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Software Quality Assurance of Information Systems in Healthcare: A Methodological Review

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Abstract: Information systems in healthcare are crucial in facilitating digital storage, retrieval and sharing of health-related data. Literature reveals many different aspects of challenges, such as usability, interoperability, security, and data quality that impede their effectiveness. The role of Software Quality Assurance (SQA) could have been vital in developing and aligning information systems with the specifications and user needs. While there are diverse tools and measures presented in the studies of information systems in healthcare, there is a notable gap in the absence of synthesis as well as analysis of tools, metrics, and models utilized in healthcare information systems SQA methodologies. This study aims to analyze and synthesize SQA methodologies in the software development life cycle of information systems in healthcare. Using the 2020 PRISMA guidelines, 26 research papers were identified from PubMed and Google Scholar databases. Quantitative analysis was then conducted to identify themes and trends, consolidated best practices, challenges and the insights derived by their respective authors. It was shown that the frequency of methods in SDLC employed vary across papers. Overall impression however is that the SQA methodologies are adapted almost equally across the papers This study is significant for its comprehensive review of SQA methodologies, its potential to improve healthcare delivery and its contribution to the ongoing discourse in enhancing the quality and effectiveness of healthcare information systems. Its novelty, among others, lies in its focus on the phases of digital health systems life cycle that are often underemphasized.

Keywords: Software Quality Assurance, Digital Health, Software Development Health Cycle, Software Quality Metrics, Software Quality Standards, Health Information Systems

1. INTRODUCTION

Information systems have become a cornerstone in healthcare systems, with Electronic Health Records (EHRs) serving as digital repositories of patient health information. Healthcare information systems aim to enhance care coordination, quality, and efficiency by making information more accessible and shareable across healthcare providers [1]–[8]. However, optimizing these systems to enhance healthcare safety, quality, and efficiency remains a challenge due to issues such as suboptimal system design, poor usability, and a lack of customizability [3], [7]–[11]. These issues underscore the importance of software quality in the context of information systems in healthcare, which is to meet the specified requirements and user needs, particularly in storing, retrieving, and managing health records [3], [12], [13]. As the healthcare landscape rapidly evolves, technology plays an increasingly significant role. However, the effectiveness of information systems heavily depends on the quality of the software that powers them [14]–[16]. Thus, software quality assurance (SQA) for information systems provides a systematic process that ensures the quality of health-related systems by monitoring and evaluating various project aspects such as hardware, infrastructure, network and server, and operating system. It is crucial because it directly impacts the quality of patient care and outcomes, the efficiency of healthcare delivery, regulatory compliance, and the overall operational efficiency of healthcare institutions [3], [7], [9], [10], [14].

The application of quality assurance in information systems in healthcare involves practices such as conducting usability testing to ensure user-friendliness, implementing training programs for users, employing user-centered design principles, and developing tailored quality assurance (QA) policies aligned with clinical settings [17]–[22]. Continuous risk assessment and validation of system changes should also be part of healthcare information systems QA to ensure the availability, integrity and privacy of healthcare information as well as guarantee adherence to established regulations, because these factors can affect the quality and safety of patient care and outcomes. The literature on SQA for healthcare is continuously evolving, with recent trends focusing on enhancing SQA practices in EHR implementation [10], [18], [20], [23]–[28], thus there is a need for improved SQA practices to enhance software quality for health-related information systems [5], [12], [19], [29]–[32]. The existing literature dictates that there is a lack of synthesis and analysis on the methodologies that are used in SQA among information systems in healthcare. Thus, the general objective of this study is to comprehensively review the methodologies of existing SQA literature to identify research gaps that can be addressed by strategic research priorities. Specifically, it is aimed to explore current practices, identify issues, and suggest targeted improvements. Only relevant literature available to date are investigated, and potential biases are acknowledged in selected studies. Key stakeholders comprising healthcare professionals, policymakers and decision makers in the national and local government, researchers, IT specialists, and government departments represent the target audience, as this study provides relevant insights to support each group in optimizing SQA for health-related information systems. A systematic literature search, critical appraisal of findings, and synthesis of results will inform the review process.

