Evaluation Frameworks for Digital Nursing Technologies: Analysis, Assessment, and Guidance

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Research Article

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Abstract

Background:

The evaluation of digital nursing technologies (DNT) plays a major role in gaining knowledge into certain aspects of a technology such as acceptance, effectiveness, or efficiency. Evaluation frameworks can help to classify the success or failure of a DNT or to further develop the technology. In general, there are many different evaluation frameworks in the literature that provide overviews of a wide variety of aspects, which makes this a highly diverse field and raises the question of how to select a suitable framework. The aim of this article is to provide transparency on existing comprehensive evaluation frameworks that can be applied to the field of DNT and to conduct a detailed analysis and assessment of these frameworks to guide field researchers.

Methods:

A three components search process was conducted to identify relevant frameworks. (1) A systematic literature search in PubMed; a narrative review (2) and (3) expert consultations. Data related to the frameworks evaluation areas, purpose, perspectives, and success definitions were extracted. Quality criteria were developed in an expert workshop and a strength and weakness assessment was carried out.

Results:

18 relevant comprehensive evaluation frameworks for DNT have been identified. 9 overarching evaluation areas, 7 categories of purposes, 5 evaluation perspectives and 3 categories of success definitions could be identified. Eleven quality criteria for the strengths and weaknesses of DNT-related evaluation frameworks were developed and the included frameworks were assessed against them.

Conclusion:

Evaluators can use the concise information and quality criteria of this article as a starting point to select and apply appropriate DNT evaluation frameworks for their research projects or to assess the quality of an evaluation framework for DNT, as well as a basis for exploring the questions raised in this article. Future research could address gaps and weaknesses in existing evaluation frameworks, which could improve the quality of future DNT evaluations.

Background

A large number of digital nursing technologies (DNTs) are currently being developed and tested in nursing practice [1, 2]. These technologies offer promising opportunities to address existing societal challenges such as the shortage of skilled workers or the increasing demand for long-term care [3]. Professional nurses point to the need for improved technological support in direct care to reduce physical strain and psychological stress [4], which e.g. could have a long-term impact on retention in the profession. On the other hand, the use and acceptance in actual clinical support appears to be rather low [5, 6].

The reasons for the lack of acceptance and usage can be very diverse, since DNT are complex interventions [7]. Specific reasons for non-adoption can be that technologies are not user-friendly (low usability) [4] or have no obvious perceptible benefit for actual work practice (job relevance, perceived usefulness) [4]. Privacy issues or cost concerns may also have an important influence for persons in need of care [8]. Scientific evaluations that provide transparent information on technologies from different perspectives and viewpoints could help to understand the bigger picture of DNT success and provide important insights on specific impact factors. However, what exactly constitutes a successful digital nursing technology is not entirely clear - mere acceptance and usage may not be sufficient as the only criteria for DNT success, as the definition of success may depend on the perspective taken.

Transparency must be created about the possibilities of evaluation aspects and existing definitions of success. Comprehensive evaluation frameworks that clearly present important aspects of evaluation play an important role in supporting researchers and developers in this process. Evaluation frameworks can be used to provide a structure for the evaluation as they provide information and definitions of technology success, evaluation areas, methods, and tools. Currie (2005) makes a distinction between four different framework types in the field of nursing and technology [9]. Generic evaluation frameworks (based on general research principles), frameworks that focus on human behaviour, frameworks that focus on social/organizational relationships and frameworks that focus on software life-cycle [9]. This article adds a meta category to this distinction, which is called comprehensive evaluation frameworks. These frameworks may include multiple parts of the aspects introduced by Currie.

There is a variety of these comprehensive evaluation frameworks in the literature and most existing comprehensive evaluation frameworks are very heterogenous in their content, approaches and methodologies. One problem is the lack of meta-information on what evaluation frameworks can contribute, which evaluation perspective they take and how they fit in with different DNT issues. There is also a lack of transparency about which of the existing frameworks focus on which purpose, evaluation areas and which success definitions they use. Overall, there seems to be a confusing number of possibilities for the evaluation of technologies in nursing. This article is therefore dedicated to build transparency in the field of DNT evaluation.

Definition of digital nursing technologies (DNT)

To clarify the object of this article, the definition for digital nursing technology (DNT) by Krick et al. 2019 [2] and Krick et al. 2020 [10] is used. DNT are technologies that i) "support the immediate action of a caregiver"; or ii) "contribute to the self-reliance of the person in need of care in such a way that direct on-site care assistance can be avoided"; or iii) "substitute the nursing support by using technology"; or iv) "support the training or education of nurses" [10]. The focal points of this article are the aspects i-iii. DNT’s can be, for example: information and communication technologies, robots, sensor, monitoring technologies, assistive device, ambient assisted living technologies, virtual reality, tracking technologies [1, 2]. These technologies do not only appear in the nursing context. They also appear in the field of digital health [11] or telemedicine [12] which can lead to overlaps in certain areas. For this reason, it makes
sense to also consider and, where appropriate, include frameworks, assessment tools and evaluation aspects from other healthcare areas when evaluating DNT.

**Objective and research question**

The objectives of this article are to provide transparency on existing comprehensive evaluation frameworks that can be applied to the field of DNT and to conduct a detailed analysis and assessment of these frameworks. The aim is to contribute to the discussion and understanding of what constitutes a good (DNT) evaluation framework and to guide field researchers in the selection and application of evaluation frameworks.

This article is thus guided by the following research questions: (i) Which comprehensive evaluation frameworks that can be applied to DNT evaluation are available in the literature? (ii) What purposes, perspectives, and definitions of success are described in these frameworks? (iii) What are the strengths and weaknesses of the included frameworks? (iv) Which areas of evaluation are represented in the frameworks and where are the most overlaps and differences between these frameworks?

