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Sustainability in Digital Health: An Analysis of Digital Health Systems from User Perspectives

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Abstract

Sustainability in digital health systems requires assessment approaches that go beyond technical and functional quality, considering long-term impacts on users, institutions, society, and the environment. This study analyzes the application of the SEEDS checklist (*Sustainability in Biomedical Software Engineering*) from the user perspective, aiming to identify opportunities to improve its user profile for digital health contexts. The research was conducted as an exploratory qualitative multiple-case study involving three digital health systems examined in four usage contexts: Meu SUS Digital, from the perspective of a common user; AGHU/EBSERH, from the perspective of a healthcare professional user; OpenEMR, from the perspective of a healthcare professional user; and the OpenEMR Patient Portal, from the perspective of a common user. The method included feasibility analysis, checklist application, comparison of results, systematization of improvement proposals, and evaluation of these proposals by the SEEDS research group. The findings indicate limitations related to the adequacy of questions to different usage contexts, the presence of overly technical items, redundancy among questions, and dependence on information not visible to end users. Based on these findings, changes were proposed involving the segmentation of the user profile, the reorganization of subthemes, and the reformulation of questions. The study provides evidence to support future improvements to the SEEDS checklist and contributes to sustainability-aware software evaluation in digital health.

Keywords: software sustainability, digital health systems, SEEDS checklist, software evaluation, user experience

1 Introduction

The ongoing digital transformation in healthcare has led to the development and adoption of digital health systems with different purposes and user groups. These systems include, for example, citizen-facing applications (Ministério da Saúde 2024), institutional hospital management systems (Empresa Brasileira de Serviços Hospitalares 2025), and international open-source electronic health record systems (OpenEMR Foundation 2025). Such systems play an important role in supporting data integration, access to health information, and improving care processes in digital health contexts (Brasil 2020; Haddad and Lima 2024). As these systems become increasingly complex and central to healthcare infrastructure, evaluating them only in terms of technical quality or functional correctness becomes insufficient. Therefore, it is also necessary to consider their sustainability over time, including their ability to remain useful, reliable, accessible, and socially relevant (Karita et al. 2022). In this direction, concepts and approaches from software engineering, such as software sustainability, can support this broader evaluation.

Software sustainability is a multidimensional concept that goes beyond environmental concerns. According to the Karlskrona Manifesto for Sustainability Design (Becker et al. 2015), sustainability in software-intensive systems involves technical, economic, social, individual, and environmental dimensions. In software engineering, this perspective emphasizes the long-term capacity of a system to evolve, be maintained, support its users, and produce positive or responsible effects in its surrounding sociotechnical context. In digital health, this discussion is particularly relevant because health systems handle sensitive data, operate under regulatory constraints, support clinical and administrative workflows, and directly or indirectly affect the well-being of patients and healthcare professionals (Shojaei et al. 2024; Sittig et al. 2020).

In this context, the SEEDS checklist (Grupo de Pesquisa SEEDS (UFCSPA) 2025), proposed by the Sustainability in Biomedical Software Engineering research group at UFCSPA, was developed as an instrument to support the assessment of sustainability in health-related software systems. The checklist is organized according to the five dimensions of sustainability and includes questions intended to guide evaluators in identifying how sustainability-related concerns are addressed in software systems. However, as a recent instrument, the checklist still has limited empirical evidence regarding its applicability in real digital health contexts, especially when applied from the user perspective. This is a relevant gap because end-users (*e.g.*, patients or healthcare professionals), do not usually have access to architectural, organizational, or infrastructure-level information that may be required to answer some sustainability-related questions.

In order to evolve checklists for sustainability and address this gap, this article applies the SEEDS checklist from the user perspective in different digital health systems and usage contexts. The study analyzes three systems in four contexts of use: Meu SUS Digital from the perspective of a common user, AGHU/EBSERH from the perspective of a healthcare professional user, OpenEMR from the perspective of a healthcare professional user, and the OpenEMR Patient Portal from the perspective of a common user. This analysis allows us to understand and evaluate how the checklist

behaves when applied to systems with different purposes, degrees of documentation availability, and user profiles.

The main focus of this work is not only to assess sustainability-related aspects of the selected systems, but also to examine the adequacy of the SEEDS user profile as an assessment instrument. More specifically, this article identifies limitations, ambiguities, redundancies, overly technical items, and questions that are not well suited to different user contexts. Based on the evidence obtained from the checklist applications, this work proposes improvements to the user profile of the instrument, including the segmentation of the original user profile into two distinct profiles, the reformulation of questions, the reorganization of subthemes, and the inclusion of additional support for users.

This study was guided by the following research question: How applicable is the SEEDS user-profile checklist for assessing sustainability in digital health systems from different user perspectives?

The contributions of this article are threefold. First, it provides empirical evidence on the application of a sustainability checklist in real digital health systems evaluated under available access conditions from the user perspective. Second, it identifies recurring limitations in the current user profile of the SEEDS checklist, particularly regarding observability, technical language, redundancy, and contextual adequacy. Third, it proposes refinements that can support future improvements of the instrument and contribute to sustainability-aware software evaluation in digital health. Thus, this work advances the discussion on how sustainability can be assessed not only as a technical property of software, but also as an experience perceived and interpreted by different types of users.

2 Methods

This study was designed as an exploratory qualitative multiple-case study, following the case study strategy proposed by (Yin 2015). The research focused on the application of the SEEDS checklist from the user perspective in digital health systems, with the aim of examining both the sustainability-related aspects perceived in the selected systems and the adequacy of the checklist user profile as an assessment instrument.

2.1 Case selection

Initially, a descriptive analysis of the three selected systems was conducted: Meu SUS Digital, AGHU/EBSERH, and OpenEMR. This step made it possible to identify their structural, functional, and contextual characteristics. The systems were selected according to criteria of institutional relevance, diversity of target users, access availability, and potential to represent different usage scenarios in digital health. The selected systems are described below:

- Meu SUS Digital: a national citizen-facing system, widely used and strategic for Brazilian digital health policy, evaluated based on its interface and functionalities accessible to users;

- AGHU/EBSERH: an institutional hospital management system adopted in Brazilian public university hospitals, with documentation and a demonstration environment available for analysis from the perspective of a healthcare professional user;
- OpenEMR: evaluation conducted in two distinct demonstration contexts, one from the perspective of a healthcare professional user and another from the perspective of a common user/patient through the demonstration Patient Portal.

The selection of systems and usage contexts aimed to cover different forms of interaction with digital health systems, including citizen-facing applications, institutional systems, and internationally adopted open-source solutions. In this step, the available access methods, main user-observable functionalities, target user profiles, and public documentation that could support the checklist application were identified. Access and evaluation challenges were also mapped for each case.

2.2 Checklist application

In this phase, the SEEDS checklist was applied exclusively through its user profile to each selected system, respecting the access conditions available in each case. The evaluation was based on practical interaction with the systems and, when necessary, complemented by public documentation, support materials, and institutional information accessible to users. The application was carried out as follows:

- Meu SUS Digital: evaluation based on the user interface, including web and mobile versions, from the perspective of a common user/patient;
- AGHU/EBSERH: evaluation conducted through the demonstration environment and publicly available documentation, from the perspective of a healthcare professional user;
- OpenEMR: evaluation conducted in two distinct contexts, one from the perspective of a healthcare professional user and another from the perspective of a common user/patient through the patient portal.

The results were recorded in spreadsheets and organized according to the checklist dimensions, namely environmental, social, economic, technical, and individual, and their respective subthemes. This systematization enabled the comparison of response patterns, the identification of items that were difficult to apply from the user perspective, the analysis of differences among the evaluated usage contexts, and the assessment of each system's adherence to the sustainability practices proposed by SEEDS. In addition, the time required to complete each application was measured, with the objective of estimating the effort required to fill out the instrument and identifying possible indications of excessive complexity or the need for usability improvements in the checklist platform. During the checklist completion process, redundancies, overly technical items, and questions inadequately suited to different usage contexts were also identified.

All checklist applications were conducted by the same evaluator to ensure procedural consistency across the four usage contexts. Although this choice may introduce individual interpretation bias, it allowed the same criteria, interpretation logic, and

recording procedure to be applied systematically to all systems. To mitigate this limitation, the evaluator registered justifications and observations during each application, and the resulting improvement proposals were later submitted to the SEEDS research group for review and agreement assessment.

2.3 Proposal of refinements to the SEEDS user profile and platform

Based on the results of the applications and the difficulties identified during the checklist completion process, a critical analysis of the structure of the checklist user profile was conducted, consolidating the items that presented opportunities for improvement. This step resulted in the systematization of changes in two complementary ways: a general table of changes, summarizing the proposed structural and conceptual adjustments, and a specific item-level table, identifying the problem, original question, subtheme, dimension, and corresponding proposal.

From this analysis, improvement proposals were developed to increase the clarity, applicability, and adherence of the checklist to the digital health context. These proposals included the segmentation of the original user profile into two profiles, one for healthcare professional users and another for common users/patients, the reformulation of questions, the removal or merging of redundant items, the reorganization of subthemes, and the inclusion of a question about user documentation in the technical dimension.

2.4 Evaluation by the SEEDS research group

After the systematization of the improvement proposals for the SEEDS checklist user profile, these proposals were submitted to the SEEDS research group through a structured form. The form included both general improvements and specific changes identified during the analysis. The general proposals included, among others, the segmentation of the user profile, the inclusion of explanatory sections about the five checklist dimensions, the addition of an informational section on the interdependence of the dimensions, the inclusion of a question about documentation, and the reorganization of selected subthemes.

The specific proposals were organized according to the type of problem identified, including repetition, redundancy, inadequacy to the user profile, lack of clarity, and inadequacy to the common user/patient profile. For each proposal or group of proposals, participants were asked to indicate agreement or disagreement and, in case of disagreement, to provide a justification. This step aimed to gather the research group's perceptions regarding the relevance, clarity, and adequacy of the proposed changes, as well as to identify points of agreement, additional adjustments, and complementary suggestions.

2.5 Consolidation of the proposed revised checklists

Based on the systematized improvement proposals and on the evaluation conducted by the SEEDS research group, two proposed revised versions of the SEEDS user-profile checklist were constructed. One version was directed to healthcare professional users,

and the other was directed to common users/patients. This step involved incorporating the content-related proposals into the checklist structure, while keeping platform-related improvements as separate recommendations for future development of the checklist platform.

2.6 Analysis and synthesis

Finally, a comparative analysis was conducted across the evaluated cases, considering how different usage contexts, user profiles, documentation availability, and system characteristics influenced the checklist application. This step made it possible to discuss both the sustainability perceived in the systems and the limitations of the instrument itself from the user perspective. The results were synthesized with support from the charts generated by the checklist, the time required for each application, the systematization of improvement opportunities, and the evaluation conducted by the SEEDS research group. This process supported the interpretation of the sustainability results, the identification of limitations in the original user profile, and the organization of evidence to guide future improvements of the SEEDS checklist.

3 Results

3.1 Overview of the checklist applications

The case selection resulted in three digital health systems evaluated in four usage contexts: Meu SUS Digital, AGHU/EBSERH, OpenEMR, and the OpenEMR Patient Portal. These systems were selected because they represent different types of digital health software, target users, access conditions, and levels of technical openness. This diversity was relevant to examine how the SEEDS user-profile checklist behaves when applied to citizen-facing, institutional, and open-source digital health systems.

Meu SUS Digital was selected as a national citizen-facing system, with web and mobile interfaces aimed at supporting access to public health information and services. Its evaluation was conducted from the perspective of a common user/patient, based on the interface and functionalities accessible to citizens. AGHU/EBSERH was selected as an institutional hospital management system adopted in Brazilian public university hospitals. Its evaluation was conducted from the perspective of a healthcare professional user, using the available demonstration environment and public documentation. OpenEMR was selected as an international open-source electronic health record system, with public documentation and broad adoption. It was evaluated in two demonstration contexts: the healthcare professional interface and the Patient Portal, allowing comparison between professional and patient-facing usage within the same software ecosystem.

Table 1 summarizes these four checklist applications, highlighting the evaluated systems, user perspectives, and access sources considered in each case.

3.2 Sustainability assessment of the evaluated systems

Table 2 summarizes the dimension-level average scores obtained in each checklist application. Scores range from 0 to 5, with higher values indicating greater perceived

Table 1 Overview of the SEEDS checklist applications

Application	System	User perspective	Access source
A1	Meu SUS Digital	Common user/patient	Web and mobile interfaces
A2	AGHU/EBSERH	Healthcare professional user	Demonstration environment and public documentation
A3	OpenEMR	Healthcare professional user	Demonstration environment and public documentation
A4	OpenEMR Patient Portal	Common user/patient	Demonstration environment and public documentation

adherence to the sustainability practices assessed by the SEEDS checklist in that dimension. These averages provide an overview of the dimension-level results and support the interpretation of the radar charts and the system-specific analyses presented in the following subsections.

The complete item-level responses for each application are provided in Appendices A, B, C, and D.

Table 2 Average scores by sustainability dimension for each checklist application

System	Environmental	Economic	Individual	Social	Technical
Meu SUS Digital	3.33	4.33	3.44	3.71	3.53
AGHU/EBSERH	3.36	4.40	3.83	3.93	4.35
OpenEMR	3.09	4.27	3.59	4.27	4.44
OpenEMR Patient Portal	3.25	3.91	3.06	3.47	3.59

3.2.1 Meu SUS Digital

The application of the SEEDS checklist to Meu SUS Digital, from the perspective of a common user/patient, showed a relatively balanced sustainability profile, with the highest average in the Economic dimension (4.33) and the lowest in the Environmental dimension (3.33), as summarized in Table 2 and illustrated in Fig. 1. The radar chart suggests that the system performs better in aspects related to access, cost-benefit, and institutional trust than in aspects related to environmental communication, user experience, and technical reliability.

