J Med Syst (2014) 38:99
DOI 10.1007/s10916-014-0099-9

SYSTEMS-LEVEL QUALITY IMPROVEMENT

# Understanding Critical Barriers to Implementing a Clinical Information System in a Nursing Home Through the Lens of a Socio-Technical Perspective

**Calvin Or · Michael Dohan · Joseph Tan**

Received: 8 January 2014 / Accepted: 1 July 2014 / Published online: 22 July 2014
© Springer Science+Business Media New York 2014

**Abstract** This paper addresses key barriers to implementing a clinical information system (CIS) in a Hong Kong nursing home setting, from a healthcare specific socio-technical perspective. Data was collected through field observations ($n$=12) and semi-structured individual interviews ($n$=18) of CIS stakeholders in a Hong Kong nursing home, and analyzed using the immersion/crystallization approach. Complex interactions relevant to our case were contextualized and interpreted within the perspective of the Sittig-Singh Healthcare Socio-Technical Framework (HSTF). Three broad clusters of implementation barriers from the eight HSTF dimensions were identified: (a) Infrastructure-based barriers, which relate to conflict between government regulations and system functional needs of users; lack of financial support; inconsistency between workflow, work policy, and procedures; and inadequacy of hardware-software infrastructural and technical support; (b) Process-based barriers, which relate to mismatch between the technology, existing work practice and workflow, and communication; low system speed, accessibility, and stability; deficient computer literacy; more experience in health care profession; clinical content inadequacy and unavailability; as well as poor system usefulness and user interface design; and (c) Outcome-based barriers, which relate to the lack of measurement and monitoring of system effectiveness. Two additional dimensions underlining the importance of the ability of a CIS to change are proposed to extend the Sittig-Singh HSTF. First, advocacy would promote the articulation and influence of changes in the system and subsequent outcomes by CIS stakeholders, and second, adaptability would ensure the ability of the system to adjust to emerging needs. The broad set of discovered implementation shortcomings expands prior research on why CIS can fail in nursing home settings. Moreover, our investigation offers a knowledge base and recommendations that can serve as a guide for future implementation strategies and policies in CIS initiatives.

**Keywords** Clinical information system · Implementation barriers · Nursing home · Socio-technical perspective

"This article is part of the Topical Collection on *Systems-Level Quality Improvement*".

C. Or (✉)
Department of Industrial & Manufacturing Systems Engineering, The University of Hong Kong, Room 8-7, 8/f., Haking Wong Building, Pokfulam, Hong Kong
e-mail: klor@hku.hk

M. Dohan · J. Tan
DeGroote School of Business, McMaster University, Hamilton, ON, Canada

M. Dohan
Faculty of Business Administration, Lakehead University, Thunder Bay, ON, Canada

## Introduction

Implementing clinical information systems (CISs) in large organizations presents opportunity to increase the quality and safety of care, while reducing cost and time in workflow. Despite these benefits, the likelihood of failure increases as systems grow in complexity, size and number of users. Failure often manifests as non-adoption of the technology by its intended users, which reflects a poor integration of the technology with the work system [1, 2], leading to disruption in the workflow. When this occurs in healthcare, users are forced to bypass the technology, or adopt informal, potentially unsafe practices that deviate from the formal protocol, resulting in implications for care quality and safety [3].

Viewing the implementation of CIS through the lens of socio-technical (ST) theory allows researchers and practitioners to understand the complex interrelations between

various elements of systems in large organizations. The key assumption of this approach is that interaction between social and technical aspects of an organization contributes to its success; therefore, a good fit needs to be found between the two. This case study contributes to the development of ST theory in healthcare by reporting on key implementation barriers of a nursing home-based CIS, in a Hong Kong nursing home setting. Guided by a healthcare specific ST framework [4], this study aims to provide insights into critical factors leading to the failure of CIS implementation through a qualitative approach. From these results, enhancements to healthcare specific ST theory will be proposed, contributing to this growing body of knowledge.