**Methods**

**Search Process**

The search process consisted of three different components (roman numerals). The goal was to identify frameworks with relevance for the nursing context according to the inclusion and exclusion criteria described further below. (i) A systematic literature search was conducted in PubMed; (ii) in addition a narrative review was carried out by searching google scholar, screening already identified literature [10] and reference lists of the systematically identified articles. (iii) Information on relevant frameworks was collected from four experts in the field of evaluation from the German "Cluster Zukunft der Pflege" (Cluster Future of Care) [13]. In this joint project, regular evaluations of digital nursing technologies have been and will be carried out in the period 2017-2022. The search terms of the systematic literature search can be found in table 1. The complete search strategy, including all three components, is shown in Figure 1.

**Eligibility criteria for systematic search**

Included scientific papers had to be published between 2005-2020 in English language. A summary and full text had to be available. All information has been gathered in March 2020 which limits the included period from January 2005 to March 2020.

The included studies had (i) either to apply an evaluation framework to a (nursing) technology or describe the development of an evaluation framework. The included frameworks had to (ii) be at least based on either a literature study, an empirical evaluation, or an expert survey. They had to (iii) be directly related to technologies in (nursing) care, or comparable fields like the evaluation of digital health applications in general, but they had to be potentially suitable for the evaluation of DNT. (iv) The technology specific focus lay on Information and Communication Technologies (ICT), telemedicine, telecare, sensor technology or robotics (or their sub-sectors), as these are the most common technology areas in nursing care (definitions by Krick et al. 2019) [2]. (v) The frameworks could refer to the evaluation of different stages of the life cycle of a technology [14] e.g. before, during or after the implementation.

Exclusion criteria were: articles (i) focussing on frameworks for the evaluation of specific medical technology fields (e.g. radiology, surgery) without relation to nursing; (ii) from developing countries or underdeveloped health systems; (iii) that described study protocols; (iv) with overviews that only present categorial systems without creating a framework; (v) focussing on frameworks related to technologies for education or training; (vi) focussing on fitness applications, wellness applications or applications for general disease prevention; (vii) in the psychiatric context; (viii) that are not comprehensive, thus only focus on individual areas such as economy or acceptance or satisfaction or usability; (ix) which refer exclusively to the implementation and not the evaluation of the implementation.

**Search terms of the systematic search in PubMed**
### Identifying relevant frameworks

All systematic search results were imported into EndNote X8 and reimported into the Excel screening workbook by VonVille [15]. A multi-step screening process was performed. The first step included screening 100 titles and 100 abstracts. The eligibility criteria were then refined. All titles were screened in the second step and the remaining abstracts in the third step. The eligibility criteria were then refined again before screening the full texts. If an identified article only applied a framework, for which the development is described in another article, this was an intermediate step for the identification of the framework. The original article of the framework was then identified and included in the further steps of the analysis.

The narrative search was performed with the knowledge and eligibility criteria of the first screening process, which enabled a much more precise identification process. Google scholar was searched with the terms “framework” AND “evaluation” AND “nursing”. Articles were screened and reference lists were also examined, snowballing through the reference lists of these articles. Reference lists of the systematically identified studies and literature from a previous search [10] was also included. This way of snowballing is important for such complex search fields. It helped to find all relevant information on frameworks as a supplement to the systematic approach [16].

The expert consultation additionally focused on the identification of relevant frameworks. The experts should name frameworks from their knowledge and list all frameworks that have been used in their projects to evaluate digital nursing technologies. The whole search and identification process can be found in Figure 1.

### Data Extraction

#### Purpose, perspective, and success definitions

The first step for data extraction was to screen all full texts of the frameworks for the technology group to which they refer, the stated purpose and the evaluation perspective [17], as well as the success definition/description (ii). This article defines the purpose of a framework as the description of what the framework is intended to achieve. The perspective describes the viewpoint from which the framework was developed and thus the viewpoint from which the evaluation results could be interpreted. The analysis of “success” focused on the definitions or descriptions of what the articles mean by “success” or “successful technology”. A qualitative synthesis was conducted to identify and categorize the included purposes, perspectives and success definitions by using textual narrative synthesis [18].

#### Strengths and weaknesses

A strengths and weaknesses analysis of the include frameworks was also carried out to answer research question (iii). The criteria to evaluate the frameworks were developed in an expert workshop with experienced researcher in the field of evaluation. The criteria are displayed in table 2. This approach was chosen because there are no universal quality criteria for the strengths and weaknesses of DNT related evaluation frameworks in the literature.

| Term                  | Term | Term | Hits |
|-----------------------|------|------|------|
| Framework             | Evaluation | Technol* | 1381 |
| Framework             | Evaluation | ICT | 24 |
| Framework AND         | Evaluation | Robot | 48 |
| Framework             | Evaluation AND Sensor | 135 |
| Framework             | Evaluation Telecare | 10 |
| Framework             | Evaluation Telemed | 97 |
| Framework             | Evaluation Digital | 260 |

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### Areas of evaluation

To answer research question (iv) all frameworks were screened for similarities in their categorisation systems. Most frameworks used different sorting systems and systematisation logics. An iterative developed data extraction form was drawn up in Excel and piloted with three frameworks. The decision was made to assign all evaluation topics of the frameworks to the generic categories "Top Category" "Subcategories" and "Specification" (Additional file 1). This step was necessary, because there is no universal systematisation to categorise the content of evaluation frameworks, but there is a kind of hierarchy that can be found in these frameworks.

### Charting the data

All extracted information on the technology group to which the frameworks refer, the stated purpose and the evaluation perspective, as well as the definition/description of success (research question ii), were charted in Excel and listed with the respective framework.

To answer research question (iv) all identified top categories were analysed to build overarching top categories that were used for the systematization of these frameworks. The analysis of all top categories of the 18 frameworks resulted in 9 generic top categories, which were then defined and formed the basis for further analysis. The definitions of these categories were generated inductively and iterative while analysing all included evaluation aspects of the frameworks (analysis in Additional file 2; definitions in table 3). Despite this process a non-overlapping categorization of these categories was not possible due to the complexity of the frameworks content and the interconnectedness of different categories.