The strongest results are associated with the public value of the system. As a free citizen-facing platform, Meu SUS Digital centralizes health information, documents, and services that would otherwise require more fragmented access. This explains the stronger Economic result and is also reflected in the subtheme-level bar chart provided in Appendix A, where perceived cost-benefit and sustainability/life cycle aspects obtained high scores. From the user perspective, this centralization may reduce indirect costs, such as time spent obtaining documents, accessing exam results, or interacting with public health services.

The weaker results point to a gap between the system's institutional relevance and the quality of the user experience. The Environmental dimension was mostly assessed

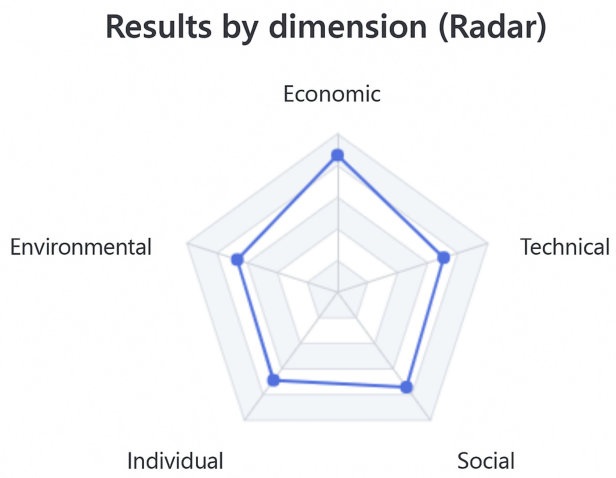


Fig. 1 Radar chart of the SEEDS checklist results for Meu SUS Digital

through indirect evidence, such as digital access to services and potential reduction of paper use, since the system does not explicitly communicate environmental strategies, indicators, or commitments. In the Individual and Technical dimensions, the results were affected by limitations related to usability, accessibility, personalization, slow response times, interruptions, and incomplete perceived integration of information. Although authentication and data protection mechanisms were positively perceived, reliability and interoperability-related aspects were less consistent.

Overall, Meu SUS Digital stands out as a high public-value digital health system, especially in terms of access and cost-benefit. However, the results also show that the user experience does not fully match the system's public-service potential. This case further exposed limitations of the original SEEDS user profile, particularly in questions that require technical, institutional, or environmental information that is not visible to common users.

3.2.2 AGHU/EBSERH

The application of the SEEDS checklist to AGHU/EBSERH, from the perspective of a healthcare professional user, showed one of the strongest overall profiles among the evaluated cases. As summarized in Table 2 and illustrated in Fig. 2, the highest average scores were obtained in the Economic (4.40) and Technical (4.35) dimensions, followed by the Social (3.93) and Individual (3.83) dimensions. The Environmental dimension presented the lowest average score (3.36), following a pattern also observed in the other evaluated systems.

The strongest results were associated with the institutional role of AGHU in supporting public hospital management. The system contributes to the centralization of

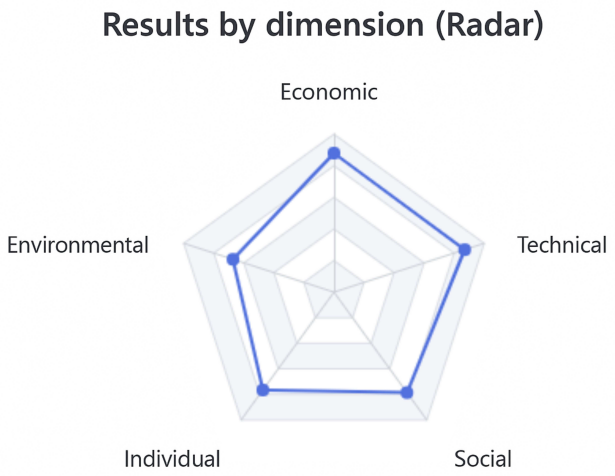


Fig. 2 Radar chart of the SEEDS checklist results for AGHU

clinical and administrative processes, supports multiprofessional workflows, and is perceived as relevant for reducing rework and improving information organization. These aspects help explain the high Economic and Technical scores, especially in subthemes related to cost-benefit, functional adequacy, interoperability, and system evolution, as detailed in the subtheme-level results provided in Appendix B.

At the same time, the assessment revealed limitations related to user experience and to the visibility of non-functional aspects. Although AGHU is perceived as useful and mature for professional practice, its complexity, need for formal training, and reliance on extensive documentation suggest a high cognitive demand. Environmental sustainability was also difficult to assess directly, since the system does not clearly communicate environmental indicators, practices, or commitments to the user. Some technical aspects, such as performance, availability, error prevention, and internal mechanisms, were only partially observable due to the use of a demonstration environment.

In the case of AGHU, the results reflect the strengths of an institutional system designed to support hospital management and professional workflows. However, the same institutional complexity that contributes to its functional scope also increases cognitive demand and makes some sustainability aspects difficult to assess from the user perspective.

3.2.3 OpenEMR

The application of the SEEDS checklist to OpenEMR, from the perspective of a healthcare professional user, showed stronger results than the patient-facing contexts, especially in the Technical, Economic, and Social dimensions. As summarized in

Table 2 and illustrated in Fig. 3, the Technical dimension obtained the highest average score (4.44), followed by the Economic and Social dimensions, both with an average score of 4.27. The Individual dimension obtained an intermediate score (3.59), while the Environmental dimension presented the lowest average score (3.09).

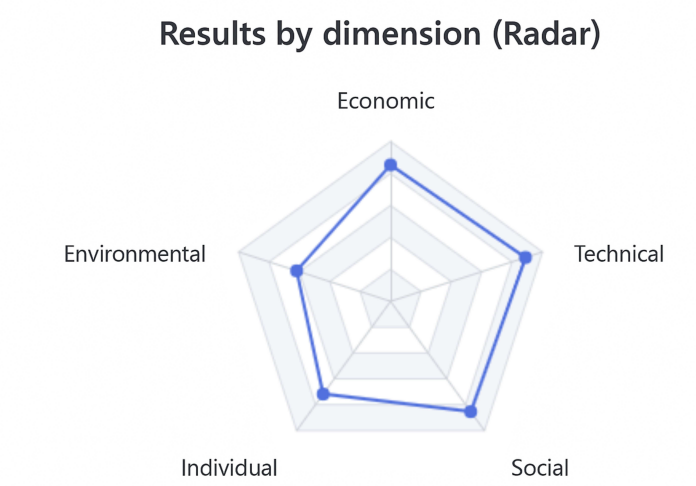


Fig. 3 Radar chart of the SEEDS checklist results for OpenEMR

OpenEMR's strongest results reflect characteristics commonly associated with mature open-source health systems. The absence of licensing costs, the availability of public documentation, the active development ecosystem, and the support for recognized interoperability standards contributed positively to the Economic and Technical dimensions. These aspects are also visible in the subtheme-level bar chart provided in Appendix C, particularly in subthemes related to functional adequacy, security and data protection, interoperability, and longevity.

The Social dimension also presented positive results, mainly because OpenEMR supports collaboration and communication among healthcare professionals through features such as messaging and shared clinical information. These functionalities may strengthen coordination, trust, and continuity of care in professional contexts. However, the results were less consistent for aspects related to broader inclusion, accessibility, and social barriers, indicating that social sustainability depends not only on collaboration features, but also on how accessible and inclusive the system is for different user profiles.

The main weaknesses were observed in the Environmental and Individual dimensions. Environmental sustainability was difficult to assess because the system does not explicitly communicate environmental practices, metrics, or commitments to users, making the evaluation dependent on indirect evidence such as digitalization and

reduced paper use. In the Individual dimension, the interface complexity, multiple workflows, incomplete translation, limited visible accessibility resources, and high cognitive demand affected the perceived user experience. Although documentation and community support are available, these resources are not fully integrated into the interface, which may reduce the sense of direct support during use.

The OpenEMR assessment highlights the sustainability potential of open-source digital health systems, particularly in terms of cost, technical evolution, interoperability, and community-based development. At the same time, the results indicate that technical maturity does not automatically translate into a positive user experience, especially when interface complexity, accessibility limitations, and non-functional information are not clearly communicated to users. This case also reinforced the need to adjust SEEDS checklist items that require technical knowledge or access to information not directly available from the user interface.

3.2.4 OpenEMR Patient Portal

The application of the SEEDS checklist to the OpenEMR Patient Portal, from the perspective of a common user/patient, showed moderate results across the sustainability dimensions. As summarized in Table 2 and illustrated in Fig. 4, the Economic dimension obtained the highest average score (3.91), followed by the Technical (3.59) and Social (3.47) dimensions. The Environmental (3.25) and Individual (3.06) dimensions presented the lowest average scores.

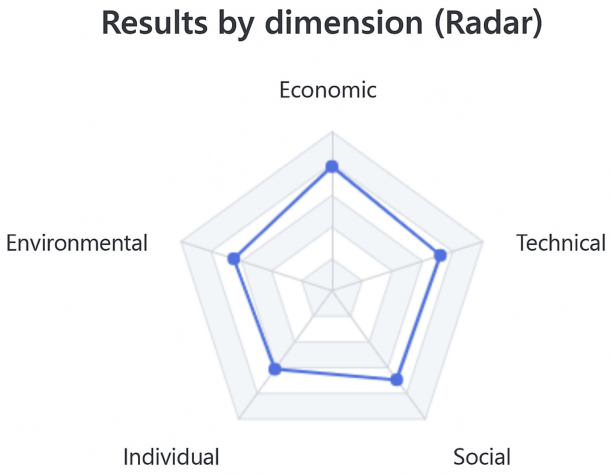


Fig. 4 Radar chart of the SEEDS checklist results for OpenEMR Patient Portal

The results indicate that the portal fulfills an important basic role by enabling access to health information and communication with healthcare professionals. This

helps explain the moderate results in the Economic, Social, and Technical dimensions. From the patient perspective, the system may reduce indirect costs associated with accessing information, support communication in care, and provide useful digital functionality. The subtheme-level bar chart provided in Appendix D shows stronger results in functional adequacy and satisfaction, sustainability and life cycle, and meaning and purpose.

However, the Patient Portal also revealed limitations that directly affect the user experience. The lower score in the Individual dimension reflects issues related to accessibility, interface clarity, lack of personalization, absence of integrated support, and limited adaptation to different user proficiency levels. These aspects are particularly relevant in a patient-facing context, where users may have different levels of digital literacy and different accessibility needs. The Environmental dimension was also difficult to assess, since the portal does not explicitly communicate environmental practices, indicators, or commitments, making the evaluation dependent mainly on indirect effects such as digital access to information and reduced paper use.

The Technical and Social results were also mixed. Although the portal provides core functions for accessing information and communicating with the healthcare team, aspects such as perceived interoperability, error validation, transparency about data use, and security communication were less evident from the user interface. Similarly, while the portal may strengthen the patient-professional relationship by supporting access and communication, it offers limited mechanisms for feedback incorporation, broader participation, or inclusion of diverse user profiles.

The Patient Portal results show that the same software ecosystem may lead to different sustainability perceptions depending on the user role and interface evaluated. While the professional OpenEMR context benefits from stronger technical and collaborative features, the patient-facing portal exposes limitations related to accessibility, clarity, support, and user empowerment. This case reinforces the need for the SEEDS checklist to distinguish more clearly between healthcare professional users and common users/patients.

3.3 Cross-case comparison

The cross-case analysis showed that the checklist results varied mainly according to the user perspective and the visibility of the information required by the SEEDS user profile. The systems evaluated from the healthcare professional perspective, AGHU/EBSERH and OpenEMR, obtained stronger results in the Technical and Economic dimensions. In contrast, the patient-facing contexts, Meu SUS Digital and the OpenEMR Patient Portal, exposed more limitations related to usability, accessibility, support, and the availability of information needed to answer technical or institutional questions.

The number of items marked as not applicable or unable to evaluate was also considered as an indicator of how much of the checklist could not be directly assessed from each user perspective. In this study, N/A refers to items that were either not applicable to the evaluated usage context or could not be assessed because the required information was not visible to the user through the interface, public documentation,

or user-accessible materials. Table 3 summarizes the number and percentage of N/A responses in each checklist application.

Table 3 Number of N/A responses in each checklist application

Application	N/A items	Percentage of checklist
Meu SUS Digital	9	10.6%
AGHU/EBSERH	6	7.1%
OpenEMR	9	10.6%
OpenEMR Patient Portal	14	16.5%

Note. N/A = Not applicable / unable to evaluate.

The distribution of N/A responses suggests different sources of applicability limitations. In the professional-user contexts, especially AGHU/EBSERH and OpenEMR, N/A responses were mainly associated with technical, environmental, or infrastructure-related aspects that were not fully observable in demonstration environments, such as energy consumption, scalability, performance under load, and interoperability behavior. In the patient-facing contexts, N/A responses more often reflected questions that were not aligned with the common user/patient perspective, such as items related to professional productivity, professional competence, institutional costs, licensing, scalability, and work continuity.

This pattern is particularly evident when comparing the two OpenEMR contexts. Although both evaluations referred to the same software ecosystem, the professional-user application resulted in 9 N/A responses, while the Patient Portal resulted in 14 N/A responses. This difference suggests that the patient-facing context provided less visibility into technical and institutional aspects and exposed more questions that were not fully suitable for common users/patients.

