technological literacy review were reflected on the existing review on AI ethics [60], presented in the Chapter 2.2. According to the deductive research approach , the justifications found for in-demand technological literacy and AI ethics were interpreted [69] as expressions of the demands for CRL. Finally, the synthesis was used to build up a sociotechnical understanding of the in-demand CRL by studying how these justifications for technological literacy and AI ethics correspond and complement with each other.

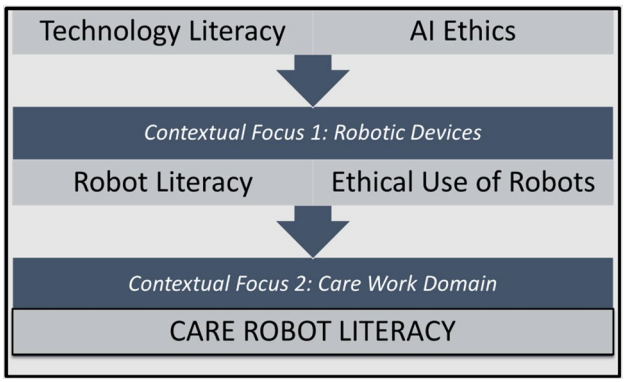

Fig. 2 Integrating general technological literacy and AI ethics into care robot literacy

4 Findings

4.1 In-demand technological literacy

The empirical studies included in the review had been published recently (in the 2020s), thus highlighting the relative novelty of the research topic of technological literacy. With regard to the contexts of these studies, Australia stood out as the country in which the most data were collected, specifically regarding the topic of digital literacy as a form of technological literacy. In terms of the conceptual variance exhibited by different literacies, digital literacy was the most commonly used type of literacy overall, followed by e-health

Table 1 Studies of technological literacy in the context of healthcare work

Publications	Research type	Country (sample)	Target population	Literacy reference	Literacy domains	Literacy objectives	Digital customer service	Technical skills	Digital knowledge management	Occupational ethics	Development skills	Communication
Coldwell-Neilson et al., [74]	Qualitative	Australia	Optometric students	Digital literacy	Functional	Enhancing computerized healthcare and telecare	x	x	x	x	x	x
Estel et al., 2022	Quantitative	Germany	Physiotherapists	Data literacy	Critical	Improving telecare	x	x	x	x		x
Kim & Jeon, [49]	Quantitative	Korea	Nursing students	eHealth literacy	Functional/ Critical	Enhancing communication and patient safety in the healthcare system			x			
Kuek & Hakkennes. 2019	Quantitative	Australia	Healthcare professionals	Digital literacy	Functional	Safer and more high-quality care		x	x		x	
McKinstry et al., [75]	Qualitative	Australia	Occupational therapy students	Digital literacy	Functional/ Communicative	Metacognitive awareness of digital literacy building occupational roles	x	x	x	x	x	x
Shiferaw et al., [76]	Quantitative	Ethiopia	Healthcare providers	Digital literacy, digital information literacy	Functional	Medical information to be recorded correctly, technologies adopted, general healthcare standards keeping up with contemporary standards, confidential patient information safety	x	x	x			

Table 1 (continued)

Publications	Research type	Country (sample)	Target population	Literacy reference	Literacy domains	Literacy objectives	Digital customer service	Technical skills	Digital knowledge management	Occupational ethics	Development skills	Communication
Slevin et al., [77]	Qualitative	Ireland	Healthcare professionals	Digital literacy	Communicative /Critical	Ensuring the needs of patients (safety and consulting) can be met satisfactorily; Professionals enhancing their understanding of digital health technology and interacting with patients by improved digital health communication skills while also trying to avoid misleading or creating confusion	x	x	x	x	x	
Sogut et al., 2022	Quantitative	Turkey	Midwifery students	eHealth Literacy	Functional	Technology self-efficacy to increase the quality of healthcare and to improve patient safety		x				
Telkar et al., 2021	Mixed method	India	Medical students	Digital literacy, data literacy	Functional/ Communicative	Improving health education, enhancing telecare		x				x

Table 1 (continued)

Publications	Research type	Country (sample)	Target population	Literacy reference	Literacy domains	Literacy objectives	Digital customer service	Technical skills	Digital knowledge management	Occupational ethics	Development skills	Communication
Wood et al., 2021	Quantitative	US	Medical students and faculty	AI technology literacy	Communicative	Providing personalized care		x		x		x

literacy and data literacy. The term robot literacy was not used in any of the studies.