In the next step, the extracted content of the subcategories from the frameworks (Additional file 2) was analysed to identify similarities and differences related to the newly built top categories (table 3). During the extraction of the category “specifications”, it was found that included aspects were vastly diverse, so that they were not suitable for any standardisation. Therefore, only the content of the subcategories was included in the charting process. When there were no subcategories, the top categories were included into this step. This was the case for the: Design and Evaluation of DHI Framework [14], Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies [19], Digi-HTA [11], CISSM [20] (in parts - because there were only specifications in form of specific questions for the top categories).

If the subcategories corresponded to a completely different sorting logic as the other frameworks and therefore did not contain any evaluable information, the “specifications” were evaluated if it contained important information. This was done for the: Khoja–Durrani–Scott Evaluation Framework [21], the layered telemedicine implementation model [22]; and the Comprehensive evaluation framework for telemedicine implementation [12].

All charting results can be found in (Additional file 2). The assignment may differ from their logic in the representation to the original assignment because the frameworks used different sorting systems and logics, which were unified in this representation. Models and frameworks often develop their own categorization logic. There is no uniformly recognized logic.

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**Table 2 Guiding categories for assessing the strengths and weaknesses of the frameworks**

| Guiding Category | Content |
|------------------|---------|
| Focus of the framework | Description of the specific focus of the framework. This can include a |
| | - description of the purpose (and the addressed question) |
| | - the application setting |
| | - the technology (area) |
| Illustration | Clarity/ complexity of illustration |
| Terminology | Transparent definitions of terms and key concepts |
| Instructions for use | Concrete application strategy and instructions for use |
| | Instruction on how the results can be interpreted |
| Scientific quality | Transparency of development process |
| | Reflection of the limitations of the framework |
| | Transferability of the framework (Settings, technologies, questions) |
Table 3. Definitions of the DNT evaluation areas

| Focus | Product/Technology | Objective Value/Effect | Individual | Organisation |
|-------|--------------------|------------------------|------------|--------------|
| This area includes what the technology focuses on in terms of its objectives and purpose and the problems and needs it aims to solve for a specific target group in a specific setting. | This area includes all aspects of the technology itself. This ranges from visual appearance to functionality and certain specific technological aspects such as interoperability. | This category includes the relevant information on evidence, aspired values as well as intended and unintended effects of the technology. | This area includes reactions and perceived impressions, as well as the behaviour and the relationship of individuals towards the technology. | This area includes aspects that are relevant in the relationship between the technology and an organisation. |
| Societal | Ethics | Economics | Strategic |
| This area includes relevant aspects of the technology in a societal context (e.g. political, juridical, regulatory, or socio-cultural aspects - Overlaps with the area of ethics are possible) | This area includes relevant ethical standards and ethical implications to be considered in relation to the technology. | This area includes relevant economic aspects for the technology (e.g. business model, price, economic evaluation). | This area includes strategic aspects that may be relevant for the introduction and dissemination of the technology. |

Results

Search results

The systematic search in PubMed generated 1957 hits. 1755 remained for screening the titles, after removing the duplicates. 113 articles were chosen to screen the abstracts, yielding 69 full-texts eligible for full-text screening. The systematic search generated a total of 22 articles to analyse for relevant frameworks. The narrative search and the expert consultations revealed 13 articles with frameworks. 26 frameworks remained for the final analysis process, after sorting out the duplicates generated by the different search processes. Eight further frameworks were discarded during the data extraction process because detailed analysis evinced that they did not meet the eligibility criteria. 18 frameworks were then included in the final analysis (Figure 1).

Analysis results

18 comprehensive evaluation Frameworks that can be applied to DNT are presented in the results section. According to the included technology categories there are n=7 frameworks related to Information and Communication technologies (with different sub-sectors), n=3 frameworks for telemedicine/telecare, and n=1 framework for sensor technologies. The remaining frameworks were generalistic frameworks from the areas of digital health (n=3), health (and care) technologies (n=2), e-health (n=1) and clinical informatics (n=1). The classification was based on the technologies derived from the articles with reference to the definitions of technology categories from Krick et al. 2019 [2](Table 3).

Purpose and perspectives of the frameworks

The purposes and the perspectives of the included frameworks were analysed to answer research question (ii). Although the included frameworks share the purpose of assessing digital technologies using specific assessment categories, the purposes described beyond this differ. The detailed assessment can be found in table 4. The qualitative synthesis identified 7 overarching categories of purposes:

1. Help and guide researchers (design and evaluation process) [14, 21, 23-29]
2. Identify success and failure factors (and help to manage them) [14, 19, 20, 22, 28, 29]
3. Assess the performance/success of a technology (outcomes, impact, errors, deficiencies) [30-33]
4. Make the results comparable [19]
5. Contribute to the quality and development of the technology [26, 28, 33]
6. Support the implementation of a technology [26-28]
7. Help in decision-making [11, 12, 33]

A further classification of the purposes could be made by dividing them into two main categories. (A) Knowledge-oriented purposes (1-4) that mainly indicate that the frameworks and their use serve to generate a certain form of knowledge. (B) practice-related purposes (5-7). These purposes could be summarised...
as application-oriented knowledge as they indicate that the knowledge shall be used for a specific action such as development, implementation or decision making.

For a deeper understanding of the purpose of a framework, it is necessary to also analyse the perspective that the framework takes as it might have an influence on how the framework is intended to achieve the purpose.

N=9 of the 18 frameworks had a universal perspective, which means that they can be applied to different perspectives or remain neutral thus the decision is left to the evaluator. The remaining 9 frameworks indicate or define for themselves, that they were developed from a specific viewpoint thus that the results could be interpreted from this viewpoint. N=4 take the perspective of a healthcare organisation, n=2 describe the healthcare system as a perspective, n=2 have the nurse's perspective as a viewpoint and n=1 is developed from an investment program perspective.

**Success Definitions/Descriptions**

The included frameworks were also analysed for contained definitions or descriptions of what they mean by “success” or “successful technology” to gain a better understanding of the differences that might exist (table 4). Most included frameworks do not have an explicit definition of success [11, 19, 21, 24, 25, 27, 30-33]. In this cases, the described evaluation criteria and the resulting interpretation of the evaluation results could be used to make a statement about the success of the technology.