Despite the fact that SQA is a classic problem that is faced with both organizational and technical challenges, its novelty lies in the systematic and comprehensive approach to reviewing SQA practices, the use of robust methodological guidelines, and the practical recommendations it offers for future research and implementation. The study highlights phases of the SDLC that are often *underemphasized*, such as deployment and perfective maintenance, showcasing their critical roles in the sustained success of healthcare information systems. This is significant as it addresses the critical need for high-quality healthcare information systems through a comprehensive review of SQA methodologies.

2. METHODOLOGY

There are three major processes undertaken in this study, they are the following:

- Identification and selection of journal articles to be subjected in this study.
- Analysis of the methodologies of the selected journal articles.
- Identification of the commonalities in their respective limitations, conclusions and recommendations.

2.1 Selection and Identification of Journal Articles

The 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was used in the identification, filtering and selection of related literature [5], [9], [24], [25], [27]–[37]. Table 1 outlined the keywords used in search strings to serve as a simple guide for the literature review. It highlights two main focus areas: *Software Quality Assurance and Healthcare Information Systems*. Each area is linked with a set of search strings, variations or terms related to the main keyword, aimed at encompassing a larger scope of relevant literature [17], [38]–[41]. Under *Software Quality Assurance*, the search strings encompass terms such as *SQA, Software Quality Process, Software Quality Metrics, Software Quality Standards, Practices, and Testing* [11]–[12], [18], [20], [29], [30], [37]–[41]. In the case of Healthcare Information Systems, the search strings comprise *EHR, Health Information Standards, Electronic Record Systems, and Digital Health Record* [21], [46]–[56].

Table 1. Keywords used in filtering search results

Area of Interest	Keywords Used
Software Quality Assurance	*SQA* *Software Quality Process* *Software Quality Metrics* *Software Quality Standards* *Practices* *Testing*
Healthcare Information Systems	*HER* *Health Information Standards* *Electronic Record Systems* *Digital Health Record*

Two relatively large and popular databases were mined. These are the Google Scholar and PubMed. Figure 1 shows that initial iteration had PubMed matched 231,815 articles while Google Scholar a whooping 3,690,000 articles. The next iteration is the classification of the initial results, pruning out of the items which are considered duplicates, or those that are non-journal articles, non-English studies, and those that are not available in Web Science nor Scopus. But the dominant criteria, those that do not involve SQA, shrank the whole population significantly, removing more than 2 million items out from the original search space. Further iterations excluded those that are considered irrelevant based on their title, abstract, and study validation. Finally, the eligibility was imposed, setting the final count of 26 journal articles.

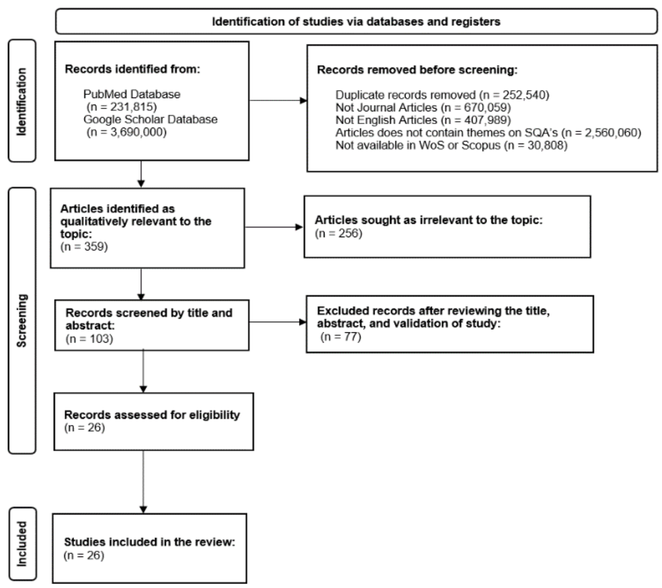

Figure 1. PRISMA flow diagram as applied in the study

2.2 Analysis of the Methodologies

After determining the journal articles subjected to this study, a methodological analysis framed within the phases of the Software Development Life Cycle (SDLC) was done. SDLC seeks to minimize project risks through forward planning so that software meets customer expectations during production and beyond [31], [59], [65]–[67]. As shown in Figure 2, the framework comprises the following phases: Requirement Analysis; Design; Implementation; Testing; Deployment; and Maintenance.