This research will result in a valid contribution to ST theory in healthcare for several reasons. First, the few studies that do exist are mainly concerned with implementation strategies for improving satisfaction about specific and targeted types of CIS [5, 6], without considering the system as a whole. Second, as the literature suggests that CIS implementation and adoption are influenced by both the social and technical parts of the work system [1], the current knowledge that is associated with only a few aspects of the social or technical parts of a work system is likely to be insufficient in explaining why CIS implementation fails. Finally, there is a need to further apply and extend current healthcare specific theoretical perspective so as to provide insights and creativity in translating accumulated knowledge into best practices.

## Background

### Clinical information systems

CISs can potentially enhance nursing home care through improved access to information and decision support resources [7–11]; thus, patient safety practitioners advocate the incorporation of the technology into nursing homes for its ongoing care quality management [12, 10]. However, despite the potential benefits, adoption of these systems lags behind other areas of investment [13–15]. In most cases, systems in nursing homes are limited to non-clinical work, such as billing, admission, transfer and discharge of residents [13]. Furthermore, many advanced features of the systems that are available are not fully utilized [16].

### Socio-technical theory

As stated earlier, ST theory concerns the interaction between human and technology [17–19]. ST theory has yielded many models over the years, each containing various components. A basic model of complexity in system design - the SHEL model [17] - emphasizes the importance of interactions among Software, Hardware, Environment ("Context"), and Liveware ("People"). The Systems Engineering Initiative for Patient Safety (SEIPS) model [18] that offers a work system thinking approach emphasizes the interaction between people, technology, environment, tasks, and organization. Another foundational study on ST theory in health informatics suggests that understanding health information technology requires a focus on the interrelation between technology and its social environment [19].

### Healthcare Socio-Technical Framework (HSTF) for technology implementation

Sittig and Singh [4] conceptualize a ST framework specific to healthcare that can be applied to study and improve the development and implementation of CISs. It has been used to classify types of errors and corresponding mitigating procedures that occur in healthcare information system implementation [20]. It has also been used to guide principles for CIS research centers [21]. As well, it has been applied to assess barriers and facilitators to clinical decision support software implementation in a small clinic setting [22]. Sittig and Singh's HSTF contains eight interdependent dimensions:

1. Hardware-Software Computing Infrastructure refers to the physical devices that comprise the system, including interface devices, the software and operating systems used to operate them, server and storage devices, communication infrastructure, and security and maintenance equipment [4].
2. Clinical Content pertains to the data describing clinical aspects of a practice, for the purpose of facilitating clinical knowledge management [4, 23], describing patients, their conditions, specialized vocabularies, and data informing clinical decisions [4]. This also includes metadata to facilitate searching and reporting [24].
3. Human-Computer Interface allows users to interact with the system in a way that facilitates workflow [4]. Considerations include how data is presented, physical design of devices, and other ergonomic issues.
4. The People dimension pertains to the humans involved with the system, including users, administrators, and designers. Concerns in this dimension include user resistance to adoption [25] and skills required for users [4].
5. The Workflow and Communication dimension refers to the steps required in coordinating users as they execute a clinical process [4]. There must be concordance between workflow and the CIS.
6. Internal Organizational Policies, Procedures and Culture refer to forces internal to an organization that affect procurement, implementation, usage and evaluation of the system [4]. External forces (see below) often influence this HSTF dimension.

7. External Rules, Regulations and Pressures include relevant forces external to the organization such as incentive programs, regulations, and availability of qualified staff in the workforce [26, 4].
8. Finally, System Measurement and Monitoring refers to the measurement of availability, system use, outcomes, and unintended consequences associated with the system [4].

## Methods

### Setting and participants

Approval of the institutional review board of the University of Hong Kong was received, and informed consent was obtained from participants. The study was conducted in a 102-bed, nonprofit nursing home in 2012, after it was found that the CIS was not used by the care staff. The system, called the Care Network for Aging (CNA), had five key modules: activity scheduling, medical and care, nursing home administration, health assessment, and health data analysis. It was designed based on the functions that the nursing home needed at the time when it was developed. Volunteer participants included registered nurses, physiotherapists, occupational therapists, health workers, IT support staff, administrative staff, and an operations manager, who all used the CNA. The CEO of the CNA vendor also participated. Nurses, physiotherapists and occupational therapists were also observed, due to their reliance on the CNA.