The qualitative synthesis of the included success definitions/ descriptions identified three categories:

1. Success is when the technology achieves its intended purpose [29]
2. Success means achieving implementation, dissemination and/or sustainability of a technology [12, 14, 22, 28]
3. A successful technology must generate a net benefit [20]
Table 4 Analysis and assessment of the frameworks

| Technology Field | Framework | Authors/Year | Perspective | Stated Purpose | Success Definition/Description |
|------------------|-----------|--------------|-------------|---------------|--------------------------------|
| Information and Communication technologies (Health Information Systems (HIS)) | Infoway benefits evaluation Framework | Francis Lau et al. 2007 [23] | Investment programs for digital technologies (to guide evaluations) | 1. Provide a high-level evidence based model to guide subsequent field evaluation | Success measured by analysing the results of the evaluation (Factors based on the van der Meijden et al. model [43]) |
| Information and Communication technologies (Health Information Technologies (EHR)) | HITREF | Sockolow et al. 2012 [24] | Universal perspective (mainly influenced by health services research and informatics) | 1. Conceptual tool for framing evaluations studies in assessing EHR-based implementations in organizational, systematic, and environmental contexts 2. Displaying evaluation criteria | No success definition (measuring the success by analysing the results of the evaluation) |
| Information and Communication technologies (Hospital Information Systems) | HIS Success Framework[29] | Sadoughi et al. 2013 29 | Universal perspective | 1. Identification of Hospital Information System success and failure factors and the evaluation methods of these factors | Success as a dynamic concept. Success is when the technology achieves its intended purpose. (+ time, budget, and user satisfaction) |
| Information and Communication technologies (Integrated Health Information Systems (IHIS)) | DIPSA Framework | Stylianides et al. 2018 [30] | Healthcare Organisation | 1. Evaluation framework for hospitals utilizing IHIS to help identify any existing deficiencies in the system | No success definition (measuring the success by analysing the results of the evaluation) |
| Information and Communication technologies (Health Information Systems) | HOPT-FIT | Yusof 2019 [31] | Healthcare Organisation (focus on technology induced errors) | 1. Evaluate HIS performance and efficiency 2. Systematically guide error evaluation 3. Describing the Human-Organisation-Technology fit | No success definition (measuring success with the included dimensions of HIS success) |
| Information and Communication technologies (Clinical Information Systems (CIS)) | CISSM | Garcia-Smith & Effken 2013 [20] | Nurse's perspective | 1. Framework for evaluating CIS success from the nurse's perspective | Success = net benefit ("degree to which a nurse believes that using a particular system enhances job performance") |
| Information and Communication technologies (Information and Communication technologies for nurses) | Adapted nursing care performance framework | Rouleau et al. 2017 [32] | Nurse's perspective | 1. Illustrate how ICTs interventions influence nursing care and impact health outcomes | No success definition (measuring the success by analysing the results of the evaluation) |
| Telemedicine/Telecare | MAST Manual | Kidhom et al. 2010 [33] | Universal perspective (user-based decision making, research) | 1. Describe effectiveness 2. Contribution to quality of care of telemedicine applications 3. Produce a basis for decision making | No success definition (measuring the success by analysing the results of the evaluation) |
| Telemedicine/Telecare | Comprehensive evaluation framework for telemedicine implementation | Chang 2015 [12] | Universal perspective (decision making for individuals, organisations, and communities) | 1. Summarising important themes for the evaluation of telemedicine systems 2. Support related stakeholders’ decision-making by promoting general understanding, and resolving arguments and controversies | Long-term implementation |
| Telemedicine/Telecare | The layered telemedicine implementation model | Broens et al. 2007 [22] | Universal perspective (the focus on individual determinants/ perspectives changes throughout the development life cycle) | 1. Detailed classification of the determinants of the success of future telemedicine implementations | Successful implementation ("putting an idea or a concept into actual practice") |
| Sensor Technologies (Connected Sensor Technologies) | Evaluation Framework for Fit-For-Purpose Connected | Coravos et al. 2020 [19] | Healthcare System Perspective | 1. Working evaluation framework that reflects different types of risks 2. Framework is conducted to better manage these risks | No success definition (success could be measured by analysing the results of the evaluation and) |
including wearables, biosensors)

| Digital Health (Digital Health Interventions (DHI)) | Design and Evaluation of DHI Framework | Kowatsch et al. 2019 [14] | Universal perspective (researchers and practitioners) | 1. Framework for the design and evaluation of DHI
2. Showing evaluation criteria and implementation barriers to be considered during the life cycle phases of DHI
3. Support researchers and practitioners from conception to large-scale implementations |

| Digital Health (Digital Healthcare Services: mHealth, AI, and robotics) | Digi HTA | Jari et al. 2019 [11] | Healthcare System Perspective (decision making) | 1. Inform decisionmakers in order to better support the introduction of new health technologies |

| Digital Health (Digital Health Technologies) | Digital Health Score Card | Mathews et al. 2019 [25] | Universal perspective (multi-stakeholder approach) | 1. Multi-stakeholder approach to objectively evaluate digital health solutions |

| Health (and care) technologies | Health Technology Adoption Framework | Poulin et al. 2013 [27] | Healthcare Organisation | 1. Framework with clear, user-validated criteria for evaluating new health technologies for adoption at the local level |

| Health (and care) technologies | NA SSS Framework [28] | Greenhalgh et al. 2017 | Universal perspective | 1. Framework to help predict and evaluate the success of a technology-supported health or social care program
2. Help to design, develop, implement, scale up, spread, and sustain technology-supported health or social care programs by identifying key challenges in different domains and the interactions between them |

| E-health programs | Khoja–Durrani–Scott Framework for eHealth Evaluation | Khoja et al. 2013 [21] | Universal perspective (included tools usable for managers, healthcare providers, and clients) | 1. Comprehensive Framework to show relevant themes for e-health evaluation |

| Clinical Informatic interventions | RE-AIM (expanded to clinical informatics) | Bakken & Ruland 2009 [26] | Healthcare Organisation (implementation in organisational practice) | 1. Used to design, implementation, evaluation, and reporting of clinical informatics with a goal of translation of research into practice |

Strength and weaknesses of the frameworks

The strengths and weaknesses of the included frameworks were analysed, to contribute to the understanding of what constitutes a good (DNT) evaluation framework and answer research question (iii). Previously developed quality criteria for DNT Frameworks were used for the assessment (as described in the methods section). A detailed analysis of the assessment can be found in table 5. (+) stands for strength and (-) describes a weakness in a certain assessment area.