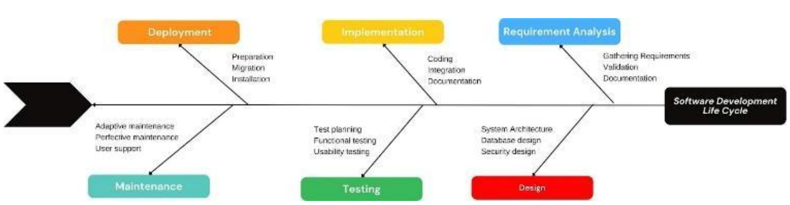

Figure 2. Phases of the Software Development Life Cycle

In the software analysis phase of the SDLC, the project requirements were gathered, validated, and documented, as well as aligned to the SQA methods. The definitions of key methods of SDLC Requirements Analysis Phase, as presented in Table 2, establish foundational understanding for readers in preparation for subsequent analyses in this phase. By employing a methodological approach, key methods in software development were articulated as presented below [18]–[75]. Design phase is defined as System Architecture, Database Design, and Security Design which is consistent with the SQA methods. Adopting a methodological approach, the researchers provide the descriptions of key methods applied in healthcare information systems development. This presentation of method definitions enhances clarity, providing opportunities for a comprehensive analysis of the Design Phase in SDLC [19], [22], [33], [57], [73], [79]–[87].

SQA is an integral part of the development process during the implementation phase where coding, integration, and documentation were systematically undertaken [62], [88]. Table 2 allows better understanding of the Implementation Phase, where the methods play a pivotal role in ensuring the quality and functionality of healthcare information systems [14], [29], [30], [58], [63], [65], [75], [77], [89]–[92].

The testing phase involves planning and application of SQA methodologies. These definitions set the foundation for delving into the deployment phase, with further provisions of definitions for clarity and understanding. It was observed that in some product delivery, additional methods may be used such as user-acceptance test. This allows end-users and stakeholders to test the functionality and usability of the platform to make sure that it meets their expectations [29], [41], [58], [59], [65], [69], [70], [73], [84], [89], [90], [93].

The deployment phase covers the preparation, installation, and migration of data consistent with the SQA methodologies [39], [40], [46], [49], [59]–[64], [72], [75]–[77], [94]–[95]. Table 2 defines key methods in the SDLC deployment phase.

The coverage of the maintenance phase includes adaptive and perfective maintenance practices, and user support. These are continually applying SQA methods for system changes whether in the underlying technology, or performance of the operations. Definitions in Table 2 provide a foundational understanding about the essential methods in the SDLC maintenance phase [39]–[41], [46], [49], [58], [62]–[76], [90].

Table 2. Definitions of Methods in the SDLC

Requirements Analysis Methods	Definition
Gathering requirements	The process of collecting and defining the functional and non-functional specifications for healthcare information systems to ensure that the software meets the needs and expectations of end-users and stakeholders. This is usually carried out by process mapping all practices and routine activities within the service.
Validation	The process of confirming the correctness and effectiveness of healthcare information systems through systematic assessment and verification.
Documentation	The process of creating and maintaining a comprehensive record, including specifications, guidelines (encroached within the service's policies, procedures, protocols and guidelines), and reports, to ensure clarity, traceability, and effective communication in the development and maintenance of healthcare information systems.
Design Methods	**Definition**
System architecture	The arrangement and configuration of components within healthcare information systems, defining their interactions and dependencies to ensure a robust and scalable framework for seamless operation.
Database design	The structuring and organization of the healthcare information systems' database, including tables, relationships, and data integrity mechanisms to facilitate efficient data storage and retrieval. The steps include database migration steps from the current system to the new one.
Security design	The establishment of protective measures (security by default or design) within healthcare information systems to safeguard sensitive patient data, involving encryption, access controls, and other security features to prevent unauthorized access and ensure data integrity, confidentiality, and availability ascribed in the data protection act.
Implementation Methods	**Definition**
Coding	The process of translating design specifications into actual code for healthcare information systems, implementing the planned functionality and features.
Integration	The combining and testing of individual components or modules of healthcare information systems to ensure they work together seamlessly as a unified system.
Documentation	The creation and maintenance of records, manuals, and guides for healthcare information systems, providing clear and accessible information for developers, testers, and users to understand and work with the software effectively.
Testing Methods	**Definition**
Test planning	The process of outlining and organizing the testing activities for healthcare information systems to ensure systematic and effective quality assurance.
Functional testing	The process of evaluating the specific functions of healthcare information systems. This includes verifying that the specific function performs as intended, detecting, and addressing any operational issues. Moreover, the process includes creation of bug reports, stratifying them in order of importance, outlining steps to replicate for verification purposes, solution creation, and resolution. Overall, this makes sure that each step and processes within the platform behaves as it should be.
Usability testing	The assessment of healthcare information systems to determine the user-friendliness and accessibility to ensure that the healthcare professionals can easily navigate and use the software for efficient patient care.
Deployment Methods	**Definition**
Preparation	The execution of requisite activities to ready the environment for healthcare information systems, including configuring settings, establishing prerequisites, and ensuring all necessary resources are in place.
Installation	The setting up healthcare information systems on the intended hardware or servers, ensuring that the software is for use and deployment.
Migration	The transfer of data and functionalities from existing systems to healthcare information systems to ensure smooth transition with minimal disruption to healthcare operations
Maintenance Methods	**Definition**
Adaptive Phase	The phase in software maintenance that involves making modifications to healthcare information systems to keep them compatible with evolving technology or changing user requirements.
Perfective maintenance	The ongoing improvement and enhancement of healthcare information systems to optimize performance, usability, and functionality based on user feedback and emerging needs.
User support	The provision of assistance and guidance to end-users of healthcare information systems, addressing queries, issues, and ensuring optimal utilization of the software.