### Data collection

This study used the triangulation technique [27], in which two research assistants (RAs) facilitated data collection. The RAs first made a set of direct observations in which they shadowed the care provider participants during their shifts in order to examine workflow. They recorded detailed information regarding the course of the caring process, settings, and CNA system use. Following the observations, the RAs conducted semi-structured individual interviews with all participants in order to identify possible factors related to system implementation barriers. Example interview questions used included: "Why did you stop using the CNA in the caring process?", "Why do you still use the CNA in the caring process?", "What factors do you perceive as barriers to the adoption of the CNA?", "What factors influence your decision and reinforce your intention to use the CNA?", "What are the most important pieces of information that you need for the use of the CNA?", and "What other organizational variables affect the use of the CNA in the caring process?" All interviews were recorded for subsequent transcription and analysis.

### Data analysis

Both field notes and text derived from interview recordings were content-analyzed using the immersion/crystallization approach [28]. The immersion/crystallization is described as follows: "the analyst immerses him- or herself into and experiences the text, emerging after concerned reflection with intuitive crystallizations, until reportable interpretations are reached" (p. 179) [28]. This analytical approach involves a systematic iterative process of data extraction, examination, pattern and theme identification, and refinement of findings. In this study, the first author and one of the RAs first independently immersed themselves in the content of the interview data, identified salient patterns or key themes, and then classified them into the eight Sittig-Singh HSTF dimensions. They also extracted representative quotes to illustrate the findings. Subsequently, they met to compare results. Discrepancies were reconciled through review and discussion. This process was repeated until their interpretations of the data had been corroborated and verified.

## Results

Ten nurses, one physiotherapist, and one occupational therapist were shadowed and observed for a total of 153 hours. Interviews were conducted with these care providers, in addition with two administrative officers, one health worker, the operations manager, one IT technician, and the CEO of the system vendor. Each interview lasted about 20 to 30 min. The findings are presented below.

### Dimension 1: Hardware-software computing infrastructure

Findings indicated that the nurses, physiotherapist, and occupational therapist were dissatisfied with the long response time and instability of the system and the computing networks. Often staff had to address immediate cases in a timely fashion. However, the long response time prevented them from using the system. As one nurse said,

> "The system start up time is too long and the network connection is sometimes unavailable. We won't be able to use the CNA if the network connection is not working. If I rely too much on the system, my work will be delayed and I won't be able to finish the work on time."

Health consultations and assessments were carried out at the bedside of residents; however, only one inconveniently accessible computer was available on each floor.

Most staff members were observed recording the assessment results using their own, self-created paper forms, and re-transcribing the data into the CNA system later that day. The physiotherapist noted,

> "I really hope there will be a portable device I can use to enter data immediately at the point of care. Currently, during therapy, I write down all the data on a paper chart and enter them into the CNA later. Sometimes, I cannot recall some of the details when I am entering the data into the CNA."

Deficiency in equipment and support was a problem in many other nursing homes in Hong Kong. According to the CEO of the CNA development company, most nursing homes lack updated technology and technical support. As the CEO claimed,

> "The IT hardware is insufficient in over 50 % of nursing homes (in Hong Kong). The nursing homes have very old computers, if any at all, and many lack Internet connection. The IT technical support in nursing homes is also very insufficient."

Dimension 2: Clinical content

The observation and interview data showed that clinical content in the CNA was not up-to-date or missing, and other essential tools (e.g., charts and forms) were inadequate. Alluded by the physiotherapist,

> "I used to check the residents' health records in the CNA, but now I ask the nurses for the paper records instead because the information in the system is usually not updated."