A recurring pattern across all cases was the difficulty of assessing the Environmental dimension from the user perspective. Environmental sustainability was mostly inferred from indirect effects, such as digitalization, reduced paper use, and potential reduction of displacement. However, explicit environmental practices, indicators, or commitments were not visible to users in the evaluated systems. This limited the assessment of environmental sustainability and indicates that some checklist items depend on evidence that is not usually available to end users.

The comparison also showed that the same sustainability dimension may require different interpretation depending on the user profile. Economic value, for example, was associated with free access in Meu SUS Digital, institutional process support in AGHU/EBSERH, open-source availability in OpenEMR, and convenience for patients in the OpenEMR Patient Portal. Similarly, technical sustainability was easier to assess in professional contexts than in patient-facing contexts. These findings support the need to distinguish between healthcare professional users and common users/patients in the SEEDS user profile.

3.4 Checklist application time

The time required to complete each checklist application was recorded as an additional indicator of the effort demanded by the SEEDS user-profile checklist. This measurement did not aim to evaluate the technical performance of the systems themselves, but rather to estimate the time needed to interpret the questions, inspect the system, consult available documentation when necessary, and register the corresponding answers and justifications.

Table 4 presents the time required for each application. The longest application was Meu SUS Digital, which required 205 minutes, followed by AGHU/EBSERH with 181 minutes and OpenEMR with 170 minutes. The OpenEMR Patient Portal required the shortest application time, with 125 minutes.

Table 4 Time required to complete each checklist application

Application	Time (minutes)
Meu SUS Digital	205
AGHU/EBSERH	181
OpenEMR	170
OpenEMR Patient Portal	125

The results indicate that applying the original SEEDS user profile requires substantial effort, even when the evaluation is conducted from the user perspective. The variation among applications was influenced by the complexity of each system, the amount of information available to the evaluator, the need to consult supporting documentation, and the number of questions that required interpretation beyond direct interface observation. The shorter application time for the OpenEMR Patient Portal can be explained, in part, by its more limited functional scope when compared with the other evaluated systems, especially the professional and institutional environments.

These findings reinforce the need to improve the clarity and applicability of the checklist for different user contexts. Reducing redundancies, rewriting overly technical questions, and distinguishing between common users and healthcare professional users may contribute to reducing the effort required to complete future applications of the instrument.

3.5 Improvement opportunities for the SEEDS user profile and platform

The checklist applications revealed improvement opportunities related both to the content of the SEEDS user profile and to the way the checklist is presented and completed on the platform. These opportunities emerged from difficulties observed during the application process, including repeated questions, redundant items, lack of clarity, overly technical wording, and questions that were not equally suitable for common users/patients and healthcare professional users.

The most relevant finding was the need to segment the original user profile into two distinct profiles: one for healthcare professional users and another for common users/patients. Several questions in the original user profile were more closely aligned with professional or institutional contexts, such as workflow, productivity, operational costs, and professional competence. As a result, these questions required adaptation or removal when applied to common user/patient contexts.

A second group of improvements was related to the wording and observability of checklist items. Some questions required technical, organizational, infrastructure-level, or institutional information that was not directly visible from the user perspective, such as energy efficiency, scalability, interoperability standards, logs, and institutional costs. Other questions combined multiple ideas in the same item or used terms that could lead to ambiguous interpretation. These findings motivated proposals to simplify wording, remove overly technical examples, merge redundant items, and reformulate questions to emphasize what can be perceived or assessed by users.

In addition to content-related changes, the applications also revealed opportunities to improve the checklist platform. These proposals were not related to the scoring of the evaluated systems, but to the usability and interpretability of the checklist itself. They included adding explanatory sections about the five sustainability dimensions, adding information about the interdependence among dimensions, improving subtheme selection controls, and preventing data loss when changing the interface language during completion.

Table 5 summarizes the main improvement proposals identified from the checklist applications. The detailed item-level mapping of specific changes, including repeated questions, redundancies, lack of clarity, inadequacy to the user profile, and inadequacy to the common user/patient profile, is provided in Appendix E.

Table 5 General improvement proposals identified from the checklist applications

Improvement category	Description	Rationale	Expected outcome
User-profile segmentation	Split the original user profile into two profiles: healthcare professional user and common user/patient.	Several questions were more suitable for professional or institutional contexts than for common user/patient contexts.	Better alignment between checklist items and user perspective.
Reduction of redundancies and repetitions	Merge, remove, or redistribute repeated or semantically overlapping questions.	The applications revealed overlap among items related to equity, inclusion, belonging, trust, cost-benefit, and data protection.	More concise checklist with lower internal redundancy.
Clarity and language simplification	Rewrite ambiguous, broad, or overly technical questions.	Some items generated interpretation difficulties or required knowledge not accessible to users.	Clearer and more user-observable questions.
Adequacy to the user profile	Remove, adapt, or relocate questions that required technical, organizational, or institutional information not visible to end users.	Some questions depended on information about infrastructure, logs, scalability, interoperability, or institutional costs.	Increased applicability of the checklist from the user perspective.
Documentation as an assessment item	Add a question about documentation and user guidance in the Technical dimension, under Functional Adequacy and Satisfaction.	Documentation was repeatedly used to support the checklist application and understand system behavior.	Explicit recognition of documentation as part of the user experience and assessment process.
Subtheme reorganization	Merge and rename subthemes that became too small or conceptually close after the proposed item removals and merging.	Some subthemes had few remaining questions after the proposed changes, reducing structural balance.	More coherent and balanced checklist structure.
Conceptual support on the platform	Add explanatory sections about each of the five sustainability dimensions.	Users may need conceptual support to interpret the dimensions before or after completing the checklist.	Improved understanding of sustainability dimensions.
Interpretation of multidimensional results	Add an informational section at the end of the assessment about the interdependence among dimensions.	Sustainability dimensions are interdependent, but this relationship was not explicit on the platform.	More systemic interpretation of checklist results.
Subtheme selection standardization	Add “Select all” and “Clear” buttons for subtheme selection.	The interaction pattern for subthemes was not fully standardized with the dimension-selection controls.	Improved consistency and reduced effort during setup.
Prevention of data loss	Add a confirmation pop-up when changing the interface language during checklist completion.	Changing the language during completion may result in loss of filled responses.	Reduced risk of data loss and rework.

3.6 Evaluation of the proposed improvements by the SEEDS research group

The proposed improvements were evaluated by eight members of the SEEDS research group through a structured form. The evaluation included both general improvement proposals and specific item-level proposals derived from the checklist applications. Overall, the results indicated broad agreement with the proposed changes. Nine of the thirteen evaluated proposal groups received unanimous agreement, while the remaining four received majority agreement, with seven out of eight participants agreeing. The proposal groups with one disagreement were related to language-change behavior on the platform, redundant feedback-related questions, questions inadequately suited to common users/patients, and the merging of Technical dimension subthemes.

Table 6 summarizes the agreement results for each group of proposals, including the observations provided in the cases of disagreement.

Table 6 SEEDS research group evaluation of the proposed improvements

Proposal group	Agreement	Disagreement	Main observation when applicable
Segmentation of the user profile	8/8	0/8	–
Explanatory sections about the five sustainability dimensions	8/8	0/8	–
Informational section on the interdependence among dimensions	8/8	0/8	–
Documentation-related question in the user profile	8/8	0/8	–
Subtheme selection controls	8/8	0/8	–
Confirmation pop-up when changing the interface language	7/8	1/8	One participant suggested that language switching could occur dynamically without clearing previous answers, using dictionaries and validated translations.
Repeated questions	8/8	0/8	–
Redundant questions	7/8	1/8	One participant suggested keeping two feedback-related items separate, as one concerns user support and the other concerns incorporation of feedback into collective improvements.
Questions inadequately suited to the user profile	8/8	0/8	–
Questions with lack of clarity	8/8	0/8	–
Questions inadequately suited to common users/patients	7/8	1/8	One participant noted that cost predictability may be difficult to assess without examples, even for professional or patient users.
Merging of Environmental subthemes	8/8	0/8	–
Merging of Technical subthemes	7/8	1/8	One participant argued that interoperability/integration and data security/protection are distinct, although complementary, technical domains.

The results supported the consolidation of the proposed improvements, especially the segmentation of the original user profile into two profiles: healthcare professional

users and common users/patients. The unanimous agreement on this proposal reinforces the relevance of distinguishing between user roles when applying the SEEDS checklist in digital health contexts. The disagreements were recorded as points for further discussion in future iterations of the instrument, since the revised checklists are proposed refinements rather than final validated versions.

3.7 Proposed revised SEEDS user-profile checklists

Based on the checklist applications, the systematized improvement proposals, and the evaluation by the SEEDS research group, two proposed revised versions of the SEEDS user-profile checklist were consolidated: one for healthcare professional users and another for common users/patients. These versions are presented as proposals to support future refinement of the instrument, not as final validated versions.

The original user-profile checklist applied in this study contained 85 questions. After the proposed removals, merges, reformulations, and profile-specific adaptations, the proposed version for healthcare professional users was reduced to 67 questions, while the proposed version for common users/patients was reduced to 63 questions. This represents a reduction of 18 questions in the professional-user version and 22 questions in the common-user/patient version, corresponding to reductions of approximately 21.2% and 25.9%, respectively.

This reduction is relevant because the checklist applications required substantial completion time, ranging from 125 to 205 minutes. Therefore, reducing repeated, redundant, overly technical, or profile-inadequate questions may contribute not only to improving the conceptual adequacy of the instrument, but also to decreasing the effort required in future applications. The complete proposed checklists are provided in Appendices F and G.

4 Discussion

The findings reinforce the understanding of software sustainability as a multidimensional concern, rather than a concept restricted to environmental impact. This is consistent with prior work in sustainable software engineering, which emphasizes technical, economic, social, individual, and environmental dimensions, as well as the long-term effects of software within socio-technical contexts (Becker et al. 2015; Penzenstadler et al. 2012; Karita et al. 2022). In this study, the applicability of the SEEDS user profile depended strongly on the observability of the information required by the checklist. This suggests that sustainability assessment instruments intended for user-based evaluation should prioritize questions that can be answered through interface interaction, user-accessible documentation, or evidence reasonably visible from the intended user perspective.

The results also align with the view of digital health systems as complex socio-technical systems, in which software, users, clinical and administrative workflows, institutional processes, sensitive data, and regulatory constraints interact (Sittig et al. 2020; Shojaei et al. 2024). The checklist applications were conducted from different user perspectives, namely healthcare professional users and common users/patients. These

perspectives involve different levels of access to technical, organizational, and operational information. Therefore, a single user profile may not adequately represent both evaluation contexts. The proposed segmentation of the SEEDS user profile responds to this limitation by adapting the checklist to different user roles while preserving its multidimensional sustainability structure.

The findings also indicate that clarity, support mechanisms, accessible wording, and consideration of different user profiles are relevant to the practical applicability of the checklist. Questions with technical wording, ambiguous scope, or low observability increased interpretation effort and often required inference. Thus, improving the checklist involves not only reducing or reformulating items, but also providing clearer conceptual support and platform-level guidance during the evaluation process.

The disagreements observed in the SEEDS group evaluation do not invalidate the proposed refinements, since all affected proposals still received majority agreement. However, they indicate points that should be further discussed by the group, including dynamic language switching on the platform, the distinction between user support and feedback incorporation into software evolution, the adaptation of cost-related examples to different user profiles, and the organization of technical subthemes. These points reinforce that the proposed revised checklists should be understood as evidence-based refinements, not as final validated versions. Future work should apply these versions in new contexts and with multiple evaluators to assess their clarity, applicability, consistency, and practical usefulness.

5 Threats to Validity

The results of this study should be interpreted considering some methodological limitations. The main threat concerns individual evaluator bias, since all checklist applications were conducted by a single evaluator. This may have influenced both the assignment of scores and the interpretation of questions, especially for items involving subjective judgment, such as usability, satisfaction, trust, accessibility, and perceived value.

Another limitation is related to the interpretation of the instrument. Some SEEDS checklist questions required technical knowledge or access to information that was not visible from the user perspective. As a result, some answers may have involved inference or were classified as not applicable when the required evidence could not be observed through the interface, documentation, or user-accessible materials.

The usage context also represents a threat to validity, although this limitation varied across cases. Meu SUS Digital was evaluated through its public web and mobile interfaces under a real user-access conditions, whereas AGHU/EBSERH, OpenEMR, and the OpenEMR Patient Portal were evaluated through demonstration environments, public documentation, or limited-access scenarios. Thus, mainly for the systems evaluated outside continuous production settings, aspects such as production performance, full interoperability, long-term availability, organizational impact, and large-scale operation could not be fully assessed.

Finally, the generalizability of the results is limited. The findings reflect the experience of one evaluator, four specific usage contexts, and three selected digital health

systems. Therefore, the results should not be generalized to all digital health systems or user profiles. Nevertheless, the study provides useful evidence for identifying recurring limitations in the SEEDS user profile and for supporting future refinements of the checklist.

6 Conclusion

This study applied the SEEDS checklist from the user perspective in three digital health systems and four usage contexts: Meu SUS Digital, AGHU/EBSERH, OpenEMR, and the OpenEMR Patient Portal. The study aimed to assess sustainability-related aspects perceived in these systems and to examine the adequacy of the SEEDS user profile as an assessment instrument for digital health contexts.

The results showed that the SEEDS user profile is useful for identifying sustainability-related strengths and weaknesses, but that its applicability varies according to the user role, system context, and visibility of the information required by the checklist. The diversity of the evaluated systems helped reveal limitations related to observability, technical wording, redundancy, and contextual adequacy.