For the recurring patterns and major themes to emerge from among the articles reviewed, a tally table was used. Inductive and deductive coding methods were further utilized to explore the SDLC and evaluate data compliance with predetermined criteria and quality standards, ensuring a thorough examination of the literature in the context of SQA for health-related information systems. Inductive coding derives the software development life cycle from the dataset, unveiling distinctive patterns and inherent challenges. On the other hand, deductive coding evaluates data compliance with predetermined criteria and established quality standards. The primary focus of the review was on assessing the methods and dimensions employed in SQA of healthcare information systems, guided by methodologies outlined in select literature.

2.3 Analysis of Research Gaps

This section provides the analysis made from the journal articles. The areas in the articles that were specifically probed were the commonality in the conclusion part, their specified limitations, and their respective authors' suggestions. The collective analysis of the journal articles reveals common conclusions highlighting the critical concern of software quality assurance in healthcare information systems. Upon review, the monitoring and further improvement of the SQA processes over time emerges as a crucial aspect for sustained success. This analysis contributes to a comprehensive understanding of the prevailing challenges and practices within the SQA domain. While examining software organizations' practices, common pitfalls include rushing quality process implementation, not following established guidelines or deviation, and the need for a more nuanced approach to address common limitations. The analysis revealed recurring challenges in SQA practices [46], [49], [60], [64], [76]. Most of the journal articles mentioned limitations of SQA practices in developing countries which include the limited research investment, knowledge gaps in SDLC, limited stakeholder interaction and consultation, absolute end-user preference, and low priority given to non-functional tests. The recommendations in the journal articles mostly tackled measures for enhancing software quality assurance practices. Emphasizing the significance of adhering to quality standards, the recommendations advocate for awareness programs, comprehensive training initiatives for software practitioners consistent to tailored national standards. The call for increased investment in research and development, prioritizing quality assurance practices, and promoting adherence to SDLC models resonates as key strategies for elevating software quality.

3. RESULTS AND DISCUSSIONS

3.1 Identified Journal Articles

The 26 journal articles selected for this study as yielded using the PRISMA are listed in the appendix. The list includes the year, author/s, and the titles.

3.2 Synthesis of Methodologies

Plotted in Figure 3 are the most common concepts synthesized from the articles, following the methods in SDLC. Shown in varying colors according to their phases, and indicated by a numeral value according to their frequency, the data reveals a snapshot of the key characteristics and findings of their authors.