4.1.1 Literacy domains

With respect to the varied sample of study designs and research questions, our first main task was to determine how the functional, communicative and critical literacy domains were emphasized in the data. In the context of technological changes in care work, technological literacy was associated most commonly with the functional value of developing digital skills. This value was described in terms of the skills and confidence associated with using digital systems in healthcare work. The critical and communicative domains of technological literacy seemed to have received less attention. These domains were used mostly in settings in which user groups were already considered to be relatively technologically savvy; hence, basic-level functional technological literacy was not prioritized.

The critical domain of technological literacy was mostly associated with the issues of safety and security regarding patient records and thus focused largely on data literacy. However, obvious overlap was observed among the different domains and definitions of technological literacy. For example, both functional and critical domains of technological literacy were emphasized in a study conducted by Kim & Jeon [49], in which e-health literacy was defined as a combination of technological skills, cognitive and sociocultural digital literacy, and self-efficacy.

The communicative domain of technological literacy appeared in definitions in which literacy was associated with an understanding of technologies rather than a certain skillset. For example, McKinstry et al. [75], adopted a communicative perspective on literacy when they described how digital literacy impacts students' readiness to forward knowledge regarding current and emerging technologies to their field of practice. Similar perspectives on professionals' technological literacy were highlighted by Slevin et al. [77], in which a lack of digital literacy was viewed as a barrier to the use of digital systems among care professionals. These authors concluded that it would be beneficial to develop the digital literacy of personnel and digital systems simultaneously, as users' needs and preferences are not sufficiently taken into account in the design phase of such systems [80].

Regarding the justifications for technological literacy in care work, studies reported different conclusions across different study populations. Whereas studies that focused on samples of professionals emphasized the ability of technological literacy to support high-quality care, studies that focused on other populations (e.g., students) were more variable in terms of theme. Psychological factors related to occupational roles, self-efficacy and self-awareness were examined in the studies included in the review.

Table 2 Examplary coding scheme for in-demand digital competence

Publication	Digital customer service	Technical and meta-skills in using digital tools	Digital knowledge management	Digital professional ethics	Develop-ment skills of tech-nology use	Others
Coldwell-Neilson et al., [74]	I effectively develop evidence-based communications for patients and colleagues	I demonstrate efficiency and effectiveness in my use of digital clinical technology during patient examinations, in order to achieve appropri-ate diagnostic outcomes	I generate, collect, organise, analyse and manage data appropriately	I interpret key resources and defend evidence-based decisions for a wide range of clinical and ethical challenges in optometric practice	I am a proactive, lifelong-learner who keeps up to date with emerging research and technology	I work effectively with colleagues in teams, including online
		I have access to, and can use, bibliographic referencing tools (e.g. EndNote)	I critically appraise the quality of scientific information			I manage my online persona and personal information strategically in order to maintain a positive and professional image
			I effectively consult research literature to fill gaps in my knowledge, and put it into practice			I communicate research effectively using multi-media
			I reflect on how to collect and communicate data			I make use of technology in order to attend case conference sessions
			I evaluate and communicate data regarding the structure and function of the visual system, giving due respect to cultural and social issues			I collaborate in a professional manner, using collaborative technolo-gies as appropriate
			compare and contrast the clinical data collected with findings re-ported in the clinical and scientific literature			I am aware of and use social and professional networks
			I adapt clinically presented information into a written case report in a clear, concise and insightful form			

Table 2 (continued)

Publication	Digital customer service	Technical and meta-skills in using digital tools	Digital knowledge management	Digital professional ethics	Develop-ment skills of tech-nology use	Others
			I use technologies to identify and synthesise discipline knowledge, evidence, data and statistics and use this to problem solve, and inform decision-making and professional best practice			

The priority of maintaining the quality of care was clearly emphasized in the findings. Partly as a result of the COVID-19 pandemic, telecare was central in many of the studies. Digital and health literacy were understood as types of social challenges that emerge in the context of the computerization of healthcare services in response to sudden changes, such as pandemics. Particular relevance to robot studies was observed in the context of the digital literacy study conducted by Slevin et al. [77], in which healthcare professionals expressed having experienced difficulty finding a common language with patients when discussing e-health solutions. The lack of a "formal language for digital health" [80] has relevance in the context of care robotics because of the posited need to communicate about both the digital system and the mobile and embodied robot.

