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A Safety Maturity Model for Technology-Induced Errors

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Abstract. In this paper we describe a review of the literature and the development of an initial maturity model for the research literature in the area of technology-induced errors and health technology safety. The capability maturity model provides a way forward for organizations to formalize their health technology safety processes and also compare their efforts in this area to other organizations to support organizational learning. The application of maturity models to technology-induced error is described.

Keywords. Safety, health technology safety, technology-induced errors, maturity models, risk management

1. Introduction

Maturity models (MM) help organizations to assess their capabilities or competencies in a domain area. Organizational units or teams use maturity models to determine what capabilities their organizations need to acquire in order to reach the next level of organizational performance in a given business context [1]. Most MMs rate performance using levels (i.e. level 1 through to 5 in maturity) [2]. MMs are used to improve electronic medical record (EMR) adoption, implementation and agility in undertaking these endeavors [2]. These adoption and implementation models are critical to organizations as they help leadership teams to assess their organization's current state, compare the organization's performance to other similar organizations, chart the organization's progression and accomplishments through the model and identify what needs to be implemented for the organization to reach the next level of maturity [2]. MMs have advanced in varying organizational domains such as digital health. In a recent review [3], the focus of these models has been on technology adoption, implementation, interoperability, analytics, and usability in the domain area of health information systems. To date, few of these models have exclusively focused on health technology safety, in particular, no MMs have focused on implementing protections against technology-induced errors. In this paper, the authors describe an initial MM developed with a primary focus on addressing health technology safety.

Health technology safety has been recognized as important public health issue that has led to the study of technology-induced errors. This emerging area of health informatics research aims to address those sources of error that arise from: "a) the design

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and development of technology, b) the implementation and customization of a technology, and c) the interactions between the operation of a technology and the new work processes that arise from a technology's use" [4]. Much of the research in this area has focused on identifying incidents where a technology-induced error had occurred. Here, researchers have focused on methods that can be used throughout the software development lifecycle and after implementation to identify and then prevent future errors. Such research is critical to preventing death, harm and injury and the significant costs to the individual and the healthcare system associated with such events [4,5]. Over the past few years, there have been several attempts to integrate newly developed approaches to preventing such errors throughout the health technology industry in vendor as well as healthcare settings with some success [6,7]. Yet, there remains a patchwork approach to integrating innovative approaches to improving health technology safety.

Maturity models offer an opportunity to aid healthcare organizations in formalizing activities and processes aimed at preventing, mitigating and monitoring for technology-induced errors. Such models are used in the general organizational literature to help organizations develop and formalize internal processes and they are used across organizations to allow for comparison, benchmarking and learning between organizations to enhance systems across an industry. Some researchers and professional organization have developed MMs to support internal organization improvements and industry wide comparisons across organizations [1,2]. One of the most commonly used MMs is the HIMSS electronic medical record adoption model which helps organizations to identify which aspects of the electronic medical record to implement and support their adoption [2,3]. This model supports inter-organizational learning as organizations can look at where they fit in the model in terms of the implementation and adoption process. Such models have also been developed for decision support systems and personal health record implementation. None of the models exclusively focus on technology-induced errors or improving technology safety within and across organizations.

2. Method

The following method was used to develop an initial MM described in this paper. The research was conducted in three phases described below.

2.1 Phase 1

In phase one we reviewed the literature on information system MMs in healthcare to identify MMs specific to strategies for addressing "technology-induced errors" in healthcare organizations. The review began with two researchers identifying keywords and conducting searches of PubMed (see Table 1).

Table 1. Model Search Terms

Keyword Terms
"maturity model" AND "system"
"maturity model" AND "safety"
"maturity model" AND "technology"
"maturity model" AND "error"
"maturity model" AND "error" AND "system"
"maturity model" AND "error" AND "technology
"maturity model" AND "error" AND "safety"

The titles and abstracts of the identified articles were then reviewed by the researchers for their possible inclusion in: (1) a MM focused on technology-induced errors or health technology safety, and (2) help with identifying gaps in the literature relevant to development of MMs focused on technology-induced errors.

2.2 Phase 2

In Phase 2 the results of the literature search were reviewed by the research team and gaps were identified. Preliminary levels for an initial MM were developed. Then the research team met to discuss the levels and disagreements were resolved through review of the articles and discussions.

2.3 Phase 3

An initial MM was created based on the results of phase 1 and 2. This model was developed specifically in the context of technology-induced errors.

3. Results

The review of the literature conducted in Phase 1 revealed that 69 articles were returned (see Table 2). Following a title, abstract and full text review, the researchers found that the MMs focused on either system implementation maturity (e.g. electronic health record features and function implementation) or on specific process implementation such as health information system adoption. As Table 2 shows there were very few articles returned for MMs in relation to technology-induced errors. We then focused our review on the 15 articles at the intersection of "maturity model" and "safety" to develop a new initial MM that incorporated some of the levels described from these articles in the new context of technology-induced errors. The layers in the newly proposed MM for technology-induced error were defined and refined through further discussion by the research team.