Based on these findings, this study proposed refinements to the SEEDS user profile, including its segmentation into two proposed versions: one for healthcare professional users and another for common users/patients. The proposed versions reduce the number of items and reorganize the checklist to improve clarity, applicability, and alignment with different user perspectives. Platform-related recommendations were also identified to improve the usability and interpretability of the checklist during future applications.

The main contribution of this work is the provision of empirical evidence to support the refinement of a sustainability assessment instrument for digital health systems. The proposed revised checklists should not be interpreted as final validated instruments, but as evidence-based proposals for future evaluation. Future work should apply these proposed revised versions in new contexts, involve multiple evaluators with different profiles, and assess whether the proposed segmentation improves clarity, consistency, completion time, and practical usefulness of the SEEDS checklist.

Supplementary information. Supplementary information is provided in Appendices A–G. The supplementary material includes the complete checklist application results and subtheme-level bar charts for each evaluated system, the item-level mapping of proposed improvements, and the proposed revised versions of the SEEDS user-profile checklist for healthcare professional users and common users/patients.

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Declarations

Funding. Not applicable.

Competing interests. The authors declare no competing interests.

Ethics approval and consent to participate. Ethics approval was not required because the study did not involve patients, clinical data, or personal/sensitive information. The SEEDS group evaluation focused only on technical and conceptual feedback regarding checklist improvement proposals.

Consent for publication. Not applicable.

Data availability. The data generated and analyzed during this study are presented in the article appendices.

Materials availability. The materials used in this study are presented in the article appendices.

Code availability. Not applicable.

Author contribution. Mariana Koerber Albino conducted the checklist applications, organized the data, analyzed the results, and drafted the manuscript. Juliana Silva Herbert and Muriel Figueredo Franco supervised the study, contributed to the interpretation of the results, and reviewed the manuscript.

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Appendix A Checklist application results for Meu SUS Digital

Table A1 presents the complete SEEDS checklist application for Meu SUS Digital from the perspective of a common user/patient. The question numbers refer to the original version of the SEEDS user-profile checklist. The response abbreviations used in the table are: SA = strongly agree; PA = partially agree; PD = partially disagree; SD = strongly disagree; and NA = not applicable or unable to evaluate.

Table A1: Complete SEEDS checklist application for Meu SUS Digital

No.	Question	Resp.
Environmental		
Environmental Reliability and Responsibility		
1	Do software updates maintain or improve energy efficiency, without unnecessarily increasing resource consumption?	NA
2	Does the user trust that the software is developed with sustainable practices (Green Software)?	PD
3	Does the system demonstrate a commitment to environmental responsibility, aligning with recognized practices and certifications (e.g., Green IT, ISO 14001)?	SD
4	Does the software convey the feeling that it helps reduce the environmental footprint of its digital health activities?	PA
Sustainable Choices and User Behavior		
5	Does the software offer energy configuration options (e.g., low-consumption profiles) that the user can adopt?	SD
6	Does the system encourage sustainable digital practices (e.g., avoiding unnecessary printing, reducing redundant data traffic)?	PA
7	Is the user informed about the environmental impacts of software use (e.g., consumption reports, green indicators)?	SD
8	Does the software promote the user's environmental awareness, showing more efficient alternatives for certain tasks?	PD
Consumption Perception and Efficiency		
9	Does the software operate stably without requiring excessive hardware resources (CPU, memory, battery)?	PA
10	Is the system's response time efficient without compromising energy consumption?	NA
11	Does the user perceive performance/energy differences between operating modes (e.g., "economy mode" vs. "high performance")?	NA
12	Does the software consume little energy on mobile devices, preserving battery life?	PA
Hardware Use and Life Cycle		
13	Does the software work adequately on older devices, extending their useful life?	NA
14	Does the system not require frequent hardware replacements to continue being used?	PA
15	Is the software compatible with different devices and environments, avoiding premature disposal of equipment?	PA
16	Does the user feel that the system contributes to reducing electronic waste by maintaining usability in the long term?	PA
Economic		

Continued on next page

Table A1: Complete SEEDS checklist application for Meu SUS Digital (continued)

No.	Question	Resp.
	Perceived Cost-Benefit	
17	Is the investment in the software (acquisition, licensing, subscription) justified by the benefits obtained in day-to-day use?	SA
18	Does the use of the system help reduce operational costs (service time, rework, paper, administrative errors)?	SA
19	Does the software optimize resources (time, supplies, infrastructure), resulting in clear economic gains for the institution/user?	SA
20	Is the training cost for using the software reasonable given the ease of learning and adoption?	SA
	Work Efficiency and Return on Investment	
21	Does the system increase professionals' productivity (e.g., more patients attended, less time spent on records)?	PD
22	Does the software reduce errors or duplication of work, avoiding waste of resources?	SA
23	Is the return on investment perceived in practice (better quality of care, greater patient trust, reduction of indirect costs)?	PA
24	Does the software contribute to faster and more assertive decisions, bringing clinical and economic gains?	SA
	Security, Reliability and Additional Value	
25	Do data security and confidentiality reinforce trust in the software, avoiding financial risks associated with leaks or regulatory fines?	PA
26	Does the system offer protections against usage errors, reducing the need for support and rework?	PD
27	Can the software be used in other contexts or domains beyond those initially planned, increasing the value of the investment?	PA
28	Do the system's reliability and availability avoid interruptions that could cause losses or delays in the work routine?	PD
	Sustainability and Life Cycle	
29	Does the software work well with existing hardware, without requiring frequent replacements or high-cost equipment?	PA
30	Is the system updated regularly without generating excessive costs or significant interruptions in services?	SA
31	Is there long-term cost predictability (licensing, support, maintenance), avoiding financial surprises?	SA
32	Is the software scalable to keep pace with demand growth without disproportionate costs?	NA
Individual		
	Wellbeing and User Experience	
33	Does the use of the software help reduce users' workload and stress, avoiding overload and digital fatigue?	PD
34	Does the interface promote a positive, clear, and intuitive experience, reducing errors and frustration?	PD
35	Is the software accessible to different user profiles (e.g., with physical, visual, cognitive limitations or low digital literacy)?	SD
36	Are there feedback or support mechanisms that ensure the user feels heard and supported when facing difficulties?	SA
37	Does the software offer adaptation and personalization options to meet the diverse needs of end users?	SD
	Equity and Inclusion	

Continued on next page

Table A1: Complete SEEDS checklist application for Meu SUS Digital (continued)

No.	Question	Resp.
38	Was the software designed considering the diversity of users (gender, age, socioeconomic context, health conditions)?	NA
39	Are there measures to reduce access inequalities (for example: works well on low-cost devices or with low connectivity)?	PD
40	Does the software ensure equal access to services, avoiding inequities (e.g., based on race, culture, or socioeconomic condition)?	PD
41	Does the use of the software not exclude minority groups, but promotes inclusion and equity in health care?	PD
Training and Development		
42	Are training and continuous support opportunities offered (when necessary) so that users can use the software with confidence and effectiveness?	PA
43	Does the software encourage users to learn about safe and sustainable practices in digital health (e.g., information security, good clinical practices)?	SD
44	Is the system adaptable to the user's proficiency level, allowing both basic use and deeper exploration by more experienced users?	PD
45	Does the use of the software contribute to expanding the user's professional competence (e.g., clinical decision support, updating with scientific evidence)?	NA
Meaning and Purpose - User		
46	Does the user perceive that the use of the software contributes significantly to improving their own health or that of their patients?	PA
47	Is there alignment between the user's ethical values (e.g., humanized care, confidentiality, empathy) and the software's objectives?	PA
48	Does the software respect and strengthen user autonomy, rather than generating a feeling of surveillance or loss of control?	SA
49	Does the system promote trust (transparency in data use, explainability of recommendations, clarity about limitations)?	SA
50	Do design decisions consider human and ethical values, avoiding biases and discrimination in the use of the software?	PA
Social		
Trust and Social Relations		
51	Does the software contribute to strengthening trust between patients, health professionals, and institutions?	PA
52	Does the use of the system promote collaboration among different professionals and sectors, rather than generating isolation or competition?	NA
53	Does the software favor clear and respectful communication between users (health professionals, patients, managers)?	PD
54	Is the system perceived as transparent in its recommendations and decisions, avoiding distrust or opacity ("black box")?	PA
Justice, Ethics and Inclusion - User		
55	Does the software ensure equal access to services, avoiding inequities (e.g., based on race, culture, gender, age, or socioeconomic condition)?	PD
56	Do design decisions consider human and ethical values, avoiding biases and discrimination in the use of the software?	PA
57	Does the system respect the confidentiality and privacy of users' health data?	SA
58	Was the software designed in a culturally sensitive way, respecting the practices, languages, and values of different communities?	PD
Belonging and Social Impact		
59	Does the use of the software strengthen the user's bond with their health community (professionals, patients, family members, caregivers)?	PA

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Table A1: Complete SEEDS checklist application for Meu SUS Digital (continued)

No.	Question	Resp.
60	Does the system contribute to increasing users' sense of belonging in relation to the health care process (not feeling like merely "data on a screen")?	PA
61	Does the software promote user empowerment, allowing them to feel as active agents in making decisions about their health?	PA
62	Does the use of the system reinforce values of solidarity, inclusion, and mutual support among users and communities?	PD
63	Is the software perceived as fair and equitable, helping to reduce social inequalities in health and expand access to quality services?	PA
64	Are there mechanisms to ensure that user feedback is considered and incorporated into the evolution of the software, increasing the feeling of belonging and real influence?	PD
65	Does the system avoid creating social barriers or stigmas, promoting inclusion rather than marginalization (e.g., people with disabilities, cultural minorities, vulnerable groups)?	PA
Technical		
Functional Adequacy and Satisfaction		
66	Does the software correctly perform the functions for which it was adopted (functional completeness and correctness)?	PD
67	Do the functionalities truly support the user's practice, without excess unnecessary or redundant steps?	PD
68	Is the system perceived as useful and reliable in the long term, justifying its continued use?	PA
69	Is the overall satisfaction level with the software high, indicating technical confidence and adherence to daily professional routine?	PD
Reliability and Performance		
70	Does the software operate stably, without frequent failures or interruptions?	SD
71	Is the system's response time adequate, without slowdowns that impair workflow?	PD
72	Does the software's performance remain consistent even with increased data volumes or number of users?	NA
73	Does the system avoid recurring errors and protect against operational failures that could compromise care or clinical data analysis?	PD
Interoperability and Integration		
74	Does the software integrate effectively with other health systems (e.g., electronic health records, imaging systems, laboratories)?	SD
75	Does the system avoid the need for duplication of records or rework across different platforms?	SD
76	Does the exchange of information between systems occur consistently, without losses or incompatibilities?	SD
77	Does the software comply with recognized health interoperability standards (when communicated to the user)?	PA
Longevity and Evolution - User		
78	Does the user perceive that the software remains up-to-date in the face of regulatory, clinical, and technological changes?	PA
79	Do system updates occur without compromising work continuity or requiring high additional costs?	SA
80	Does the software remain useful and adaptable even in the face of new demands or usage contexts?	PA
81	Is there a system evolution history that demonstrates the developers' long-term commitment?	PA

Continued on next page

Table A1: Complete SEEDS checklist application for Meu SUS Digital (continued)

No.	Question	Resp.
Security and Data Protection		
82	Does the user feel confident that their data (or patients' data) is protected against unauthorized access?	SA
83	Does the system ensure confidentiality and integrity of information at all stages of use?	SA
84	Are there clear authentication and activity logging mechanisms (logs) that increase trust in the system?	PA
85	Does the software convey transparency about how data is used, stored, and shared?	SA

Note. Response abbreviations: SA = Strongly agree; PA = Partially agree; PD = Partially disagree; SD = Strongly disagree; NA = Not applicable / unable to evaluate.



Fig. A1 Subtheme-level bar chart of the SEEDS checklist results for Meu SUS Digital

Appendix B Checklist application results for AGHU/EBSERH

Table B2 presents the complete SEEDS checklist application for AGHU/EBSERH from the perspective of a healthcare professional user. The question numbers refer to the original version of the SEEDS user-profile checklist. The response abbreviations used in the table are: SA = strongly agree; PA = partially agree; PD = partially disagree; SD = strongly disagree; and NA = not applicable or unable to evaluate.