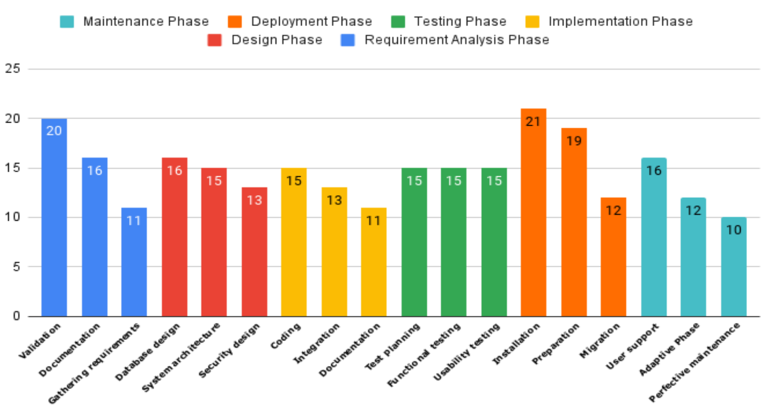

Figure 3. Software Quality Assurance Methods in the Software Development Life Cycle of Healthcare Information Systems

As shown in Table 3, *validation* in the first phase of SDLC, for example, emerged dominantly in the articles, while *gathering of requirements* is only half the frequency. All of the areas in the second and third phases were shown to be relatively of equal importance. Interestingly, all areas in the Testing Phase were equally tackled across all of the articles. Lastly, varying frequencies were noted in the last two phases. This recognition underscores the integral role of validation in ensuring the quality of software development during the requirements analysis phase. The *database design* methodologies dominated in 16 articles. It is followed by *system architecture* being undertaken in 15 articles and *security design* in 13 articles.

Coding which appears most frequently during implementation. The emphasis on rigorous validation implies recognition of continuous quality checks' vital role in identifying defects before full system rollout. This is followed by the number of journals indicating *integration* methods. Lastly, *documentation* is incorporated in 11 among the journal articles subjected in this review. *Test planning* emerges in the examined articles as the most widely employed assurance methodology during validation processes, highlighting planning's effectiveness for structured procedures tailored to system complexity. Both *functional and usability testing* garner equal attention, recognizing their symbiotic roles in comprehensively assessing capabilities and end-user experience before deployment. The most commonly cited software quality assurance practice in the deployment phase is *installation*. This signifies the critical importance of smooth system deployment and transitions for end-user adoption. Careful *installation procedures*, *upfront preparation*, and *data migration planning* are vital for ensuring new systems integrally replace legacy ones. The emphasis on installation and transition readiness demonstrates that quality considerations cannot end when development does; quality must be maintained all the way through live deployment. Smooth roll-outs position organizations for achieving full value from software investments.

The most prevalent quality assurance focuses during the maintenance phase are user support, adaptive maintenance, and perfective maintenance. This highlights that sustaining system adoption requires ongoing support for addressing user issues, changing needs, and desired enhancements over time. Proactive user assistance keeps systems usable. Adaptive changes maintain alignment with evolving environments. Perfective upgrades prevent stagnation relative to user expectations or competition.

Table 3. Software Quality Assurance in the Software Development Lifecycle.

	Requirements Analysis Methods			Design Methods			Implementation Methods			Testing Methods			Deployment Methods			Maintenance Methods		
Journal ID	**Validation**	**Documentation**	**Gathering**	**Database Design**	**System Architecture**	**Security Design**	**Coding**	**Integration**	**Documentation**	**Test Planning**	**Functional Testing**	**Usability Testing**	**Installation**	**Preparation**	**Migration**	**User Support**	**Adaptive Phase**	**Perfective Maintenance**
[28]	✓		✓		✓	✓	✓	✓			✓	✓	✓				✓	
[43]	✓		✓			✓			✓	✓	✓		✓					
[89]		✓		✓	✓	✓	✓	✓								✓	✓	✓
[93]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	
[96]	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓		✓		✓
[97]	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	
[98]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
[99[	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓

[100]	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
[101]	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
[102]	✓	✓		✓		✓	✓			✓	✓		✓	✓	✓	✓	✓	
[103]	✓	✓		✓				✓		✓	✓	✓	✓	✓	✓	✓		
[104]	✓						✓	✓		✓			✓	✓	✓			
[105]	✓				✓			✓		✓	✓		✓	✓	✓			
[106	✓	✓		✓						✓			✓	✓	✓	✓		
[107	✓						✓			✓			✓	✓	✓			
[108]	✓				✓					✓			✓	✓	✓			✓
[109]	✓											✓	✓	✓				
[110]	✓	✓	✓	✓		✓	✓		✓		✓		✓	✓		✓	✓	✓
[111]		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓	✓
[112]	✓	✓	✓	✓	✓	✓		✓	✓			✓	✓	✓		✓	✓	✓
[113]		✓	✓	✓	✓	✓	✓	✓	✓			✓				✓	✓	✓
[114]	✓	✓		✓	✓							✓	✓	✓		✓		
[115]												✓						
[116]																		✓
[117]											✓	✓	✓	✓		✓		
	20	16	11	16	15	13	15	13	11	15	15	15	21	19	12	16	12	10

The methodological analysis of the targeted journal articles provides valuable insights into the prevalent SQA methods during various phases of the software development life cycle. The results imply a consistent emphasis on fundamental SQA methods across different phases, emphasizing the importance of *Validation, Documentation, and Gathering Requirements* during the *Requirement Analysis Phase, Database Design, System Architecture, and Security Design* during the *Design Phase*, and *Coding, Integration, and Documentation* during the *Implementation Phase*, among others. Understanding the consistent application of these SQA methods throughout the software development life cycle highlights the need for continuous research and refinement in these areas. Future studies could delve into the effectiveness of these methods in real-world healthcare information systems implementations and explore innovative approaches to enhance their application. Additionally, there is an opportunity for researchers to investigate the impact of emerging technologies on SQA practices, ensuring adaptability to evolving healthcare landscapes. This exploration is crucial for fostering a culture of excellence in information systems development and contributing to the continuous improvement of software quality in the healthcare domain.

In comparison to other reviews or studies, the results align with established literature, indicating a shared recognition of the importance of identified SQA methodologies. The consistency in the prevalence of these methods across various studies suggests a methodological robustness and a collective understanding within the academic community regarding their significance and are likely to be foundational and widely accepted within the field. The results show agreement with existing studies, and it is essential to recognize the variations that may exist due to contextual factors, specific research scopes, or variations in the implementation of SQA methodologies. Such differences may stem from the diverse contexts of the studied software development projects, organizational structures, or specific industry requirements. Thus, while the overall alignment with existing literature is observed, researchers should remain attentive to contextual factors influencing the variations in the prevalence of specific SQA practices.

3.3 Synthesis of Research Gaps

In this section, the commonalities in the conclusions, recommendations and limitations as provided by the authors of the journal articles subjected in this research are explored. The authors of the articles investigated in this study mostly concluded that software quality assurance in health-related information systems is a critical concern that varies across software companies. Table 4 shows that software developers tend to rush into implementing a software quality assurance process without a prior establishment of functional software quality assurance practices within individual departments. Additionally, they need to observe and improve their SQA processes from time to time. When an established SQA process or activity is being applied for different projects, the suitability and effectiveness of the process should be monitored for future improvements. However, due to some factors this is not usually implemented and improvements are not made. Furthermore, evading some already established processes and/or not adhering strictly to the specified order. Typically, organizations tend to deviate from strict adherence to quality management processes, leading to a decline in the overall quality of the produced software. Numerous research studies have investigated the implementation of quality in the software development processes of organizations.

The analysis of the journal articles has unveiled recurrent limitations that are integral to understanding software quality assurance practices and challenges. This provides valuable insights into the prevailing SQA practices and enumerated several limitations and areas for further research. Several papers address the limitations and challenges facing developing countries in the areas of software quality assurance, healthcare, education, and environmental sustainability. Among the limitations mentioned is the lack of investment in research, development, and infrastructure necessary to establish a robust quality culture and implement advanced technologies. Another is the limited knowledge and application of management frameworks and standards, such as total quality management and European quality assurance frameworks, which hinder the integration of transformative learning for sustainable development in healthcare information systems. Challenges in the adoption of healthcare information systems, integration of data across diverse enterprises, and optimization of supply chain networks have been observed in various studies. These challenges stem from constraints such as limited resources, institutional quality, and system complexity.

Based on the authors of the papers investigated, recommendations for enhancing software quality assurance practices in developing countries mostly include sensitizing software practitioners to the significance of adhering to quality standards through the establishment of locally tailored standards. The papers primarily recommended that software practitioners in developing countries should be made aware of the importance of adhering to international quality standards and practices, and should be provided with training on the proper implementation of these standards.