Furthermore, instead of using the few charts and forms included in the CNA, the staff created their own paper charts and forms and mainly used them to record and store data. The physiotherapist added,

> "The CNA provides some charts for me to document the results of the therapy assessments, but the contents and format of the charts are not useful, so I don't use them. I create my own set of paper forms for the documentation."

A nurse also said,

> "The CNA does not provide all the charts and forms we need to record the health check data. It includes only one or two sets. There are many other forms we need that are not included in the system."

Dimension 3: Human-computer interface

A number of human-computer interaction design problems with the system were found. The system was not designed to alert users about the operation errors they committed, or to avoid putting them in those error-prone situations in the first place. For instance, we observed that staff occasionally closed the data files without saving them. The system failed to include necessary safeguards, thereby violating a fundamental design principle of notifying users when data may be destroyed [29, 30]. A nurse said,

> "You see the 'yes' and 'close' buttons, but you have to remember to click 'yes' after updating the record, before you click 'close'. Some new users just click the 'close' button after the update and the page closes right away. All the information entered is not saved and is gone, and they don't even realize it because there is no warning message."

When error messages did appear, they did not provide informative feedback or potential courses of action. Often, care providers did not understand the reason or meaning of the message. Argued by the occupational therapist,

> "The error message comes up on the screen, but I don't know what it means and what to do. Let me click 'yes' now and see what happens."

Some caregivers found several aspects of the system to be useful, but still chose not to use the system because the interface and design did not allow them to print copies of the charts and forms. As a result, the caregivers created personalized spreadsheets and manually copied information from the CNA records into the spreadsheet.

Dimension 4: People

Users who were familiar with the CNA interface, were at ease with computers, had good computer skills, and had positive attitudes toward automated documentation accepted and incorporated the CNA into their daily work much more proficiently. A computer-literate nurse who found the system easy to use said while using the system,

> "I think it is easy to get the work done with the CNA … Look, it's done! Finished! Just like that, very straight forward!"

However, another nurse complained,

> "I prefer handwriting. Using the computer is difficult for me. I don't think the CNA is easy to use. It takes so

much time to type. I want to finish my work quickly, so I choose to write by hand."

In addition, acceptance and adoption were likely to maintain when the users believed that the technology was useful and met their needs. Said one nurse,

"The system has a number of features that we don't need; they are nice but not useful for our daily work."

Experienced caregivers expressed that their work habits and practice were not easily changed by the CNA, as they chose to rely on their knowledge and handwritten notes rather than the technology. A senior nurse observed,

"Nurses who are new to this nursing home may rely heavily on the CNA. But for someone like me, who has been in the profession for more than twenty years, the CNA is a young and new system. I only use the system to assist me in finishing part of my job. But almost all of the time I rely on myself, the knowledge in my head, and my handwritten notes."

Dimension 5: Workflow and communication

The CNA was poorly integrated into the nursing home care workflow. The introduction of the CNA altered routines, resulting in additional unnecessary steps in work procedures. Further, the system was not designed to have certain mandatory fields accepted as input, forcing staff to maintain supplementary paper records, leading to increased workload. One nurse said,

"I find the CNA adds to my workload as I record all the information on paper, and after that I also need to update the same pieces of information in the CNA system."

Another nurse said,

"Sometimes we need to make two or even three copies of the same records. This helps us to communicate the residents' cases and exchange information more quickly, but we have to do more work."

The nursing home expected the staff to exchange information using the CNA system. However, phone calls, inter-shift meetings, and face-to-face encounters were the primary means of information transfer. The CNA was a less frequently used communication tool in the nursing home. As the administrative officer said,

"I rarely use the CNA to get information. If I want information, I just call them [the caregivers]."

The information stored in the system was incomplete, due to inadequate usage of the system by the care staff. The physiotherapist and occupational therapist refused to use the CNA, and as a result, their information that was supposed to be entered in the system was left blank. The physiotherapist said,

"As I don't use the CNA to record the assessment results, others cannot see them. It's blank."

The occupational therapist also added,

"If my colleagues want assessment results, I just give them a copy of my paper forms. I don't need the system."