Table B2: Complete SEEDS checklist application for AGHU/EBSERH

No.	Question	Resp.
Environmental		
Environmental Reliability and Responsibility		
1	Do software updates maintain or improve energy efficiency, without unnecessarily increasing resource consumption?	NA
2	Does the user trust that the software is developed with sustainable practices (Green Software)?	PA
3	Does the system demonstrate a commitment to environmental responsibility, aligning with recognized practices and certifications (e.g., Green IT, ISO 14001)?	PD
4	Does the software convey the feeling that it helps reduce the environmental footprint of its digital health activities?	PA
Sustainable Choices and User Behavior		
5	Does the software offer energy configuration options (e.g., low-consumption profiles) that the user can adopt?	SD
6	Does the system encourage sustainable digital practices (e.g., avoiding unnecessary printing, reducing redundant data traffic)?	PA
7	Is the user informed about the environmental impacts of software use (e.g., consumption reports, green indicators)?	SD
8	Does the software promote the user's environmental awareness, showing more efficient alternatives for certain tasks?	PD
Consumption Perception and Efficiency		
9	Does the software operate stably without requiring excessive hardware resources (CPU, memory, battery)?	PA
10	Is the system's response time efficient without compromising energy consumption?	NA
11	Does the user perceive performance/energy differences between operating modes (e.g., "economy mode" vs. "high performance")?	NA
12	Does the software consume little energy on mobile devices, preserving battery life?	NA
Hardware Use and Life Cycle		
13	Does the software work adequately on older devices, extending their useful life?	NA
14	Does the system not require frequent hardware replacements to continue being used?	PA
15	Is the software compatible with different devices and environments, avoiding premature disposal of equipment?	PA
16	Does the user feel that the system contributes to reducing electronic waste by maintaining usability in the long term?	PD
Economic		

Continued on next page

Table B2: Complete SEEDS checklist application for AGHU/EBSERH (continued)

No.	Question	Resp.
Perceived Cost-Benefit		
17	Is the investment in the software (acquisition, licensing, subscription) justified by the benefits obtained in day-to-day use?	SA
18	Does the use of the system help reduce operational costs (service time, rework, paper, administrative errors)?	SA
19	Does the software optimize resources (time, supplies, infrastructure), resulting in clear economic gains for the institution/user?	SA
20	Is the training cost for using the software reasonable given the ease of learning and adoption?	SA
Work Efficiency and Return on Investment		
21	Does the system increase professionals' productivity (e.g., more patients attended, less time spent on records)?	PA
22	Does the software reduce errors or duplication of work, avoiding waste of resources?	PA
23	Is the return on investment perceived in practice (better quality of care, greater patient trust, reduction of indirect costs)?	PA
24	Does the software contribute to faster and more assertive decisions, bringing clinical and economic gains?	PA
Security, Reliability and Additional Value		
25	Do data security and confidentiality reinforce trust in the software, avoiding financial risks associated with leaks or regulatory fines?	SA
26	Does the system offer protections against usage errors, reducing the need for support and rework?	PA
27	Can the software be used in other contexts or domains beyond those initially planned, increasing the value of the investment?	PA
28	Do the system's reliability and availability avoid interruptions that could cause losses or delays in the work routine?	PA
Sustainability and Life Cycle		
29	Does the software work well with existing hardware, without requiring frequent replacements or high-cost equipment?	PA
30	Is the system updated regularly without generating excessive costs or significant interruptions in services?	PA
31	Is there long-term cost predictability (licensing, support, maintenance), avoiding financial surprises?	SA
32	Is the software scalable to keep pace with demand growth without disproportionate costs?	NA
Individual		
Wellbeing and User Experience		
33	Does the use of the software help reduce users' workload and stress, avoiding overload and digital fatigue?	PD
34	Does the interface promote a positive, clear, and intuitive experience, reducing errors and frustration?	PD
35	Is the software accessible to different user profiles (e.g., with physical, visual, cognitive limitations or low digital literacy)?	PD
36	Are there feedback or support mechanisms that ensure the user feels heard and supported when facing difficulties?	PA
37	Does the software offer adaptation and personalization options to meet the diverse needs of end users?	PA
Equity and Inclusion		

Continued on next page

Table B2: Complete SEEDS checklist application for AGHU/EBSERH (continued)

No.	Question	Resp.
38	Was the software designed considering the diversity of users (gender, age, socioeconomic context, health conditions)?	PD
39	Are there measures to reduce access inequalities (for example: works well on low-cost devices or with low connectivity)?	PA
40	Does the software ensure equal access to services, avoiding inequities (e.g., based on race, culture, or socioeconomic condition)?	PA
41	Does the use of the software not exclude minority groups, but promotes inclusion and equity in health care?	PD
Training and Development		
42	Are training and continuous support opportunities offered (when necessary) so that users can use the software with confidence and effectiveness?	SA
43	Does the software encourage users to learn about safe and sustainable practices in digital health (e.g., information security, good clinical practices)?	PA
44	Is the system adaptable to the user's proficiency level, allowing both basic use and deeper exploration by more experienced users?	PA
45	Does the use of the software contribute to expanding the user's professional competence (e.g., clinical decision support, updating with scientific evidence)?	PA
Meaning and Purpose - User		
46	Does the user perceive that the use of the software contributes significantly to improving their own health or that of their patients?	SA
47	Is there alignment between the user's ethical values (e.g., humanized care, confidentiality, empathy) and the software's objectives?	SA
48	Does the software respect and strengthen user autonomy, rather than generating a feeling of surveillance or loss of control?	PA
49	Does the system promote trust (transparency in data use, explainability of recommendations, clarity about limitations)?	PA
50	Do design decisions consider human and ethical values, avoiding biases and discrimination in the use of the software?	PD
Social		
Trust and Social Relations		
51	Does the software contribute to strengthening trust between patients, health professionals, and institutions?	SA
52	Does the use of the system promote collaboration among different professionals and sectors, rather than generating isolation or competition?	SA
53	Does the software favor clear and respectful communication between users (health professionals, patients, managers)?	SA
54	Is the system perceived as transparent in its recommendations and decisions, avoiding distrust or opacity ("black box")?	PA
Justice, Ethics and Inclusion - User		
55	Does the software ensure equal access to services, avoiding inequities (e.g., based on race, culture, gender, age, or socioeconomic condition)?	PA
56	Do design decisions consider human and ethical values, avoiding biases and discrimination in the use of the software?	PD
57	Does the system respect the confidentiality and privacy of users' health data?	SA
58	Was the software designed in a culturally sensitive way, respecting the practices, languages, and values of different communities?	SD
Belonging and Social Impact		
59	Does the use of the software strengthen the user's bond with their health community (professionals, patients, family members, caregivers)?	PA

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Table B2: Complete SEEDS checklist application for AGHU/EBSERH (continued)

No.	Question	Resp.
60	Does the system contribute to increasing users' sense of belonging in relation to the health care process (not feeling like merely "data on a screen")?	PD
61	Does the software promote user empowerment, allowing them to feel as active agents in making decisions about their health?	PA
62	Does the use of the system reinforce values of solidarity, inclusion, and mutual support among users and communities?	PD
63	Is the software perceived as fair and equitable, helping to reduce social inequalities in health and expand access to quality services?	PA
64	Are there mechanisms to ensure that user feedback is considered and incorporated into the evolution of the software, increasing the feeling of belonging and real influence?	SA
65	Does the system avoid creating social barriers or stigmas, promoting inclusion rather than marginalization (e.g., people with disabilities, cultural minorities, vulnerable groups)?	PD
Technical		
Functional Adequacy and Satisfaction		
66	Does the software correctly perform the functions for which it was adopted (functional completeness and correctness)?	SA
67	Do the functionalities truly support the user's practice, without excess unnecessary or redundant steps?	PA
68	Is the system perceived as useful and reliable in the long term, justifying its continued use?	SA
69	Is the overall satisfaction level with the software high, indicating technical confidence and adherence to daily professional routine?	PA
Reliability and Performance		
70	Does the software operate stably, without frequent failures or interruptions?	PA
71	Is the system's response time adequate, without slowdowns that impair workflow?	PA
72	Does the software's performance remain consistent even with increased data volumes or number of users?	PA
73	Does the system avoid recurring errors and protect against operational failures that could compromise care or clinical data analysis?	PA
Interoperability and Integration		
74	Does the software integrate effectively with other health systems (e.g., electronic health records, imaging systems, laboratories)?	SA
75	Does the system avoid the need for duplication of records or rework across different platforms?	PA
76	Does the exchange of information between systems occur consistently, without losses or incompatibilities?	PA
77	Does the software comply with recognized health interoperability standards (when communicated to the user)?	PA
Longevity and Evolution - User		
78	Does the user perceive that the software remains up-to-date in the face of regulatory, clinical, and technological changes?	SA
79	Do system updates occur without compromising work continuity or requiring high additional costs?	PA
80	Does the software remain useful and adaptable even in the face of new demands or usage contexts?	SA
81	Is there a system evolution history that demonstrates the developers' long-term commitment?	SA

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Table B2: Complete SEEDS checklist application for AGHU/EBSERH (continued)

No.	Question	Resp.
Security and Data Protection		
82	Does the user feel confident that their data (or patients' data) is protected against unauthorized access?	SA
83	Does the system ensure confidentiality and integrity of information at all stages of use?	SA
84	Are there clear authentication and activity logging mechanisms (logs) that increase trust in the system?	PA
85	Does the software convey transparency about how data is used, stored, and shared?	PD

Note. Response abbreviations: SA = Strongly agree; PA = Partially agree; PD = Partially disagree; SD = Strongly disagree; NA = Not applicable / unable to evaluate.

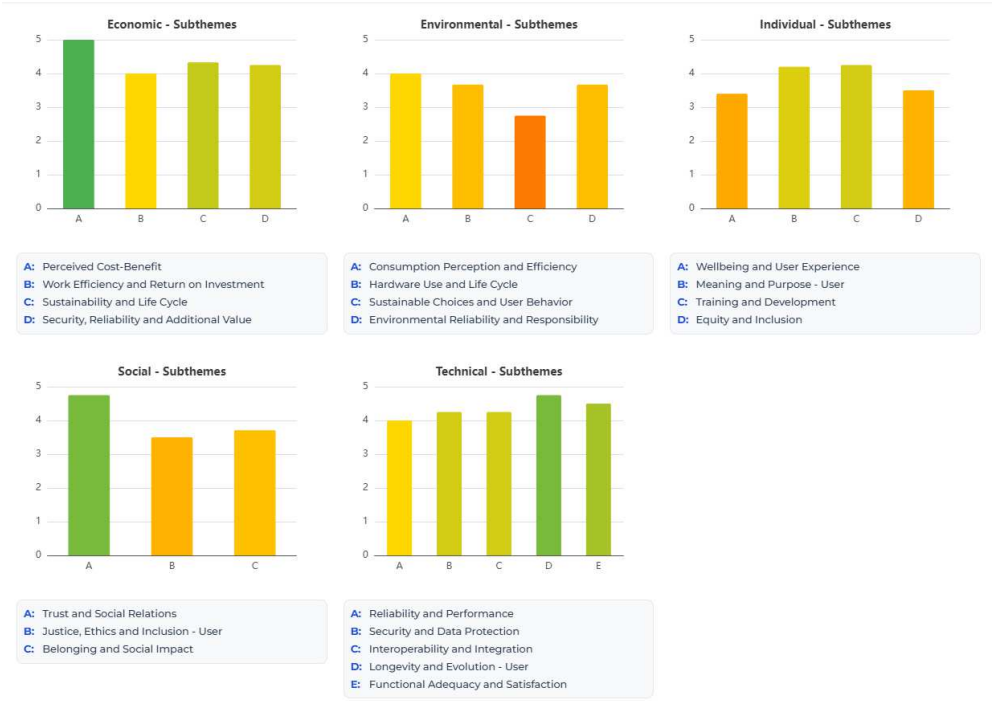


Fig. B2 Subtheme-level bar chart of the SEEDS checklist results for AGHU

Appendix C Checklist application results for OpenEMR

Table C3 presents the complete SEEDS checklist application for OpenEMR from the perspective of a healthcare professional user. The question numbers refer to the original version of the SEEDS user-profile checklist. The response abbreviations used in the table are: SA = strongly agree; PA = partially agree; PD = partially disagree; SD = strongly disagree; and NA = not applicable or unable to evaluate.

Table C3: Complete SEEDS checklist application for OpenEMR

No.	Question	Resp.
Environmental		
Environmental Reliability and Responsibility		
1	Do software updates maintain or improve energy efficiency, without unnecessarily increasing resource consumption?	NA
2	Does the user trust that the software is developed with sustainable practices (Green Software)?	SD
3	Does the system demonstrate a commitment to environmental responsibility, aligning with recognized practices and certifications (e.g., Green IT, ISO 14001)?	SD
4	Does the software convey the feeling that it helps reduce the environmental footprint of its digital health activities?	PA
Sustainable Choices and User Behavior		
5	Does the software offer energy configuration options (e.g., low-consumption profiles) that the user can adopt?	SD
6	Does the system encourage sustainable digital practices (e.g., avoiding unnecessary printing, reducing redundant data traffic)?	PA
7	Is the user informed about the environmental impacts of software use (e.g., consumption reports, green indicators)?	SD
8	Does the software promote the user's environmental awareness, showing more efficient alternatives for certain tasks?	SD
Consumption Perception and Efficiency		
9	Does the software operate stably without requiring excessive hardware resources (CPU, memory, battery)?	PA
10	Is the system's response time efficient without compromising energy consumption?	NA
11	Does the user perceive performance/energy differences between operating modes (e.g., "economy mode" vs. "high performance")?	NA
12	Does the software consume little energy on mobile devices, preserving battery life?	NA
Hardware Use and Life Cycle		
13	Does the software work adequately on older devices, extending their useful life?	NA
14	Does the system not require frequent hardware replacements to continue being used?	PA
15	Is the software compatible with different devices and environments, avoiding premature disposal of equipment?	SA
16	Does the user feel that the system contributes to reducing electronic waste by maintaining usability in the long term?	PD
Economic		

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Table C3: Complete SEEDS checklist application for OpenEMR (continued)