Table 4. Common Conclusions, Common Limitations and Common Recommendations of the Studies

Common Conclusions	**Studies**
Even when SQA practices are implemented, issues such as lack of training, inadequate documentation, and insufficient communication can impede their success.	**16**- [89, 93, 96, 98, 99, 100, 101, 102, 103, 106, 110, 111, 112, 113, 114, 116]
Challenges inhibiting the practice of software quality must be identified and addressed to improve the overall state of the industry.	**15**- [28, 89, 93, 96, 97, 98, 99, 100, 101, 104, 107, 110, 111, 113, 114]
Internationally recognized quality standards such as ISO and CMMI are not always followed, even by organizations that have obtained the certificates	**15**- [28, 43, 93, 96, 98, 99, 100, 101, 102, 103, 105, 110, 111, 112, 116]
Software quality assurance practices are crucial for the success of software projects, as they result in higher reliability and easier maintenance of software systems and products.	**19**- [28, 43, 89, 93, 96, 98, 99, 100, 101, 102, 103, 104, 105, 106, 110, 111, 112, 113, 114]
Organizational factors can have a significant impact on software quality and failure-proneness.	**10**- [89, 96, 98, 99, 108, 110, 111, 112, 113, 116]
Common Limitations	**Studies**
Limited research on software quality assurance practices in developing countries	**15**- [28, 43, 93, 96, 97, 98, 99, 100, 101, 102, 101, 105, 110, 111, 117]
Limited knowledge and application of Software Development Life Cycles.	**11**- [28, 43, 93, 96, 97, 98, 110, 111, 112, 113, 116]
Low priority given to non-functional tests (such as usability, performance, and security tests).	**15**- [28, 89, 93, 96, 97, 98, 99, 100, 101, 102, 103, 104, 107, 110, 111]
Limited investment in software testing and software engineering education.	**16**- [28, 43, 93, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108]
Limited research on the test tools used in software testing in developing countries.	**12**- [28, 89, 93, 97, 98, 99, 100, 102, 110, 111, 112, 113]
Common Recommendations	**Studies**
Increase awareness and education on quality standards	**10**- [28, 97, 100, 103, 104, 105, 107, 109, 111, 116]
\Implement quality frameworks and tools	**11**- [43, 93, 96, 97, 98, 100, 101, 110, 111, 112, 113]
Provide formal training in SQA.	**12**- [28, 89, 93, 97, 98, 99, 100, 102, 110, 111, 112, 113]
Increase investment in research and development	**15**- [28, 43, 93, 96, 97, 98, 99, 100, 101, 102, 104, 107, 110, 111, 113]
Prioritize quality assurance practices	**15**- [89, 93, 96, 97, 98, 99, 100, 101, 102, 104, 107, 110, 111, 113, 117]
Improve communication and collaboration	**16**- [28, 43, 93, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108]
Promote adherence to SDLC models	**21**- [28, 43, 93, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 112, 114, 117]

4. CONCLUSION AND RECOMMENDATIONS

Most of the articles investigated in this study that employs SDLC adhere to varying degrees of SQA across all methodologies specified. This paper was able to synthesize the most common concepts, including the themes in the limitations, conclusions and recommendations. Based on the SQA of the SDLCs, the most dominant methodology indicated in the journal papers is *Installation* in the *Deployment Phase*, followed by *Validation* in the *Requirement Phase*. Most of the remaining methodologies are of varying frequencies across the different phases except for the *Testing Phase*. Least mentioned among them is the *Perfective Maintenance*. Interestingly, the number of papers mentioning the methodologies in the *Testing Phase* are equal. Further, it was shown that most studies reveal that SQA practices in healthcare are crucial for the success of software projects, as they result in higher reliability and easier maintenance of software systems and products. Most of the papers also indicated limited investment in software testing and software engineering education. And lastly, almost all of the said papers recommended to promote adherence to the SDLC model.

Future works may work on specific problems and opportunities in healthcare information systems quality assurance to get a better understanding of the field. More investigations may also be done to see if quality assurance practices actually adhere to the rules, ensure data accuracy and satisfy clienteles. Finally, it is recommended to explore other strategies in making reliable software systems, handle scale and growth and adapt to change.

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