4.1.2 Digital competence

The most frequently recognized competency-related demands in the literature were technical skills and metaskills, digital knowledge management, digital customer service and digital professional ethics. Additionally, development skills, interprofessional interactions (an emergent factor not present in the original model of digital competence), and the establishment of a professional identity and image (an emergent factor not present in the original model of digital competence) were mentioned. These findings substantiate the observation that functional literacy is more prevalent than communicative and critical literacy domains. Digital competence was especially valued in terms of skills pertaining to the use of technology such as information systems.

Occupational ethics was considered either to be a phenomenon that had not been strictly defined [75, 77, 81] investigated from a data security perspective [82], biomedical perspective in terms of the need for legislation or clinical guidelines [77, 82] or as potential safety risks due to inaccurate or ill-suited data [77]. While these are important aspects of care ethics, more relational perspectives on care seemed to have been missing [83]. The limited explicit focus on ethical issues might have been the result of the studied non-intelligent technologies.

4.2 Synthesis of technological literacy with AI ethics

The justifications for technological literacy and AI ethics were theoretically synthesized from a sociotechnical perspective in which CRL was understood as building from technological and social occupational demands [84, 85]. Among the insights uncovered in this study, digital skills and patient safety as well as ethical and situational awareness were interpreted as the primary justifications for in-demand

CRL among healthcare professionals. The results are illustrated in Fig. 3.

4.2.1 Digital skills and patient well-being

Empirical studies on technological literacy in care work have reported two primary findings. Technological literacy has been justified, first, as a means of supporting professionals' digital skills, thereby serving as a precondition for the development of telecare services in particular; and second, as a way of providing high-quality care. An emphasis on digital skills supported prior research in which technological literacy skills are viewed as a way of ensuring that healthcare professionals could keep pace with the technologization of healthcare [86, 87]. Accordingly, high-quality care refers to the process of developing and maintaining safe, reliable and optimal care for patients and ensuring successful interaction between the patient and the professional. In Slevin et al. [80], this process was described as enabling professionals to discuss digital services to patients clearly but without being patronizing.

Overall, not only individual competencies but also professional understanding have been the focus of research. This summarizing finding links CRL, first, with definitions of general technological literacy and the ability to use, understand and evaluate robots, and second, with professional care ethics, in which care competencies and relational aspects of care are essential. In other words, addressing both the general robot literacy, and the domain specific features or care robotization are crucial in understanding CRL. Although technical and social competencies can be viewed as separate from each other, a sociotechnical approach emphasizes the fact that the technical and the social are intertwined. Without a holistic and sociotechnical form of CRL, practitioners do not have the means to build trust in the robot or, for example, to make decisions regarding blame attributions when a robot functions unexpectedly [88]. As a conclusion, CRL entails a complex, sociotechnical set of competencies from general digital skills to specialized occupational skills.

Among the occupational demands for AI ethics when implementing assistive robots, privacy, data control, deception and autonomy were prioritized in Boarda et al. [60]. Given that these priorities are all connected to patient well-being, technological literacy and AI ethics in healthcare are both identified as prioritizing patient well-being. For this reason, patient well-being is also defined as one of the main justifications for CRL. First, the practitioner's skill and confidence in using care robots have indirect positive effects on patient safety. Second, concerns regarding privacy and autonomy in data management have direct impacts on patients' rights, autonomy and well-being as well as professional care ethics. However, in the included literature, ethical aspects were reasonably scarcely addressed, as only Shiferaw et al. [76] explicitly addressed privacy, Estel et al. (2022) and Shiferaw et al. [76] data control, and Slevin et al. (2020) and Wood et al (2021) deception (in the form of acknowledging the irreplaceability of human contact).