No.	Question	Resp.
Perceived Cost-Benefit		
17	Is the investment in the software (acquisition, licensing, subscription) justified by the benefits obtained in day-to-day use?	SA
18	Does the use of the system help reduce operational costs (service time, rework, paper, administrative errors)?	PA
19	Does the software optimize resources (time, supplies, infrastructure), resulting in clear economic gains for the institution/user?	PA
20	Is the training cost for using the software reasonable given the ease of learning and adoption?	SA
Work Efficiency and Return on Investment		
21	Does the system increase professionals' productivity (e.g., more patients attended, less time spent on records)?	PA
22	Does the software reduce errors or duplication of work, avoiding waste of resources?	PA
23	Is the return on investment perceived in practice (better quality of care, greater patient trust, reduction of indirect costs)?	PA
24	Does the software contribute to faster and more assertive decisions, bringing clinical and economic gains?	PA
Security, Reliability and Additional Value		
25	Do data security and confidentiality reinforce trust in the software, avoiding financial risks associated with leaks or regulatory fines?	SA
26	Does the system offer protections against usage errors, reducing the need for support and rework?	PA
27	Can the software be used in other contexts or domains beyond those initially planned, increasing the value of the investment?	PA
28	Do the system's reliability and availability avoid interruptions that could cause losses or delays in the work routine?	PA
Sustainability and Life Cycle		
29	Does the software work well with existing hardware, without requiring frequent replacements or high-cost equipment?	PA
30	Is the system updated regularly without generating excessive costs or significant interruptions in services?	PA
31	Is there long-term cost predictability (licensing, support, maintenance), avoiding financial surprises?	SA
32	Is the software scalable to keep pace with demand growth without disproportionate costs?	NA
Individual		
Wellbeing and User Experience		
33	Does the use of the software help reduce users' workload and stress, avoiding overload and digital fatigue?	PD
34	Does the interface promote a positive, clear, and intuitive experience, reducing errors and frustration?	PD
35	Is the software accessible to different user profiles (e.g., with physical, visual, cognitive limitations or low digital literacy)?	SD
36	Are there feedback or support mechanisms that ensure the user feels heard and supported when facing difficulties?	PA
37	Does the software offer adaptation and personalization options to meet the diverse needs of end users?	PD
Equity and Inclusion		

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Table C3: Complete SEEDS checklist application for OpenEMR (continued)

No.	Question	Resp.
38	Was the software designed considering the diversity of users (gender, age, socioeconomic context, health conditions)?	PD
39	Are there measures to reduce access inequalities (for example: works well on low-cost devices or with low connectivity)?	NA
40	Does the software ensure equal access to services, avoiding inequities (e.g., based on race, culture, or socioeconomic condition)?	PD
41	Does the use of the software not exclude minority groups, but promotes inclusion and equity in health care?	SD
Training and Development		
42	Are training and continuous support opportunities offered (when necessary) so that users can use the software with confidence and effectiveness?	SA
43	Does the software encourage users to learn about safe and sustainable practices in digital health (e.g., information security, good clinical practices)?	PA
44	Is the system adaptable to the user's proficiency level, allowing both basic use and deeper exploration by more experienced users?	PA
45	Does the use of the software contribute to expanding the user's professional competence (e.g., clinical decision support, updating with scientific evidence)?	PA
Meaning and Purpose - User		
46	Does the user perceive that the use of the software contributes significantly to improving their own health or that of their patients?	SA
47	Is there alignment between the user's ethical values (e.g., humanized care, confidentiality, empathy) and the software's objectives?	SA
48	Does the software respect and strengthen user autonomy, rather than generating a feeling of surveillance or loss of control?	PA
49	Does the system promote trust (transparency in data use, explainability of recommendations, clarity about limitations)?	PA
50	Do design decisions consider human and ethical values, avoiding biases and discrimination in the use of the software?	PD
Social		
Trust and Social Relations		
51	Does the software contribute to strengthening trust between patients, health professionals, and institutions?	SA
52	Does the use of the system promote collaboration among different professionals and sectors, rather than generating isolation or competition?	SA
53	Does the software favor clear and respectful communication between users (health professionals, patients, managers)?	PA
54	Is the system perceived as transparent in its recommendations and decisions, avoiding distrust or opacity ("black box")?	SA
Justice, Ethics and Inclusion - User		
55	Does the software ensure equal access to services, avoiding inequities (e.g., based on race, culture, gender, age, or socioeconomic condition)?	PD
56	Do design decisions consider human and ethical values, avoiding biases and discrimination in the use of the software?	PA
57	Does the system respect the confidentiality and privacy of users' health data?	SA
58	Was the software designed in a culturally sensitive way, respecting the practices, languages, and values of different communities?	PA
Belonging and Social Impact		
59	Does the use of the software strengthen the user's bond with their health community (professionals, patients, family members, caregivers)?	SA

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Table C3: Complete SEEDS checklist application for OpenEMR (continued)

No.	Question	Resp.
60	Does the system contribute to increasing users' sense of belonging in relation to the health care process (not feeling like merely "data on a screen")?	SA
61	Does the software promote user empowerment, allowing them to feel as active agents in making decisions about their health?	SA
62	Does the use of the system reinforce values of solidarity, inclusion, and mutual support among users and communities?	PD
63	Is the software perceived as fair and equitable, helping to reduce social inequalities in health and expand access to quality services?	PA
64	Are there mechanisms to ensure that user feedback is considered and incorporated into the evolution of the software, increasing the feeling of belonging and real influence?	PA
65	Does the system avoid creating social barriers or stigmas, promoting inclusion rather than marginalization (e.g., people with disabilities, cultural minorities, vulnerable groups)?	PD
Technical		
Functional Adequacy and Satisfaction		
66	Does the software correctly perform the functions for which it was adopted (functional completeness and correctness)?	SA
67	Do the functionalities truly support the user's practice, without excess unnecessary or redundant steps?	PA
68	Is the system perceived as useful and reliable in the long term, justifying its continued use?	SA
69	Is the overall satisfaction level with the software high, indicating technical confidence and adherence to daily professional routine?	PA
Reliability and Performance		
70	Does the software operate stably, without frequent failures or interruptions?	PA
71	Is the system's response time adequate, without slowdowns that impair workflow?	PA
72	Does the software's performance remain consistent even with increased data volumes or number of users?	NA
73	Does the system avoid recurring errors and protect against operational failures that could compromise care or clinical data analysis?	PD
Interoperability and Integration		
74	Does the software integrate effectively with other health systems (e.g., electronic health records, imaging systems, laboratories)?	SA
75	Does the system avoid the need for duplication of records or rework across different platforms?	PA
76	Does the exchange of information between systems occur consistently, without losses or incompatibilities?	NA
77	Does the software comply with recognized health interoperability standards (when communicated to the user)?	SA
Longevity and Evolution - User		
78	Does the user perceive that the software remains up-to-date in the face of regulatory, clinical, and technological changes?	SA
79	Do system updates occur without compromising work continuity or requiring high additional costs?	PA
80	Does the software remain useful and adaptable even in the face of new demands or usage contexts?	SA
81	Is there a system evolution history that demonstrates the developers' long-term commitment?	SA

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Table C3: Complete SEEDS checklist application for OpenEMR (continued)

No.	Question	Resp.
Security and Data Protection		
82	Does the user feel confident that their data (or patients' data) is protected against unauthorized access?	SA
83	Does the system ensure confidentiality and integrity of information at all stages of use?	PA
84	Are there clear authentication and activity logging mechanisms (logs) that increase trust in the system?	SA
85	Does the software convey transparency about how data is used, stored, and shared?	PA

Note. Response abbreviations: SA = Strongly agree; PA = Partially agree; PD = Partially disagree; SD = Strongly disagree; NA = Not applicable / unable to evaluate.

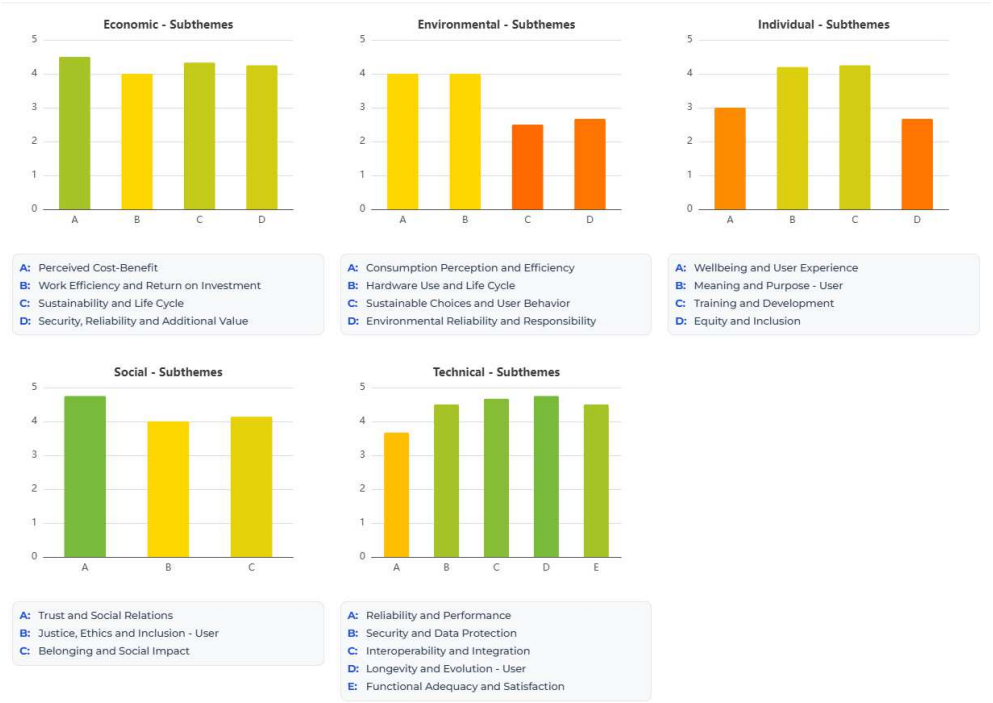


Fig. C3 Subtheme-level bar chart of the SEEDS checklist results for OpenEMR

Appendix D Checklist application results for the OpenEMR Patient Portal

Table D4 presents the complete SEEDS checklist application for the OpenEMR Patient Portal from the perspective of a common user/patient. The question numbers refer to the original version of the SEEDS user-profile checklist. The response abbreviations used in the table are: SA = strongly agree; PA = partially agree; PD = partially disagree; SD = strongly disagree; and NA = not applicable or unable to evaluate.

Table D4: Complete SEEDS checklist application for the OpenEMR Patient Portal

No.	Question	Resp.
Environmental		
Environmental Reliability and Responsibility		
1	Do software updates maintain or improve energy efficiency, without unnecessarily increasing resource consumption?	NA
2	Does the user trust that the software is developed with sustainable practices (Green Software)?	SD
3	Does the system demonstrate a commitment to environmental responsibility, aligning with recognized practices and certifications (e.g., Green IT, ISO 14001)?	SD
4	Does the software convey the feeling that it helps reduce the environmental footprint of its digital health activities?	PA
Sustainable Choices and User Behavior		
5	Does the software offer energy configuration options (e.g., low-consumption profiles) that the user can adopt?	SD
6	Does the system encourage sustainable digital practices (e.g., avoiding unnecessary printing, reducing redundant data traffic)?	PA
7	Is the user informed about the environmental impacts of software use (e.g., consumption reports, green indicators)?	SD
8	Does the software promote the user's environmental awareness, showing more efficient alternatives for certain tasks?	SD
Consumption Perception and Efficiency		
9	Does the software operate stably without requiring excessive hardware resources (CPU, memory, battery)?	SA
10	Is the system's response time efficient without compromising energy consumption?	NA
11	Does the user perceive performance/energy differences between operating modes (e.g., "economy mode" vs. "high performance")?	NA
12	Does the software consume little energy on mobile devices, preserving battery life?	NA
Hardware Use and Life Cycle		
13	Does the software work adequately on older devices, extending their useful life?	PA
14	Does the system not require frequent hardware replacements to continue being used?	PA
15	Is the software compatible with different devices and environments, avoiding premature disposal of equipment?	SA
16	Does the user feel that the system contributes to reducing electronic waste by maintaining usability in the long term?	PD
Economic		

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Table D4: Complete SEEDS checklist application for the OpenEMR Patient Portal (continued)

No.	Question	Resp.
	Perceived Cost-Benefit	
17	Is the investment in the software (acquisition, licensing, subscription) justified by the benefits obtained in day-to-day use?	PA
18	Does the use of the system help reduce operational costs (service time, rework, paper, administrative errors)?	PA
19	Does the software optimize resources (time, supplies, infrastructure), resulting in clear economic gains for the institution/user?	PA
20	Is the training cost for using the software reasonable given the ease of learning and adoption?	PD
	Work Efficiency and Return on Investment	
21	Does the system increase professionals' productivity (e.g., more patients attended, less time spent on records)?	NA
22	Does the software reduce errors or duplication of work, avoiding waste of resources?	PA
23	Is the return on investment perceived in practice (better quality of care, greater patient trust, reduction of indirect costs)?	PA
24	Does the software contribute to faster and more assertive decisions, bringing clinical and economic gains?	PA
	Security, Reliability and Additional Value	
25	Do data security and confidentiality reinforce trust in the software, avoiding financial risks associated with leaks or regulatory fines?	PA
26	Does the system offer protections against usage errors, reducing the need for support and rework?	PD
27	Can the software be used in other contexts or domains beyond those initially planned, increasing the value of the investment?	NA
28	Do the system's reliability and availability avoid interruptions that could cause losses or delays in the work routine?	PA
	Sustainability and Life Cycle	
29	Does the software work well with existing hardware, without requiring frequent replacements or high-cost equipment?	SA
30	Is the system updated regularly without generating excessive costs or significant interruptions in services?	NA
31	Is there long-term cost predictability (licensing, support, maintenance), avoiding financial surprises?	NA
32	Is the software scalable to keep pace with demand growth without disproportionate costs?	NA
	Individual	
	Wellbeing and User Experience	
33	Does the use of the software help reduce users' workload and stress, avoiding overload and digital fatigue?	PD
34	Does the interface promote a positive, clear, and intuitive experience, reducing errors and frustration?	PD
35	Is the software accessible to different user profiles (e.g., with physical, visual, cognitive limitations or low digital literacy)?	SD
36	Are there feedback or support mechanisms that ensure the user feels heard and supported when facing difficulties?	SD
37	Does the software offer adaptation and personalization options to meet the diverse needs of end users?	PD
	Equity and Inclusion	