The assessment revealed difference and similarities of the included frameworks. All frameworks included a description of their intended purpose and the addressed question(s). 14 out of 18 included frameworks do not explicitly describe an application setting, which is since these frameworks were developed with generic setting approaches. They therefore received a (+) in the evaluation for the universality of the setting and at the same time a (-) because they are not specifically related to a setting. However, most frameworks describe specific technology areas on which they focus. Only 6 have universal designs, for potentially different technologies, so that they have been assessed with a (+) for universality and a (-) for being unspecifically. Due to their elaboration, n=12 of the frameworks are easily transferable to other contexts. N=11 frameworks have a very clear visual presentation and n=9 contain a visual representation of connections and relationships of individual aspects within the framework. On the other hand, this means that n=7 frameworks were not without visual weaknesses and n=9 frameworks did not show visual connections between the aspects they contained. Almost all frameworks (n=15) contained transparent definitions of terms and key concepts and are transparent in the development process (n=14). But many of the included frameworks have weaknesses in applicability, clear guidance, and assistance for the interpretation of the results. Only n=9 frameworks are strong in the description of an application strategy and instructions for use and only n= 6 contain good advice on how to interpret the results. Furthermore, many articles on the frameworks do not contain any or not sufficient discussion of the weaknesses and limitations (n=11). The frameworks with the highest scores across all assessment categories were:
1. Health Technology Adoption Framework [27] strengths n=9, weaknesses n=1 (no visualization of connections and relationships within the framework) and strength/weaknesses n= 1 (transferability limited to surgical context).

2. CISSM [20] strengths n = 9, weaknesses n=1 (no description of the limitations) and strength/weaknesses n= 1 (transferability limited to hospital context).

3. NASSS Framework [28] strengths n=8, and strengths/weaknesses n=3 (no clear focus on an application setting, no clear focus on a technology (area), and no applicable strategy to use the framework.)

The detailed analysis of the assessment can be found in table 5. Closer descriptions of the strengths and weaknesses can be found in Additional file 3.
| Frameworks                                      | Description of the purpose (and the addressed question(s)) | Description of the application setting | Description of the technology (area) | Clarity/complexity of illustration | Visualization of connections and relationships within the framework | Transparent definitions of terms and key concepts | Concrete application strategy and instructions for use | Instruction on how the results can be interpreted | Transparency of development process |
|------------------------------------------------|-------------------------------------------------------------|----------------------------------------|--------------------------------------|------------------------------------|---------------------------------------------------------------|--------------------------------------------------------|--------------------------------------------------------|-----------------------------------------------------------------|-----------------------------------------------|
| Infoway benefits evaluation Framework [23]     | +                                                          | +/-                                     | +/                                   | +                                  | +                                                            | -                                                      | -                                                      | +                                                               | -                                                            |
| HITREF[24]                                     | +                                                          | +/-                                     | +/                                   | +                                  | +                                                            | +                                                      | -                                                      | -                                                               | +                                                            |
| HIS Success Framework [29]                     | +                                                          | +                                       | -                                    | -                                  | +                                                            | +                                                      | -                                                      | -                                                               | +                                                            |
| DIPSA Framework [30]                           | +                                                          | +                                       | -                                    | -                                  | +                                                            | -                                                      | -                                                      | +                                                               | -                                                            |
| HOPT-FIT [31]                                  | +                                                          | +/-                                     | +/                                   | +                                  | -                                                            | -                                                      | -                                                      | -                                                               | -                                                            |
| CISSM [20]                                     | +                                                          | +                                       | +/                                   | +                                  | +                                                            | +                                                      | +                                                      | +                                                               | -                                                            |
| Adapted nursing care performance framework [32]| +                                                          | +/-                                     | +/                                   | +                                  | +                                                            | -                                                      | +/                                                     | -                                                               | -                                                            |
| MAST Manual [33]                               | +                                                          | +/-                                     | -                                    | -                                  | +                                                            | +                                                      | -                                                      | -                                                               | -                                                            |
| Comprehensive evaluation framework for telemedicine implementation [12] | +                                                          | +/-                                     | +/                                   | +                                  | -                                                            | -                                                      | -                                                      | -                                                               | -                                                            |
| The layered telemedicine implementation model [22] | +                                                          | +/-                                     | +/                                   | +                                  | +                                                            | +                                                      | +/                                                     | -                                                               | -                                                            |
| Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies [19] | +                                                          | +/-                                     | +/                                   | +                                  | -                                                            | +                                                      | +                                                      | +                                                               | -                                                            |
| Design and Evaluation of DHI Framework [14]    | +                                                          | +/-                                     | +/-                                  | -                                  | -                                                            | +                                                      | +                                                      | -                                                               | +                                                            |
| Digi HTA [11]                                  | +                                                          | +/-                                     | +/                                   | +                                  | +                                                            | +                                                      | +                                                      | -                                                               | +                                                            |
| Digital Health Score Card [25]                 | +                                                          | +/-                                     | +/-                                  | +                                  | +                                                            | -                                                      | -                                                      | -                                                               | -                                                            |
| Health Technology Adoption Framework [27]      | +                                                          | +                                       | +/                                   | +                                  | -                                                            | +                                                      | +                                                      | +                                                               | +                                                            |
| NASSS Framework [28]                           | +                                                          | +/-                                     | +/-                                  | +                                  | +                                                            | +                                                      | +/                                                     | +                                                               | -                                                            |
| Khoja–Durrani–Scott Framework for e-Health Evaluation [21] | +                                                          | +/-                                     | +/-                                  | +                                  | +                                                            | +                                                      | +                                                      | -                                                               | +                                                            |
| RE-AIM (expanded to clinical informatics) [26]  | +                                                          | +/-                                     | +/-                                  | -                                  | -                                                            | +                                                      | +                                                      | +                                                               | +                                                            |
Areas of evaluation in relation to the assigned perspectives

A detailed analysis of the included areas of evaluation of the frameworks was carried out to answer research question (iv). The complete analysis can be followed in Additional file 1 and Additional file 2. The analysis resulted in definitions for evaluation areas that are described in table 3.