The ambivalence between the safety and the privacy of the patient exhibited a clear link with data literacy and the ways in which a robot-literate professional would able to understand and express to others the conflicting objectives associated with care robot use, monitoring and data collection. Thus, the connection between technological literacy and AI ethics is evident. Hereby, privacy and transparency are classified as the most emphasized subcategories of patient well-being in the context of sociotechnical CRL.

4.2.2 Ethical and situational awareness

Situational awareness was interpreted as another main justification for CRL. From the technology literacy perspective, healthcare professionals must know how to read the situations and risks of robotic assistance. Such situational awareness, which has previously been discussed as a form of communicative and critical technological literacy [42], is reflected in AI ethics by a demand of careful assessment of robot's suitability in various tasks and situations.

"Some people just need human contact"

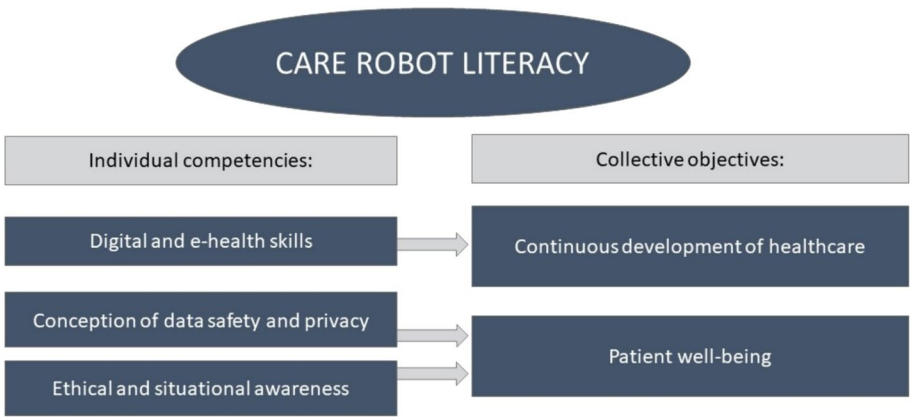

Fig. 3 Justifications for in-demand care robot literacy

From the AI ethics perspective, situational appraisal entails an acknowledgment of the true capabilities of the robot and ethical ways of expressing those capabilities to others, particularly patients.

"Low-quality data can create dangerous situations"

As always, clinical guidelines are used as a foundation for the task of evaluating the suitability of technological or robotic assistance in the context of care work [80, 82]. Overall, CRL calls for situational awareness with regard to both using the robot and communicating about the robot. CRL implies that in order to read a robot, one needs imperative understanding of its capabilities and limitations in changing social environments.

5 Discussion

We propose that the concept of CRL can serve as a theoretical framework that combines central demands for AI ethics and technological literacy in contemporary healthcare. In this study, the relevance of context-specific robot literacy is emphasized based on a multifaceted, sociotechnical understanding of healthcare robotization. Our findings show that, as an occupational asset, CRL would be valued for the digital and professional skills as well as the ethical, situational awareness in support of the ultimate objective of patient safety and well-being—even in robotization.

This study advocates for the future significance of CRL as a substantial addition to the terminology in healthcare research and practice. Robots are emerging in care domains, adding new dimensions to the existing concept of service robotization. [3]. Following Potter [74], we rationalized the conceptualization of CRL as a linguistic concept, to be realized as a distinct phenomenon and simultaneously open to debate and further development, such as quantification. Ultimately, the concept of CRL is required due to the high degree of variance among robot types and their domains [81, 89]. While general robot literacy can offer understanding of the human-robot-relationship at a more macro-level, more domain-sensitive concepts such as CRL are needed to define, explain, and highlight distinct and context-dependent phenomena. Defining the necessity of any type of (technological) literacy is a matter of value judgments [90], and in a healthcare, this refers to the distinct need to conserve values such as patient safety, quality of care, care work ethics, equality, the security and privacy of digital health data, the availability of a competent workforce and cost efficiency [86, 91].

CRL holds relevance also within the context of working life, distinguishing itself from more traditional perspectives that perceive robot literacy solely as a technical skill acquired through informal education. Robot literacy as a term in working life studies includes, for example, the imperative in which ensuring successful collaboration, the human workers must accept and trust the robots [88], as well as understand their roles and possibilities [92]. To foster robot acceptance, some social robots are programmed not only for instrumental functions but also ambitiously designed to display cooperative behaviors and communicative skills [93]. Robots that exhibit both normative and performative functions in healthcare, call for a specific concept of CRL.