Dimension 6: Internal organizational policies, procedures and culture

Key areas of concern included the following:

a) Adoption of the CNA was not mandatory, resulting in incomplete records in the CNA system. Despite this, the staff acknowledged that incomplete information could limit the care delivery of other providers;
b) The workflow of the system was not consistent with the work policy, for example, caregivers needed to add new drug names to the medication list of the CNA for the residents during the update of the CNA care records; however, only the operations manager could add new names onto the system list; and,
c) The operations manager stated that signing care records was one of the policies and procedures in the care process. Frequently, nurses spent a long time simply signing off piles of records during the shift. Unfortunately, the CNA did not provide the feature of electronic signature. The manager said,

"The task efficiency could have been facilitated if the e-signature feature was added to the system."

Dimension 7: External rules, regulations and pressures

Interviewing the operations manager revealed that there was no financial support from the government for CIS adoption in Hong Kong. The manager stated,

"The government did not provide us with any financial support or other kinds of incentives for the CNA implementation. The program is entirely self-funded."

Furthermore, although including e-signature in the CNA could reduce workload and improve task efficiency, government regulations forbade e-signature in the health care domain in Hong Kong. As the manager said,

> "Even though the CNA is able to achieve the e-signature function, the regulations in Hong Kong limit the use of e-signatures in health care domain. So we still have to sign lots of documents by hand."

Dimension 8: System measurement and monitoring

Notwithstanding, the CNA developer failed to monitor or assess the system performance regularly. The manager said,

> "The CNA developer does not send technical staff for periodic system checks. They send people here only when we have problems and call them."

Moreover, failure to follow up led to a communication gap between the users and CNA developers. Even though the CNA developers updated their system several times, the care staff felt that the version updates failed to address their needs. The manager stated,

> "Three versions have been released since we implemented the CNA, but… not very different from each other. The different versions included changes in the administration and finance modules but that is not so useful to us."

A nurse added,

> "We are told that there will be a new version, but I feel it is always the same."

## Discussion

Incorporating concepts from other system design models, this study applied the Sittig-Singh HSTF to explore and organize factors related to why the nursing home CIS was abandoned. Findings suggest three broad clusters of barriers encompassing the eight HSTF dimensions to implementing CISs in a nursing home setting as summarized in Table 1.

First, infrastructure-based factors encompass the external environmental forces, the internal organization contexts as well as corporate vision and investments in CIS infrastructure. Prior studies indicate that government policies and incentive programs are associated with the implementation and uptake of technology-based information exchange and CIS by health care practitioners [31–33]. Similarly, in our study, the responses of the operations manager regarding perceived barriers to the adoption of the CIS also partly support the idea that financial incentives and supportive government policies related to design and development of CIS can either stimulate or break the technology adoption efforts. Although the nursing home studied was able to self-finance the CIS and follow the policy of not using e-signature in signing documents, it was observed that the lack of government financing or supportive policies were prime factors in the non-adoption of CIS for Hong Kong nursing homes. Groundwork needs to be laid regarding the cost of computerization and how the CIS would be designed for safe and productive practices. CIS vendors clearly have a commercial incentive to bring their product to market quickly, if not safely. Nonetheless, executive support and involving clinicians and CIS users in the development of policy may have beneficial effects on effective, efficient, safe, secure and satisfying CIS development and diffusion, and therefore commercial success of well-designed systems. Alignment of corporate with CIS goals and strategies is a sure means of building a reliable CIS infrastructure and networks [3, 4].