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Table D4: Complete SEEDS checklist application for the OpenEMR Patient Portal (continued)

No.	Question	Resp.
38	Was the software designed considering the diversity of users (gender, age, socioeconomic context, health conditions)?	NA
39	Are there measures to reduce access inequalities (for example: works well on low-cost devices or with low connectivity)?	PA
40	Does the software ensure equal access to services, avoiding inequities (e.g., based on race, culture, or socioeconomic condition)?	PD
41	Does the use of the software not exclude minority groups, but promotes inclusion and equity in health care?	PD
Training and Development		
42	Are training and continuous support opportunities offered (when necessary) so that users can use the software with confidence and effectiveness?	SD
43	Does the software encourage users to learn about safe and sustainable practices in digital health (e.g., information security, good clinical practices)?	SD
44	Is the system adaptable to the user's proficiency level, allowing both basic use and deeper exploration by more experienced users?	SD
45	Does the use of the software contribute to expanding the user's professional competence (e.g., clinical decision support, updating with scientific evidence)?	NA
Meaning and Purpose - User		
46	Does the user perceive that the use of the software contributes significantly to improving their own health or that of their patients?	SA
47	Is there alignment between the user's ethical values (e.g., humanized care, confidentiality, empathy) and the software's objectives?	SA
48	Does the software respect and strengthen user autonomy, rather than generating a feeling of surveillance or loss of control?	PA
49	Does the system promote trust (transparency in data use, explainability of recommendations, clarity about limitations)?	PD
50	Do design decisions consider human and ethical values, avoiding biases and discrimination in the use of the software?	PD
Social		
Trust and Social Relations		
51	Does the software contribute to strengthening trust between patients, health professionals, and institutions?	PA
52	Does the use of the system promote collaboration among different professionals and sectors, rather than generating isolation or competition?	PA
53	Does the software favor clear and respectful communication between users (health professionals, patients, managers)?	PA
54	Is the system perceived as transparent in its recommendations and decisions, avoiding distrust or opacity ("black box")?	PD
Justice, Ethics and Inclusion - User		
55	Does the software ensure equal access to services, avoiding inequities (e.g., based on race, culture, gender, age, or socioeconomic condition)?	PD
56	Do design decisions consider human and ethical values, avoiding biases and discrimination in the use of the software?	PD
57	Does the system respect the confidentiality and privacy of users' health data?	PA
58	Was the software designed in a culturally sensitive way, respecting the practices, languages, and values of different communities?	PD
Belonging and Social Impact		
59	Does the use of the software strengthen the user's bond with their health community (professionals, patients, family members, caregivers)?	SA

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Table D4: Complete SEEDS checklist application for the OpenEMR Patient Portal (continued)

No.	Question	Resp.
60	Does the system contribute to increasing users' sense of belonging in relation to the health care process (not feeling like merely "data on a screen")?	PA
61	Does the software promote user empowerment, allowing them to feel as active agents in making decisions about their health?	PA
62	Does the use of the system reinforce values of solidarity, inclusion, and mutual support among users and communities?	PD
63	Is the software perceived as fair and equitable, helping to reduce social inequalities in health and expand access to quality services?	PD
64	Are there mechanisms to ensure that user feedback is considered and incorporated into the evolution of the software, increasing the feeling of belonging and real influence?	SD
65	Does the system avoid creating social barriers or stigmas, promoting inclusion rather than marginalization (e.g., people with disabilities, cultural minorities, vulnerable groups)?	PD
Technical		
Functional Adequacy and Satisfaction		
66	Does the software correctly perform the functions for which it was adopted (functional completeness and correctness)?	SA
67	Do the functionalities truly support the user's practice, without excess unnecessary or redundant steps?	SA
68	Is the system perceived as useful and reliable in the long term, justifying its continued use?	SA
69	Is the overall satisfaction level with the software high, indicating technical confidence and adherence to daily professional routine?	PA
Reliability and Performance		
70	Does the software operate stably, without frequent failures or interruptions?	PA
71	Is the system's response time adequate, without slowdowns that impair workflow?	PA
72	Does the software's performance remain consistent even with increased data volumes or number of users?	NA
73	Does the system avoid recurring errors and protect against operational failures that could compromise care or clinical data analysis?	PD
Interoperability and Integration		
74	Does the software integrate effectively with other health systems (e.g., electronic health records, imaging systems, laboratories)?	PA
75	Does the system avoid the need for duplication of records or rework across different platforms?	PA
76	Does the exchange of information between systems occur consistently, without losses or incompatibilities?	NA
77	Does the software comply with recognized health interoperability standards (when communicated to the user)?	SD
Longevity and Evolution - User		
78	Does the user perceive that the software remains up-to-date in the face of regulatory, clinical, and technological changes?	PD
79	Do system updates occur without compromising work continuity or requiring high additional costs?	NA
80	Does the software remain useful and adaptable even in the face of new demands or usage contexts?	PA
81	Is there a system evolution history that demonstrates the developers' long-term commitment?	SD

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Table D4: Complete SEEDS checklist application for the OpenEMR Patient Portal (continued)

No.	Question	Resp.
Security and Data Protection		
82	Does the user feel confident that their data (or patients' data) is protected against unauthorized access?	PA
83	Does the system ensure confidentiality and integrity of information at all stages of use?	PD
84	Are there clear authentication and activity logging mechanisms (logs) that increase trust in the system?	PD
85	Does the software convey transparency about how data is used, stored, and shared?	SD

Note. Response abbreviations: SA = Strongly agree; PA = Partially agree; PD = Partially disagree; SD = Strongly disagree; NA = Not applicable / unable to evaluate.



Fig. D4 Subtheme-level bar chart of the SEEDS checklist results for the OpenEMR Patient Portal

Appendix E Item-level improvement proposals for the SEEDS user profile

The following tables present the item-level improvement proposals derived from the application of the SEEDS checklist. The question numbers refer to the original version of the user-profile checklist. A same question may appear in more than one category when it presented more than one type of improvement opportunity.

Table E5 Item-level proposals related to repeated questions in the original SEEDS user-profile checklist

Group	Original question(s)	Dimension(s)	Subtheme(s)	Proposed change
1	Questions 40 and 55	Individual; Social	Equity and Inclusion; Justice, Ethics and Inclusion	Keep Question 40 and remove Question 55.
2	Questions 50 and 56	Individual; Social	Meaning and Purpose; Justice, Ethics and Inclusion	Remove both items due to inadequacy to the user profile.

Table E6 Item-level proposals related to redundant questions in the original SEEDS user-profile checklist

Group	Original question(s)	Dimension(s)	Subtheme(s)	Proposed change
1	Questions 6 and 8	Environmental	Sustainable Choices and User Behavior	Merge the questions and remove the example related to "redundant data traffic".
2	Questions 9 and 29	Environmental; Economic	Perception of Consumption and Efficiency; Sustainability and Life Cycle	Remove Question 9 and remove the excerpt about "existing hardware" from Question 29.
3	Questions 10 and 71	Environmental; Technical	Perception of Consumption and Efficiency; Reliability and Performance	Remove Question 10 and keep Question 71.
4	Questions 13, 14, and 15	Environmental	Hardware Use and Life Cycle	Merge the questions into a single revised item.
5	Questions 26 and 73	Economic; Technical	Security, Reliability and Additional Value; Reliability and Performance	Keep Question 26 and add an example to Question 73.
6	Questions 30 and 79	Economic; Technical	Sustainability and Life Cycle; Longevity and Evolution	Keep Question 30 and remove the excerpt about costs from Question 79.
7	Questions 35 and 37	Individual	Well-being and User Experience	Merge the questions into a single revised item.
8	Questions 36 and 64	Individual; Social	Well-being and User Experience; Belonging and Social Impact	Keep Question 36 and remove Question 64.
9	Questions 40 and 41	Individual	Equity and Inclusion	Merge the questions into a single revised item.
10	Questions 54, 49, and 85	Social; Individual; Technical	Trust and Social Relations; Meaning and Purpose; Data Security and Protection	Remove Question 54, remove the excerpt about "transparency in data use" from Question 49, and keep Question 85.
11	Questions 55, 63, and 65	Social	Justice, Ethics and Inclusion; Belonging and Social Impact	Remove Question 55 and merge Questions 63 and 65, moving the resulting item to the Individual dimension, subtheme Equity and Inclusion.
12	Questions 60 and 61	Social	Belonging and Social Impact	Merge the questions into a single revised item.
13	Questions 68 and 80	Technical	Functional Suitability and Satisfaction; Longevity and Evolution	Remove Question 68 and keep Question 80.
14	Questions 74 and 76	Technical	Interoperability and Integration	Merge the questions into a single revised item.
15	Questions 82 and 83	Technical	Data Security and Protection	Merge the questions into a single revised item.

Table E7 Item-level proposals related to questions inadequately suited to the user profile

Group	Original question	Dimension	Subtheme	Proposed change
1	Question 1	Environmental	Environmental Reliability and Responsibility	Replace the technical wording related to energy efficiency.
2	Question 2	Environmental	Environmental Reliability and Responsibility	Rewrite as "The software communicates that it was developed with sustainable practices" and remove the term "Green Software".
3	Question 3	Environmental	Environmental Reliability and Responsibility	Rewrite as "The system demonstrates to the user a commitment to environmental responsibility" and remove the reference to certifications.
4	Question 6	Environmental	Sustainable Choices and User Behavior	Remove the example related to "redundant data traffic".
5	Question 12	Environmental	Perception of Consumption and Efficiency	Rewrite as "The user feels that the software consumes...", emphasizing user perception.
6	Question 32	Economic	Sustainability and Life Cycle	Remove the question.
7	Question 38	Individual	Equity and Inclusion	Rewrite as "The user feels that the software was designed...", emphasizing user perception.
8	Question 50	Individual	Meaning and Purpose	Remove the question.
9	Question 56	Social	Justice, Ethics and Inclusion	Remove the question.
10	Question 77	Technical	Interoperability and Integration	Remove the question.
11	Question 83	Technical	Data Security and Protection	Rewrite the item to avoid overly technical wording related to confidentiality and integrity.
12	Question 84	Technical	Data Security and Protection	Remove the excerpt about logs, and add an example related to login and password.

Table E8 Item-level proposals related to lack of clarity in the original SEEDS user-profile checklist

Group	Original question	Dimension	Subtheme	Proposed change
1	Question 11	Environmental	Perception of Consumption and Efficiency	Clarify that the economic mode refers to the system, not to the device.
2	Question 18	Economic	Perceived Cost-Benefit	Reorient the question toward the user's perception.
3	Question 24	Economic	Work Efficiency and Return on Investment	Remove the excerpt "bringing clinical and economic gains", as the complement may confuse the answer.
4	Question 27	Economic	Security, Reliability and Additional Value	Rewrite the question to avoid ambiguity regarding additional value.
5	Question 29	Economic	Sustainability and Life Cycle	Replace the term "hardware" with clearer wording.
6	Question 40	Individual	Equity and Inclusion	Replace "ensure" with less absolute terms such as "favors" or "contributes to".
7	Question 43	Individual	Training and Development	Remove "sustainable", as this aspect is already covered in Question 6.
8	Question 44	Individual	Training and Development	Replace "adaptable" with "supports different levels of proficiency".
9	Question 47	Individual	Meaning and Purpose	Replace "humanized care" with "commitment to care".

Table E9 Item-level proposals related to questions inadequately suited to the common user/patient profile

Group	Original question	Dimension	Subtheme	Proposed change
1	Question 18	Economic	Perceived Cost-Benefit	Replace "operational costs" with "costs related to care" and adapt the examples.
2	Question 19	Economic	Perceived Cost-Benefit	Remove the question.
3	Question 21	Economic	Work Efficiency and Return on Investment	Remove the question.
4	Question 23	Economic	Work Efficiency and Return on Investment	Replace "greater patient trust" with "greater trust".
5	Question 25	Economic	Security, Reliability and Additional Value	Remove the reference to regulatory fines.
6	Question 27	Economic	Security, Reliability and Additional Value	Remove the question.
7	Question 28	Economic	Security, Reliability and Additional Value	Remove the expression "work routine".
8	Question 31	Economic	Sustainability and Life Cycle	Remove the examples.
9	Question 33	Individual	Well-being and User Experience	Remove "workload" and "overload".
10	Question 43	Individual	Training and Development	Replace the examples with "and care with their health information".
11	Question 45	Individual	Training and Development	Remove the question.
12	Question 46	Individual	Meaning and Purpose	Remove "of their patients".
13	Question 49	Individual	Meaning and Purpose	Replace the examples.
14	Question 52	Social	Trust and Social Relations	Remove "and sectors, rather than generating isolation and competition".
15	Question 53	Social	Trust and Social Relations	Remove "managers".
16	Question 69	Technical	Functional Suitability and Satisfaction	Remove "professional".
17	Question 71	Technical	Reliability and Performance	Replace "workflow" with "use".
18	Question 72	Technical	Reliability and Performance	Remove "number of users".
19	Question 79	Technical	Longevity and Evolution	Replace "work continuity" with "continuity of care".