Table 6 shows a comparison of the frameworks regarding the evaluation areas they contain. The results of the analysis of these areas indicate where the frameworks have their main areas of focus. The colour coding in the table signals that a framework covers a certain area. The allocation was based on the definitions and the sorting logic described in the methods section. The specific perspective that was described for the frameworks was also included in the table to crosscheck whether it is possible to make generalised statements about the existence of certain evaluation areas in relation to the perspective taken.

Most frameworks (n=17) contained evaluation aspects of the area of objective value/effect. Also, the evaluation of the specific product/technology aspects (n=16) and the relationship of individuals to the technology (n=14) was largely represented.

Societal (n=10) and strategic (n=6) aspects, as well as ethical aspects (n=4), were not as frequent. A closer look reveals that these aspects are particularly rare when the perspective described is the healthcare organisation or the nurses. At the same time, these aspects are jointly represented three times in the assessment if the perspective "universal" was assigned (in the HIS Success Framework [29], MAST Manual [33] and the Khoja–Durrani–Scott Framework for e-Health Evaluation [21]).

The evaluation area “focus” is not as frequently represented overall. Only n=5 frameworks contain aspects of this area. All frameworks containing this aspect come from the “universal” perspective. The area contains evaluation aspects that can be used as starting point for the design of a DNT or DNT evaluation by conducting a “needs analysis” (related to the addressed problems and needs of a target group).

Frameworks for which a universal perspective has been described (n = 9) also more often cover more areas at all (coverage of 7.2 areas on average). While frameworks for which a healthcare organisation perspective is described (n=4) only cover 4 areas on average (none of them covers the areas focus, societal or ethics), and frameworks with the nurse’s perspective (n=2) only cover 2 respective 4 areas (none of them covers the aspects focus, societal, ethics, economic or strategic). The included frameworks with a healthcare system perspective (n=2) cover 4 areas on average (none of them covers the areas focus, individual, organisation, ethics, or strategic) and the only framework with an investment program perspective covers 5 areas (does not include the areas focus, societal, ethics or strategic). A mapping of the content of the frameworks to the evaluation areas was carried out and can be found in table 6.
### Discussion

The aim of this study was to contribute to the understanding of what constitutes a good (DNT) evaluation framework and to guide field researchers in the selection and application of evaluation frameworks. This aim resulted in four research questions: (i) Which comprehensive evaluation frameworks that can be applied to DNT evaluation are available in the literature? (ii) What purposes, perspectives, and definitions of success are described in these frameworks? (iii) What are the strengths and weaknesses of the included frameworks? (iv) Which areas of evaluation are represented in the frameworks and where are the most overlaps and differences between these frameworks?

18 different comprehensive evaluation frameworks that met the inclusion criteria in the field of DNT could be identified. Unlike other overviews of evaluation frameworks, which either had a very technology-specific focus (e.g. on health information systems [34]) or a different thematic orientation (e.g. on HTA[35]), this article had a broad approach on comprehensive frameworks for DNT. Although a specific definition of DNT was used, there is inevitable overlap to different other themes like e-health or digital health which makes a general distinction very difficult. It should be noted that the included frameworks for specific technology categories in this article cover only a part of the technologies that can be subsumed under DNT. For example, evaluation frameworks for monitoring technologies, assistive devices or ambient assisted living, are not included [2]. The reason for this is that too much heterogeneity of technologies should be avoided in this article and the included technologies make up a significant proportion of the DNTs discussed in the literature [2]. Also, the included generic frameworks can potentially be used for the evaluation of further technologies, which allows generalisable statements about evaluation areas for DNT.

The differentiation of DNT frameworks from other evaluation frameworks can and should be further discussed. Some important aspects are covered in this article. The perspective of a framework is essential to put the definitions of success in a framework into context and to understand a potential interpretation of
the evaluation categories. There should also be clarity about the purpose of the framework to apply it appropriately, and transparency about where frameworks have their respective strengths and weaknesses. All these issues were analysed and are discussed in the following.

**Purposes**

It is important to understand that although the included frameworks share the purpose of assessing digital technologies using specific evaluation categories, the purposes described beyond this differ. Most included frameworks were developed to (i) help and guide researchers in the design and realisation of an evaluation [14, 21, 23-29], and/or (ii) to support the identification of success and failure factors (and to help managing them) [14, 19, 20, 22, 28, 29]. Four frameworks were specifically designed to (iii) assess the performance/success of a technology (outcomes, impact, errors, deficiencies) [30-33], but only one framework stated that it should (iv) help to make the results comparable [19]. This could be since the other articles simply assume the comparability issue to be implicitly logical and have therefore not named it explicitly as a purpose. These four purpose categories could be summarised as application-oriented purposes (except the part of managing the success and failure factors). This category mainly indicates that the frameworks and their use serve to generate a certain form of knowledge.