Second, process-based factors represent the key drivers for determining successful organization change with, or its resistance to change without, CIS adoption. These factors include the "People" dimension, the human-computer interface, clinical content, and workflow and communications. First, users will resist the technology when it is perceived as incompatible with their expectations and needs. System developers should have a thorough knowledge of the clinical workflow and a deep understanding of user requirements so that systems can be designed to function in concordance with user needs and wants. Attaining this goal will require strong managerial support, peer support and the active involvement of end-users in many change processes, for example, systems design, development and implementation [34–36]. Moreover, cognitive analyses [37–40] and careful attention to human factors design principles for fitting automation to physical operations [41] and cognitive tasks [42, 43] are key steps for designers to understand and address user needs and limitations for new technology. In our study case, the system interface was inadequate, which was one of the critical barriers to the uptake of the system. CIS users expect a system that is useful and effective, as well as easy to use [44, 45]. Users' perceptions have been found to shape their attitudes toward the technology, eventually determining their adoption or non-adoption [e.g., 2, 46, 47]. Conducting usability tests and applying usability design heuristics are critical methodologies to improve usability and utility of the technology [48–51]. Mismatch between the technology and existing work practice can significantly promote an implementation failure. Our analysis revealed that if the technology was not built for the existing workflow and user needs, the CIS introduced might decrease efficiencies, block workflows, increase cognitive

**Table 1** The three clusters of barriers to implementing CISs and their associated implementation challenges identified

| | |
|---|---|
| Infrastructure-Based Factors | |
| External rules, regulations and pressures | |
| •Lack of government financial support & incentives for CIS implementation | •Conflict between government regulations and system features expected in the technology |
| Internal organizational policies, procedures and culture | |
| •Lack of policy for the use of the technology | |
| •Culture of voluntary use of the technology | •Inconsistency between actual workflow and work policy and recommended procedures |
| Hardware & software computing infrastructure | |
| •Slow computers & information access | •Obsolete equipment |
| •Slow transfer of information to the system | •Lack of technical support |
| •Instable computing system & network | •Inconvenient access to the computer terminal |
| Process-Based Factors | |
| People | |
| •Lack of computer skill sets and knowledge | |
| •Poor attitudes toward automated documentation | |
| •Unfamiliarity with the system | |
| •Lack of perceived usefulness of the system | •Inability of system to address user needs and limitations |
| •More experience in the care profession | |
| Human-computer interface | |
| •Lack of safeguards to prevent users from committing errors | |
| •Lack of error messages | |
| •Meaningless and uninformative error messages | |
| •Lack of error recovery mechanism | •Lack of constructive solutions for the errors committed |
| •Deficient in essential features (e.g., printing) in the interface | |
| Clinical content | |
| •Not up-to-date or incomplete clinical data and information in the records | •Inadequate tools (e.g., electronic forms and charts) for recording and storing data |
| •Workflow and communication | |
| •Unexpected change to the original workflow by the technology | •Limited communication due to incomplete data and information in the system |
| •Additional workload and unnecessary work steps due to the use of the technology | |
| Outcome-Based Factors | |
| System measurement and monitoring | |
| •Lack of technical staff to monitor and assess the technology performance | •Failure to follow up on user requirements and to incorporate them into the system |
| •Passive monitoring and maintenance of the system | |

efforts, and create additional unnecessary steps in the work procedures and communications. Although the literature has emphasized that meaningful use of CIS is based largely on the extent to which the design of system is compatible with the workflow and work system [52, 53], the 'fit' issue is often overlooked. To avoid all these unintended consequences, it is important to understand, prior to the system implementation, how the care team members carry out the tasks and communicate with each other, and to identify bottlenecks in the workflow, such that the practitioners can more effectively determine the areas and gaps that require IT applications. As demonstrated by previous studies, workflow analysis can aid in redesigning key processes [54–56].

Third, outcome-based factors are the last set of factors in which performance with the use of the technology should be monitored post-implementation to determine the extent in which CIS adoption was (or was not) beneficial. While there is a tendency for organization managers to rely on vendors to improve the systems being installed with updates and newer versions, as in our study case, it should be emphasized that it is the organization managers who must be responsible ultimately to assess the user satisfaction with the implemented system. After all, the goals of the vendors are not going to be the same as that of the organization.