Table 2. Maturity Model Search Results

Keyword Terms	Resulting Number of Papers Returned
"maturity model" AND "system"	29
"maturity model" AND "safety"	15
"maturity model" AND "technology"	24
"maturity model" AND "error"	1
"maturity model" AND "error" AND "system"	0
"maturity model" AND "error" AND "technology	0
"maturity model" AND "error" AND "safety"	0
Total Number of Papers Returned	69

In our first discussions, we identified that MMs from the health informatics and health information technology literature. We found that they typically consist of five or more different levels. The levels draw on an organization's ability to address a particular problem, event or issue. In Level 1 organizations employ ad hoc responses. In Level 2 organizations employ repeatable activities in response to problems, events or issues. In Level 3 organizations fully define and respond to problems or issues. In Level 4

organizations create formal structures to manage these processes and in Level 5 organizations have formal managed processes to respond to problems, issues and events, continually monitor and focus on optimization and improved safety (see Figure 1).

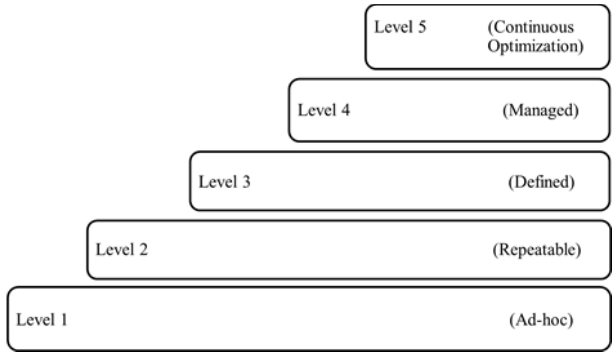

Figure 1. Generic Maturity Model Levels.

In Figure 2, we map the findings from our literature review and discussions on to generic layers of a capability MM (described in Figure 1), specifically in the context of technology-induced errors to arrive at a new model in the context of technology-induced error (TIE).

Level	Description	Practice Area	Key Safety Practices	Desired Outcomes
1	Ad-hoc	• Planning for Requirements Gathering	• Interviews • Focus Groups	
2	Repeatable	• Requirements Gathering • Project Planning • Project Tracking an Oversight • Contract (and Subcontract) Management • Quality Assurance • Configuration Management	• Interviews • Focus Groups • Team meetings and Review	• Requirements are free of TIE.
3	Defined	• Organizational Process Definition • Organizational Process Description • Peer Reviews • Software Management • Intergroup Coordination • Training	• Systems Modelling • White Box Testing • Black Box Testing • Usability Testing • Workflow Testing • Clinical Simulation Testing	• Models that are free of TIE. • Programming code that is free of TIE. • User interface features and functions that are free of TIEs. • Workflows that are free of TIEs. • Technology savvy and resilient users.
4	Managed	• Process Management • Quality Management	• Control Charts • Run Charts	• Software that is free of TIE. • Services that are free of TIE.
5	Optimization	• Learning from Technology-induced Errors • Technology Change Management • Process Change Management	• Qualitative Coding of Individual Incident Reports for Technology-induced Errors • Root Cause Analyses • Usability Testing • Simulation Testing • Data Analytics of Technology-induced Errors	• Ensuring ongoing continuous improvement (CI) to address the root causes of defects that are inherent in processes, tools, and designs and that have a significant impact.

Figure 2. Maturity Model for Technology-induced Error

In the context of the research literature we focused on methodologies as applied to technology-induced errors. Level 1 represents organizations where the practices and activities surrounding a technology are ad-hoc or reactive to events in an organization. In Level 2 we identified that organizations identified activities associated with managing and repeated activities for events related to technology-induced error. In Level 3 safety activities focused on technology-induced errors were defined and enacted when errors occurred. In Level 4 activities were not only defined and enacted specific to technology-induced errors, but they are part of organizational processes and technology-induced errors were actively managed. Lastly, Level 5 represents organizations where there is a formalized program of activities aimed at identifying, diagnosing, addressing, mitigating and monitoring for technology-induced errors with a focus on improving safety through optimization (see Figure 1). Figure 2 also shows how the five generic MM levels can be mapped to: (1) practice areas, (2) key safety practices and (3) desired outcomes.

4. Conclusion

Maturity models help organizations to assess their capabilities or competencies in a given area. They are used extensively in the general organizational literature. In the health informatics research literature, there have emerged several MMs that have helped healthcare organizations and systems with specific health information technology activities such as the adoption of electronic health records, personal health records and decision support systems. None of this research has focused specifically on technology-induced errors. In the absence of a MM that allows for and supports the development of within and between organizational processes and activities, we have developed an initial MM that focuses on processes, methods and monitoring approaches for technology-induced errors. The MM helps to diagnose, mitigate and monitor for these safety issues with the goal to improve the safety of technology systems and overall patient care. Our ongoing work is focusing on the validation of the initial model.

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