Some included frameworks indicate a more practice-related purpose by stating to (v) contribute to the quality and development of the technology [26, 28, 33], (vi) supporting the implementation of a technology [26-28] or (vii) help in decision-making [11, 12, 33]. Theses purposes could be summarised as application-oriented knowledge generation. As the classification shows, a DNT framework can have several purposes from both categories: knowledge generation and application orientation. The knowledge-oriented categories i, ii, iii, iv and the practice-related category vi are in line with seven out of eight general attributes of evaluation frameworks in healthcare identified by Bradford et al. (2019) (1. simplify a complex (evaluation) process, 2. provide structure (for an evaluation), 3. facilitate the evaluation process, 4. promote meaningful evaluation, 5. identify and explain outcomes, 6. generate transferable lessons, 7. identify mechanisms driving or inhibiting change) [36]. Bradford and colleagues also consider it an important element that frameworks help to identify relevant stakeholders [36]. This element was not mentioned as a purpose by any of the included frameworks. One reason for this could be that it is a prerequisite to identify stakeholders before conducting a stakeholder analysis on DNTs - so that the identification process was not seen as the actual purpose. In any case, the identification of relevant stakeholders can be an important part of the evaluation of DNT. A systematic review of HTA frameworks for e-health technologies by Vis et al. (2020) [35] also describes the relevance of the application oriented purposes v and vii - which could be due to the practice orientation of the HTA field. In general, DNT evaluation and DNT relevant evaluation frameworks can consider knowledge-oriented and application-oriented purposes. It does not make a framework better or worse if it belongs to only one of the categories. But having a clear definition of a purpose is a quality criterion when choosing a good framework. Researcher must be aware of the intended purpose of a framework when choosing their evaluation approach.

**Perspective and evaluation categories**

A closer look at the included perspectives of the frameworks raises the question of whether the perspective under which a framework has been developed, may have an impact on the evaluation categories included. The analysis of the included frameworks revealed five contained perspectives: universal, healthcare system, healthcare organisation, nurses, and investment program perspective.

N=9 of the 18 frameworks had a universal perspective, which means that they can be applied to different perspectives thus the decision is left to the evaluator. Frameworks for which a universal perspective has been described cover more evaluation areas in general (coverage of 7,2 areas on average), what supports this assumption. Frameworks for which a healthcare organisation perspective is described only cover 4 areas on average (none of them covers the areas focus, societal or ethics), and frameworks with the nurse’s perspective only cover 3 areas on average (none of them covers the aspects focus, societal, ethics, economic or strategic). The included frameworks with a healthcare system perspective (n=2) cover 4 areas on average (none of the covers the areas focus, individual, organisation, ethics, or strategic) and the only framework with an investment program perspective covers 5 areas (does not include the areas focus, societal, ethics or strategic). The perspective with which a framework has been developed is therefore always an important consideration to consider when selecting a framework, as this could influence the evaluation aspects included.

In addition, there are several stakeholder perspectives that were not taken as the main perspective in the included frameworks. These perspectives are the payers perspective, the perspective of the patient / person in need of care and the perspective of the informal caregiver. All these perspectives are particularly important in the context of DNTs. However, it should be mentioned that these perspectives are often included in the universal frameworks like the patient perspective in the MAST [33] or the 3rd party payment aspect in the comprehensive evaluation framework for telemedicine implementation [12]. In summary, when selecting and applying a comprehensive evaluation framework to evaluate a DNT, the perspective of a framework to choose and the intended perspective of the evaluation should always be reflected upon and contrasted.

**Success Definitions/Descriptions**

It is not easy to define what a successful digital nursing technology is. Nguyen et al. (2014) argue that success of a technology may be “disputed depending on the interests of the evaluating party.” [37] This is in line with the success description of Lau (2009) who sees it in the context of an “ongoing negotiation and adaptation of interrelationships” of the involved healthcare professionals [38]. A large multi stakeholder Delphi study conducted by McNair and colleagues (2006) [39] declared that “success cannot be characterized along one single axis” and therefore define that success means the fulfilment or non-fulfilment of five consensus based aspects: (1) the widely usage in daily practice, (2) the fulfilment of the role and tasks it was planned for (in a specific environment), (3) the support of good medical practice (benefitting the patient), (4) benefitting the healthcare organization and working conditions, (5) be easily upgradeable to adapt to the developments in practice [39].

Aspects 1-4 from McNair and colleagues were also identified as success definitions of the analysed frameworks in this article (1. Success is when the technology achieves its intended purpose [29]; 2. Success means achieving implementation, dissemination and/or sustainability of a technology [12, 14, 22,
28]. 3. A successful technology must generate a net benefit [20]). This suggests that these aspects could be universal definitions of success aspect for digital nursing technologies. Aspect 5 of the McNair study could be added as equally important.

But looking at success from a certain perspective in a specific context might lead to additional perceptions or definitions of success – which could influence the evaluation. An example of this is a focus group study on technologies for aging with 29 stakeholders (older adults, care professionals, managers, social work organizations, technology designers and policy makers), defined four aspects of technology success: (1) technology focusses on older adults needs and wishes in the development (2) technology is accepted by older adults, (3) technology provides benefits to older adults, and (4) favourable prerequisites for the use of technology by older adults exist [40].

In view of these differences in definition, it must be considered that “success” of a DNT is a relative term, made up of various aspects and depths of success definitions, the selection of which depends strongly on the evaluation perspective. This insight is decisive for the evaluation of a DNT because it should always be reflected for whom and from which perspective an evaluation is conducted and what is considered as successful.

**Strengths And Weaknesses Of The Frameworks**

The strengths and weaknesses analysis process in this article identified framework components where more guidance would be beneficial, and which are important to consider when selecting a DNT evaluation framework. The assessment included the focus of a framework, the illustration, terminology, instructions for use and the scientific quality. The strengths and weaknesses criteria were created especially for DNT evaluation frameworks although there are other quality criteria that could be applied from other healthcare fields - for example, Bradford et al. (2019) [36]. They provide 6 quality criteria for frameworks, from which most are similar to the criteria in this article. Bradford et al. additionally suggest assessing whether the frameworks help to identify and include stakeholders and identify mechanisms driving or inhibiting change – which might be also helpful to consider when selecting a framework.

The results of the framework assessment presented in this article need to be seen in a wider context. The evaluation was carried out with the question of a general assessment of perceived strengths and weaknesses. Several aspects could have been rated differently in other contexts, e.g., assessing the transferability of a framework to only a specific context as for the Health Technology Adoption Framework [27] and the CISSM [20] as a strength or a weakness depends on the viewpoint of the planned evaluation. If the setting is set to a surgical context the Health Technology Adoption Framework might be the perfect choice although it is not transferable to other contexts. The classification of the need for visual representation could also be reflected differently. If a framework is intended exclusively to show a range of evaluation possibilities, then a graphical representation is not necessarily required.