In light of this, the Sittig-Singh HSTF could be extended to incorporate two dimensions that reflect the ability of a system

to manage change. These proposed dimensions would incorporate the ability to respond to demands on the CIS by adapting to emerging needs, whilst maintaining its cohesion and meeting the needs of the system actors [57]. First, a new dimension, titled Advocacy, as part of the process-based cluster, would encompass all the processes related to articulating, communicating and influencing both the need for change and desired outcomes. It is clear from the results that many users were experiencing difficulties using the system, because it was not congruent with workflow, violated common usability principles, and other user assumptions. Even so, contact with the developers of the system was limited. Although updates were performed, the knowledge that would be valuable to the developers in improving the system (manifesting here in the form of various "fixes" the users created in lieu of adopting the system outright) did not reach the developers, and therefore were not included. Advocacy processes here may take the form of staff or management initiating contact with the developer, regarding negative experiences with using the system, and desired changes. Outcomes of this process would take the form of changes to configurations, systems, or vendors, in a way that incorporates user feedback. Second, as part of the infrastructure-based cluster, and closely linked with the Advocacy dimension, Adaptability can address how a CIS responds to various changes in the environment, emerging system requirements, insufficient system components and technological advancement [57]. The link between the ability to reconfigure firm resources and performance is well-developed under the dynamic capabilities research [58, 59], as well as under the various quality improvement paradigms such as Lean Healthcare [60] and Six Sigma [61]. It seems that there is a function for updating the system, but this function is ineffectual in actually responding to the context in which it is used or the concerns of the users. As noted, extending the Sittig-Singh HSTF with these added dimensions could further provide novel thinking in translating accumulated knowledge on change management into CIS implementation best practices.

## Conclusions

This study aimed at identifying reasons for failure of a CIS implemented at a nursing home, through the lens of a healthcare specific ST framework [4]. This case is one in which the care providers and the other CIS stakeholders reported why the system was not appropriate and was eventually rejected. Although the reasons identified were apparently critical to the implementation, the organization failed to carefully consider them prior to the development of the technology. Some of the implementation challenges could not be overcome easily (e.g., external forces); however, the likelihood of implementation success would have been greater if more attention was paid to capturing and acting upon the other barriers and facilitators during the early stage of the implementation.

The results provide a number of useful insights into the challenges of CIS implementation faced by many health informatics practitioners. First, more depth is brought to the Sittig-Singh HSTF. Second, the importance of the ability of a system to change is accentuated. Given the spirit of ST frameworks to view systems in their entirety, and also the desire to produce an integrative model of healthcare system implementation, the ability to change should be investigated as a part of such a framework in future research.

**Acknowledgments** This work was supported by the Department of Industrial and Manufacturing Systems Engineering at the University of Hong Kong. We thank the Chief Executive and the manager of the nursing home for their support of this study. We are grateful to all the interviewees for their time. We also thank Jing Xu and Henry Wong for their effort in data collection and initially preparing this paper.

**Conflict of interest** The authors declare that they have no conflict of interest.

## References

1. Karsh, B., Holden, R. J., and Or, C. K. L., Human factors and ergonomics of health information technology implementation. In: Carayon, P. (Ed.), *Handbook of Human Factors and Ergonomics in Health Care and Patient Safety*, 2nd edition. CRC Press, Boca Raton, pp. 249–264, 2011.
2. Or, C. K. L., Wong, K., Tong, E., and Sek, A., Private primary care physicians' perspectives on factors affecting the adoption of electronic medical records: a qualitative pre-implementation study. *WORK: A Journal of Prevention, Assessment and Rehabilitation*, 2014. doi:10.3233/WOR-131808.
3. Vogelsmeier, A. A., Halbesleben, J. R. B., and Scott-Cawiezell, J. R., Technology implementation and workarounds in the nursing home. *Journal of the American Medical Informatics Association* 15(1):114–119, 2008. doi:10.1197/jamia.M2378.
4. Sittig, D. F., and Singh, H., A new sociotechnical model for studying health information technology in complex adaptive healthcare systems. *Quality and Safety in Health Care* 19(suppl 3):i68–i74, 2010.
5. Alexander, G. L., Rantz, M., Flesner, M., Diekemper, M., and Siem, C., Clinical information systems in nursing homes: an evaluation of initial implementation strategies. *Computers Informatics Nursing* 25(4):189–197, 2007. doi:10.1097/01.ncn.0000280589.28067.18.
6. Armer, J. M., Harris, K., and Dusold, J. M., Application of the concerns-based adoption model to the installation of telemedicine in a rural Missouri nursing home. *Journal for Nurses in Staff Development* 20(1):42–49, 2004.
7. Liu, D., Castle, N. G., and Diesel, J., Does use of advanced information technology in commercial minimum data set systems improve quality of nursing home care? *American Journal of Medical Quality* 25(2):116–127, 2010. doi:10.1177/1062860609354637.
8. Alexander, G. L., and Wakefield, D. S., Information technology sophistication in nursing homes. *Journal of the American Medical Directors Association* 10(6):398–407, 2009. doi:10.1016/j.jamda.2009.02.001.
9. Handler, S. M., Sharkey, S. S., Hudak, S., and Ouslander, J. G., Incorporating INTERACT II clinical decision support tools into