The current research emphasizes CRL as a social practice in constantly developing sociotechnical environment. In addition to technical skills, healthcare practitioners are expected to acknowledge the more systemic dimension of technologized services. Our findings support the notion that healthcare organizations benefit from robot literate employees who have the capability to *read* robots for their invisible features, as well as *read* the environment for its readiness for robot implementation and need of new regulation [76].

Data safety, privacy, and transparency are integral components of CRL, as emphasized in the literature on technological literacy [94] and AI ethics [61, 62]. CRL is required for the responsible use of robots in the context of healthcare work, which is sensitive, regulated and morally laden. In addition to the extant literature on AI ethics in healthcare, we observed that occupational ethics could provide guidance for communicative and critical CRL as well as the ways in which practitioners find suitable roles for robots.

CRL accounts for the specificities of the institutional healthcare, such as the basic skills required to use the interactional and technical interfaces associated with robotic systems, the ability to involve robots in care encounters and manage information, and the development of both technology and work practices, all of which must be performed in an ethically sound manner. Individual technical skills, including the confidence to use digital systems and digital knowledge management, are valued assets of healthcare practitioners. This conclusion emerges from both the technological literacy review conducted as part of this research and a previously published review of the literature on AI ethics [60]. Thus, the demand for robot-literate practitioners entails the motivation to have technologically competent staff who are skilled in managing the technologizing care work while continuing to provide optimal care [28, 95]. Poor literacy among practitioners poses a risk when, instead of optimal technology use, digital service paths are not utilized adequately, resulting in patients failing to receive advice and support [86, 87].

Digital and e-health skills are also reflected in the collective objectives of the development of healthcare. Individual skills are viewed as important, if not imperative, with regard to the sustainable, continuous development of healthcare. Without technologically competent staff, healthcare organizations are not able to keep pace with technological

innovations such as the integration of robots. However, it should be acknowledged that situational and political processes underpin learning in the workplace [31]. Overall, the ability to take full advantage of technological advancements is also beneficial for practitioners' sense of professional identity and ethical code as well as their well-being at work [96].

Coming to terms with any type of literacy entails learning certain norms, values and practices of a social environment [30]. However, in the absence of CRL, practitioners have only limited ability to demand the development of more ethical and context-appropriate robots. Ultimately, our findings highlight the fact that CRL is useful due to its focus on digital skills and ethical, situational awareness in support of the ultimate objective of patient safety and well-being. We suggest that CRL should be understood a necessary literacy in contemporary, technology-saturated care work, thereby contributing to the socialization of individuals into the meaning-making practices involved in everyday work life [6, 97]. Robot-literate healthcare practitioners are considered to have the opportunity to play an active role in the sociotechnical system and therefore to be able to find optimal ways of implementing new robotic technologies in their work.

As care robots remain an emerging form of technology, it can be argued that CRL has special significance as a theoretical tool for the future development of robotized, relevant and ethical care practices. Technological literacy in general and CRL in particular are assets for future working life, where intelligent systems and automation will not just replace but renew and reorganize work. This orientation toward the future connects CRL to the concept of multiliteracy that promotes active participation in the design of meaning and that of "social futures" [6]. Similarly, CRL is also a practice that involves designing social futures, in which care robots are assigned specific meanings and uses. As an emerging skill that will become increasingly relevant in the future, CRL is in line with the concept of futures literacy, which was created by UNESCO [98] to encompass the skills required to imagine and construct the future [99, 100].

5.1 Limitations and strengths

The main limitation of this study pertains to the data collected for the scoping review. In addition to the relatively small sample size, the individual studies included a variety of different types of technology. One reason for the fact that few studies were found is that previous studies on health technological literacy have focused almost exclusively on patients, customers and consumers as the users of technology rather than emphasizing healthcare practitioners. One might also consider the study's design, which focused on a hypothetical interrelationship between technological literacy and AI ethics instead of a more open-ended perspective, as a potential limitation.