Another critical point is the necessity of a framework application strategy, the lack of which has been criticized for the NASSS Framework [28]. Does a framework always have to contain an application strategy? If not, then the lack of a strategy would not be a weakness.

By showing and applying assessment possibilities for DNT frameworks this article gives guidance for the selection of appropriate DNT evaluation frameworks. An assessment of strengths and weaknesses in combination with the other important information presented in this article is crucial.

**Limitations Of The Article**

It is important to discuss the limitations of such an extensive procedure as described in this article. A search process with three components was chosen for this article. (1) Systematic search in PubMed, (2) narrative search in Google Scholar and reference lists, (3) experts. Additional databases could have been systematically searched. Experience from previous systematic search processes in such complex fields has shown that the combination of systematic search and other methods is a good way to identify relevant articles [10]. However, such a search procedure always leaves a chance that something has remained undiscovered.

Also, the exclusion criteria were very strict. Only literature published in the English language was included. The DNT related criteria were based on the knowledge of Krick et al 2019 [2] and Krick et al. 2020 [10] but still led to a heterogeneity of included frameworks due to the broadness of the field.

Only comprehensive and technology related frameworks were included which excluded many specific frameworks that potentially could also have been included. Frameworks focussing exclusively on special fields like health economics or acceptance could have been included, because they are certainly relevant for DNT, but were excluded due to their specificity and the large number of different frameworks available. Generalistic evaluation frameworks for (complex) healthcare interventions like the Consolidated Framework for Implementation Research (CFIR) [41] or on HTA Frameworks could have also been included (e.g. Integrate HTA [42]) – but it was necessary to limit the included frameworks to allow statements on this specific field of research.

The framework analysis itself has further limitations. Due to the heterogeneity of the frameworks and the difference in their content the categories and the assignment of the framework content to these categories is subjective. Even though the process of evaluation and classification was carried out with the utmost care, a non-overlapping categorization of these categories was not possible due to the complexity of the frameworks content and the interconnectedness of different categories. There are overlaps between the category technology and individual as well as ethics and societal. It should also be considered that the generalised statements made in this article can only provide initial indications in this specific field. No statistical analysis was carried out, but a qualitative and hypothesis-generating analysis.

Despite the described limitation, this article makes an important contribution to further research in the field of DNT evaluation.

**Conclusion**

This research article provides transparency in the complex field of DNT evaluation. 18 relevant comprehensive evaluation frameworks for DNT have been identified. These frameworks focussed on different purposes and included various evaluation perspectives. The analysis and mapping in this article provide
great transparency on the included similarities and differences, evaluation areas, success definitions, strengths, and weaknesses. The assessment of whether a DNT evaluation framework is considered good should be based on the transparency of the description of these aspects and the fulfilment of the quality criteria described.

The general role of evaluation frameworks should be further analysed. What exactly should DNT evaluation frameworks contribute to the scientific community? The diversity and heterogeneity of frameworks that was presented in this article shows, that there is not one definition of the term "evaluation framework" in the field of DNT. The question of what constitutes a good DNT framework could also be further explored using the criteria of this article as a starting point.

Future research could also address questions regarding to what makes a successful DNT. The definition of what a "successful" DNT is and the role of the evaluation perspective and the purpose of the evaluation should be discussed when analysing this question.

Overall, evaluators can use the concise information and quality criteria of this article as a starting point to select DNT evaluation frameworks for their research projects or to assess the quality of an evaluation framework for DNT, as well as a basis for exploring the open research questions raised.

**Abbreviations**

CFIR: Consolidated Framework for Implementation Research; CIS: Clinical Information Systems; CISSM: Clinical Information Systems Success Model; DHI: Digital Health Interventions; DIPSA: Development of an Evaluation Framework for Health Information Systems; DNT: digital nursing technologies; EHR: Electronic Health Records HIS: Health Information System; HTA: Health Technology Assessment, HITREF: Health Information Technology Evaluation Framework; HOPT-FIT: Human, Organization, Process and Technology-fit; IS: Information System; ICT: Information and Communication Technology; IHIS: Integrated Health Information Systems; MAST: Model for Assessment of Telemedicine; mHealth: mobile health; NASSS: nonadoption, abandonment, scale-up, spread, and sustainability; NCPF: nursing care performance framework; RE-AIM: Reach, Effectiveness, Adoption, Implementation, and Maintenance.

**Declarations**

**Availability of data and materials**

The datasets used and/or analysed during the current study are included in this published article and the Additional files.

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**Declarations**

**Authors' contributions**

TK conceptualized and conducted the study. The author authorized the final version of the manuscript that was submitted.

**Ethics approval and consent to participate**

Not applicable.

**Consent for publication**

Not applicable.

**Competing interests**

There are no competing interests to declare.

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**Figures**

| Identification | n=1,557 titles and abstracts from systematic PubMed search |
|----------------|----------------------------------------------------------|
|                | Filters after removal of duplicates (n=1,735)            |
|                | Titles screened (n=1,715)                                |
|                | Titles excluded (n=1642)                                 |
|                | Abstracts excluded (n = 46)                              |
|                | - framework unsuitable for nursing content (17)          |
|                | - off topic (13)                                        |
|                | - medical/psychiatric (8)                               |
|                | - no framework included (6)                             |
|                | Full-text articles assessed for eligibility (n=69)       |
|                | Full-texts excluded (n=43)                              |
|                | - framework unsuitable for nursing content (37)          |
|                | - no framework included (2)                             |
|                | - medical/psychiatric (1)                               |
|                | Full-texts eligible for framework identification (n=26)  |
|                | Frameworks identified from systematic search (n=256)     |
|                | Frameworks excluded while data extraction                 |
|                | - framework unsuitable for nursing content (18)          |
|                | Frameworks included in data extraction (n=26)            |
|                | Relevant frameworks included in results (n=18)           |
Figure 1

Search results and framework selection process

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Add.File1FrameworkAnalysis.pdf
- Add.File2EvaluationAreas.pdf
- Add.File3Detailedstrengthandweaknessanalysis.pdf