Appendix F Proposed revised checklist for healthcare professional users

Table F10 presents the proposed revised version of the SEEDS user-profile checklist for healthcare professional users. The table preserves the multidimensional structure of the original checklist while incorporating the proposed content-related refinements.

Table F10: Proposed revised SEEDS checklist for healthcare professional users

No.	Question
Environmental	
Environmental Reliability and Responsibility	
1	Do software updates maintain or improve the efficient use of resources without unnecessarily increasing system consumption?
2	Does the software communicate that it was developed with sustainable practices?
3	Does the system demonstrate to the user a commitment to environmental responsibility?
4	Does the software convey the perception that it helps reduce the environmental footprint of digital health activities?
Sustainable Choices and User Behavior	
5	Does the software offer energy configuration options, such as low-consumption mode, that the user can adopt?
6	Does the system encourage sustainable digital practices, such as avoiding unnecessary printing, while promoting the user's environmental awareness?
7	Is the user informed about the environmental impacts of software use, such as consumption reports or green indicators?
Efficiency and Device Life Cycle	
8	Does the user perceive performance or energy differences between system operation modes, when available, such as "economy mode" and "high performance"?
9	Does the user feel that the software consumes little energy on mobile devices, preserving battery life?
10	Is the software compatible with different devices, without requiring frequent replacement or premature disposal of equipment?
11	Does the user feel that the system contributes to reducing electronic waste by maintaining long-term usability?
Economic	
Perceived Cost-Benefit	
12	Is the investment in the software, including acquisition, licensing, or subscription, justified by the benefits obtained in daily use?
13	Does the use of the system help reduce operational costs, such as service time, rework, paper use, or administrative errors?
14	Does the software optimize resources, such as time, supplies, and infrastructure, resulting in clear economic gains for the institution or user?
15	Is the training cost for using the software reasonable given its ease of learning and adoption?
Work Efficiency and Return on Investment	
16	Does the system increase professionals' productivity, such as by enabling more patients to be seen or reducing time spent on records?
17	Does the software reduce errors or duplication of work, avoiding waste of resources?
18	Is the return on investment perceived in practice, such as better quality of care, greater patient trust, or reduction of indirect costs?

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Table F10: Proposed revised SEEDS checklist for healthcare professional users (continued)

No.	Question
19	Does the software contribute to faster and more assertive decisions?
Security, Reliability and Additional Value	
20	Do data security and confidentiality reinforce trust in the software, avoiding financial risks associated with leaks or regulatory fines?
21	Does the system offer protections against usage errors, reducing the need for support and rework?
22	Can the software be used in contexts or domains beyond those initially planned, broadening the usefulness of the investment?
23	Do the system's reliability and availability avoid interruptions that could cause losses or delays in the work routine?
Sustainability and Life Cycle	
24	Does the software avoid requiring frequent device replacement or high-cost equipment?
25	Is the system updated regularly without generating excessive costs or significant interruptions in services?
26	Is there long-term cost predictability, including licensing, support, and maintenance, avoiding financial surprises?
Individual	
Well-being and User Experience	
27	Does the use of the software help reduce users' workload and stress, avoiding overload and digital fatigue?
28	Does the interface promote a positive, clear, and intuitive experience, reducing errors and frustration?
29	Is the software accessible and adaptable to different user profiles, including people with physical, visual, or cognitive limitations, or low digital literacy?
30	Are there feedback or support mechanisms that ensure the user feels heard and supported when facing difficulties?
Equity and Inclusion	
31	Does the user feel that the software considers the diversity of users, such as gender, age, socioeconomic context, and health conditions?
32	Are there measures to reduce access inequalities, for example by working well on low-cost devices or with low connectivity?
33	Does the software favor equal access to health services, avoiding inequities based on race, culture, or socioeconomic condition?
Training and Development	
34	Are training and continuous support opportunities offered, when necessary, so that users can use the software with confidence and effectiveness?
35	Does the software encourage users to learn about safe practices in digital health, such as information security and good clinical practices?
36	Does the system support different levels of user proficiency, allowing both basic use and deeper exploration by more experienced users?
37	Does the use of the software contribute to expanding the user's professional competence, such as clinical decision support or updating with scientific evidence?
Meaning and Purpose	
38	Does the user perceive that the use of the software contributes significantly to improving their own health or that of their patients?
39	Is there alignment between the user's ethical values, such as commitment to care, confidentiality, and empathy, and the software's objectives?

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Table F10: Proposed revised SEEDS checklist for healthcare professional users (continued)

No.	Question
40	Does the software respect and strengthen user autonomy, without generating a feeling of surveillance or loss of control?
41	Does the system promote trust through explainability of recommendations and decisions and clarity about limitations?
Social	
Trust and Social Relations	
42	Does the software contribute to strengthening trust among patients, healthcare professionals, and institutions?
43	Does the use of the system promote collaboration among different professionals and sectors, instead of generating isolation or competition?
44	Does the software favor clear and respectful communication among users, including healthcare professionals, patients, and managers?
Justice, Ethics and Inclusion	
45	Does the software promote equitable access and inclusion in health, without creating social barriers or stigmas, such as for people with disabilities, cultural minorities, or vulnerable groups?
46	Does the system respect the confidentiality and privacy of users' health data?
47	Was the software designed in a culturally sensitive way, respecting the practices, languages, and values of different communities?
Belonging and Social Impact	
48	Does the use of the software strengthen the user's bond with their health community, including professionals, patients, family members, and caregivers?
49	Does the software promote users' sense of belonging and empowerment, allowing active participation in decisions about their health?
50	Does the use of the system reinforce values of solidarity, inclusion, and mutual support among users and communities?
Technical	
Functional Adequacy and Satisfaction	
51	Does the software correctly perform the functions for which it was adopted, including functional completeness and correctness?
52	Do the functionalities truly support the user's practice, without excessive unnecessary or redundant steps?
53	Does the software provide adequate documentation and guidance to support correct system use by users?
54	Is the overall satisfaction level with the software high, indicating technical confidence and adherence to daily professional use?
Reliability and Performance	
55	Does the software operate stably, without frequent failures or interruptions?
56	Is the system response time adequate, without slowdowns that impair workflow?
57	Does the software maintain good performance even with increased data volume or number of users?
58	Does the system avoid recurring errors and protect against operational failures, such as unintended file deletion, that could compromise care?
Interoperability and Security	
59	Does the software integrate effectively with other health systems, such as electronic health records, imaging systems, and laboratories, ensuring consistent information exchange?
60	Does the system avoid the need for duplicate records or rework across different platforms?

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Table F10: Proposed revised SEEDS checklist for healthcare professional users (continued)

No.	Question
61	Does the system adequately protect users' information, avoiding unauthorized access or unauthorized changes?
62	Are there clear authentication mechanisms, such as login and password, increasing trust in the system?
63	Does the software convey transparency about how data are used, stored, and shared?
Longevity and Evolution	
64	Does the user perceive that the software remains up to date in the face of regulatory, clinical, and technological changes?
65	Do system updates occur without compromising work continuity?
66	Does the software remain useful and adaptable even in the face of new demands or usage contexts?
67	Is there a system evolution history that demonstrates the developers' long-term commitment?

Appendix G Proposed revised checklist for common users/patients

Table G11 presents the proposed revised version of the SEEDS user-profile checklist for common users/patients. The table preserves the multidimensional structure of the original checklist while adapting wording and content to the patient-facing context.

Table G11: Proposed revised SEEDS checklist for common users/patients

No.	Question
Environmental	
Environmental Reliability and Responsibility	
1	Do software updates maintain or improve the efficient use of resources without unnecessarily increasing system consumption?
2	Does the software communicate that it was developed with sustainable practices?
3	Does the system demonstrate to the user a commitment to environmental responsibility?
4	Does the software convey the perception that it helps reduce the environmental footprint of digital health activities?
Sustainable Choices and User Behavior	
5	Does the software offer energy configuration options, such as low-consumption mode, that the user can adopt?
6	Does the system encourage sustainable digital practices, such as avoiding unnecessary printing, while promoting the user's environmental awareness?
7	Is the user informed about the environmental impacts of software use, such as consumption reports or green indicators?
Efficiency and Device Life Cycle	
8	Does the user perceive performance or energy differences between system operation modes, when available, such as "economy mode" and "high performance"?
9	Does the user feel that the software consumes little energy on mobile devices, preserving battery life?
10	Is the software compatible with different devices, without requiring frequent replacement or premature disposal of equipment?
11	Does the user feel that the system contributes to reducing electronic waste by maintaining long-term usability?
Economic	
Perceived Cost-Benefit	
12	Is the investment in the software, including acquisition, licensing, or subscription, justified by the benefits obtained in daily use?
13	Does the user trust that using the system helps reduce costs related to care, such as displacement, rework, or unnecessary printing?
14	Is the training cost for using the software reasonable given its ease of learning and adoption?
Work Efficiency and Return on Investment	
15	Does the software reduce errors or duplication of work, avoiding waste of resources?
16	Is the return on investment perceived in practice, such as better quality of care, greater trust, or reduction of indirect costs?
17	Does the software contribute to faster and more assertive decisions?
Security, Reliability and Additional Value	

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Table G11: Proposed revised SEEDS checklist for common users/patients (continued)

No.	Question
18	Do data security and confidentiality reinforce trust in the software, avoiding financial risks associated with leaks?
19	Does the system offer protections against usage errors, reducing the need for support and rework?
20	Do the system's reliability and availability avoid interruptions that could cause losses or delays?
Sustainability and Life Cycle	
21	Does the software avoid requiring frequent device replacement or high-cost equipment?
22	Is the system updated regularly without generating excessive costs or significant interruptions in services?
23	Is there long-term cost predictability, avoiding financial surprises?
Individual	
Well-being and User Experience	
24	Does the use of the software help reduce user stress, avoiding digital fatigue?
25	Does the interface promote a positive, clear, and intuitive experience, reducing errors and frustration?
26	Is the software accessible and adaptable to different user profiles, including people with physical, visual, or cognitive limitations, or low digital literacy?
27	Are there feedback or support mechanisms that ensure the user feels heard and supported when facing difficulties?
Equity and Inclusion	
28	Does the user feel that the software considers the diversity of users, such as gender, age, socioeconomic context, and health conditions?
29	Are there measures to reduce access inequalities, for example by working well on low-cost devices or with low connectivity?
30	Does the software favor equal access to health services, avoiding inequities based on race, culture, or socioeconomic condition?
Training and Development	
31	Are training and continuous support opportunities offered, when necessary, so that users can use the software with confidence and effectiveness?
32	Does the software encourage users to learn about safe practices in digital health and care with their health information?
33	Does the system support different levels of user proficiency, allowing both basic use and deeper exploration by more experienced users?
Meaning and Purpose	
34	Does the user perceive that the use of the software contributes significantly to improving their own health?
35	Is there alignment between the user's ethical values, such as commitment to care, confidentiality, and empathy, and the software's objectives?
36	Does the software respect and strengthen user autonomy, without generating a feeling of surveillance or loss of control?
37	Does the system promote trust by presenting information and guidance in a clear and understandable way for patients?
Social	
Trust and Social Relations	
38	Does the software contribute to strengthening trust among patients, healthcare professionals, and institutions?

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Table G11: Proposed revised SEEDS checklist for common users/patients (continued)

No.	Question
39	Does the use of the system promote collaboration among different professionals in patient care?
40	Does the software favor clear and respectful communication between users and healthcare professionals?
Justice, Ethics and Inclusion	
41	Does the software promote equitable access and inclusion in health, without creating social barriers or stigmas, such as for people with disabilities, cultural minorities, or vulnerable groups?
42	Does the system respect the confidentiality and privacy of users' health data?
43	Was the software designed in a culturally sensitive way, respecting the practices, languages, and values of different communities?
Belonging and Social Impact	
44	Does the use of the software strengthen the user's bond with their health community, including professionals, patients, family members, and caregivers?
45	Does the software promote users' sense of belonging and empowerment, allowing active participation in decisions about their health?
46	Does the use of the system reinforce values of solidarity, inclusion, and mutual support among users and communities?
Technical	
Functional Adequacy and Satisfaction	
47	Does the software correctly perform the functions for which it was adopted, including functional completeness and correctness?
48	Do the functionalities truly support the user's practice, without excessive unnecessary or redundant steps?
49	Does the software provide adequate documentation and guidance to support correct system use by users?
50	Is the overall satisfaction level with the software high, indicating technical confidence and adherence to daily use?
Reliability and Performance	
51	Does the software operate stably, without frequent failures or interruptions?
52	Is the system response time adequate, without slowdowns that impair use?
53	Does the software maintain good performance even with increased data volume?
54	Does the system avoid recurring errors and protect against operational failures, such as unintended file deletion, that could compromise care?
Interoperability and Security	
55	Does the software integrate effectively with other health systems, such as electronic health records, imaging systems, and laboratories, ensuring consistent information exchange?
56	Does the system avoid the need for duplicate records or rework across different platforms?
57	Does the system adequately protect users' information, avoiding unauthorized access or unauthorized changes?
58	Are there clear authentication mechanisms, such as login and password, increasing trust in the system?
59	Does the software convey transparency about how data are used, stored, and shared?
Longevity and Evolution	
60	Does the user perceive that the software remains up to date in the face of regulatory, clinical, and technological changes?

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Table G11: Proposed revised SEEDS checklist for common users/patients (continued)

No.	Question
61	Do system updates occur without compromising continuity of care?
62	Does the software remain useful and adaptable even in the face of new demands or usage contexts?
63	Is there a system evolution history that demonstrates the developers' long-term commitment?