This study provides insights into healthcare practitioners and their robot literacy. The aspects of digital health literacy do not extend to the complexity of the robotic devices as combinations of software and physically mobile hardware. This reflects the complexity of robot literacy as compared to technological literacy in general. Robot literacy is as practice-oriented and context-dependent as the process of robotization itself. Robot literacy must be viewed as a precondition for the successful deployment of new and intelligent technology.

Based on the scoping review of the literature on technological literacy and a synthesis with the literature on AI ethics, this study provided an integrative conceptualization of the core motivations associated with CRL. The rationale underlying the sociotechnical concept of CRL was to ensure that the phenomenon would not be viewed simply as another technological term in the general field of technological change. Instead, the implementation and use of care robots in a specific care environment are understood to entail a distinct set of practical and ethical issues that highlight the need for a specific concept of CRL.

5.2 Implications

Technological progress in healthcare robotics calls for an integrative conceptual framework for CRL that can be used across disciplines ranging from education and nursing sciences to more technology-oriented user experience (UX) studies. CRL required its own distinct concept, first, for the distinct nature of care work where technologies cannot be implemented without considering occupational care ethics [25]. Second, because the term CRL is valuable not only for practitioners and end users but also for technology developers. In light of the need for CRL as a distinct concept, the product development processes for industrial, service, and care robots would benefit from being differentiated from the outset.

We observe many opportunities to employ CRL as a theoretical tool. One such opportunity involves conducting empirical research to facilitate the formulation and refinement of a questionnaire aimed at assessing proficiency in the context of CRL. Validating a quantitative scale would develop the theory further and guide care robot research, relevant interventions and the implementation of care robots. The need for quantified measure of CRL emphasizes its district nature. Existing robot literacy questionnaires provide only small part of the dimensions that should be included to the CRL scale. One indicator of the need for context-specific measurements in robotization, is that robot studies suffer from replicability challenges, arguably because of the wide range of the robot types [101].

CRL plays an important role in the complex task of introducing robots into human-centered care work, and it is recommended that this literacy should be included in commonplace user experience and care robot acceptance studies. Correspondingly, to develop a theoretical understanding of how robot literacy is actualized in literacy events [102] qualitative studies, especially those examining work practices in naturally occurring healthcare encounters, would be valuable. As a novel concept, CRL could also be a topic for further systematic reviews in the future.

To improve theoretical understanding of CRL, we make several suggestions. First, the topic of healthcare ethics was identified in the context of technological literacy studies, albeit without specific references to robots. The relationships among care practices, ethics and CRL represent an important avenue of further inquiry. Second, development skills related to technological literacy were discussed in terms of an individual's characteristics or virtue, for example, with regard to being proactive toward learning [81], adopting positive attitudes toward patient education [77, 80], or understanding the incompatibility among information systems [103]. A point that is missing from this conceptualization pertains to the practices involved in shaping what the work-technology intersection could become. Instead of merely adopting preexisting technologies, healthcare management should actively develop the work processes. Moreover, practitioners and patients should be more actively engaged in the process of assessing the effects of innovations [104].

Finally, future studies should focus on the different pedagogical implementations involved in introducing the CRL to students and practitioners. Just as in general education readying students for using and understanding AI and robots [84], CRL would have a justified place in the vocational curriculum as a specific form of media or technology education.

6 Conclusion

In this study, care robotization was viewed from a sociotechnical perspective. The conceptual research focused on relationships between technological literacy and AI ethics to develop a context-specific theoretical framework of the in-demand CRL. The proposed conceptualization of CRL aims to shift the multiliteracy discourse from a technology-centered discourse into a more holistic discourse by arguing that CRL involves elements from both technological literacy and AI ethics. Especially the awareness of AI ethics and occupational ethics in the concept of CRL emphasizes the domain-specific view that posits that successful interaction among practitioners and patients is crucial—also in robotization. As a new and relevant concept, CRL takes seriously the interconnections between AI ethics and the ethics of care work as well as the multiple literacy skills that are required to make use of the full potential of responsible robotization. By maintaining and facilitating individual technical skills and competences, as well as ensuring the acceptance in the social environment, CRL enables the continuous and innovative development of healthcare without compromising the priority of patient well-being. As such, CRL contributes to high-quality care as well as sustainable healthcare services in the future.

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Declarations

Conflict of interest The authors declare that they have no competing interests.

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