nursing home health information technology. *Annals of Long-Term Care* 19(11):23–26, 2011.
10. Institute of Medicine, Building organizational capacity. In: Wunderlich, G. O., and Kohler, P. O. (Eds.), *Improving the Quality of Long-Term Care*. National Academy Press, Washington, pp. 220–234, 2001.
11. Baril, C., Gascon, V., and Brouillette, C., Impact of technological innovation on a nursing home performance and on the medication-use process safety. *J Med Syst* 38(3):1–12, 2014. doi:10.1007/s10916-014-0022-4.
12. Institute of Medicine, Key capabilities of an electronic health record system: Letter report. In: Aspden, P., Corrigan, J. M., Wolcott, J., and Erickson, S. M. (Eds.), *Patient Safety: Achieving a New Standard for Care*. National Academies Press, Washington, pp. 430–470, 2004.
13. Resnick, H. E., Manard, B. B., Stone, R. I., and Alwan, M., Use of electronic information systems in nursing homes: United States, 2004. *Journal of the American Medical Informatics Association* 16(2):179–186, 2009. doi:10.1197/jamia.M2955.
14. Poon, E. G., Jha, A. K., Christino, M., Honour, M. M., Fernandopulle, R., Middleton, B., Newhouse, J., Leape, L., Bates, D. W., Blumenthal, D., and Kaushal, R., Assessing the level of healthcare information technology adoption in the United States: a snapshot. *BMC Medical Informatics and Decision Making* 6(1):1–9, 2006. doi:10.1186/1472-6947-6-1.
15. Poon, C. C. Y., Wong, Y. M., and Zhang, Y. T., M-Health: The development of cuff-less and wearable blood pressure meters for use in body sensor networks. IEEE/NLM Life Science Systems and Applications Workshop, Bethesda, 2006.
16. Liu, D., and Castle, N. G., Health information technology in nursing homes. *Journal of Applied Gerontology* 28(1):38–58, 2008. doi:10.1177/0733464808321887.
17. Edwards E (1972) Man and machine: Systems for safety. In Proceedings of British Airline Pilots Associations Technical Symposium British Airline Pilots Associations, London P 21–36
18. Carayon, P., Hundt, A. S., Karsh, B. T., Gurses, A. P., Alvarado, C. J., Smith, M., and Brennan, P. F., Work system design for patient safety: the SEIPS model. *Quality and Safety in Health Care* 25(Suppl I):i50–i58, 2006.
19. Berg, M., Aarts, J., and van der Lei, J., ICT in health care: Sociotechnical approaches. *Methods Inf Med* 42(4):297–301, 2003.
20. Sittig, D. F., and Singh, H., Defining health information technology-related errors: new developments since to err is human. *Archives of Internal Medicine* 171(14):1281–1284, 2011. doi:10.1001/archinternmed.2011.327.
21. Sittig, D. F., and Joe, J. C., Toward a statewide health information technology center (abbreviated version). *Southern Medical Journal* 103(11):1111–1114, 2010. doi:10.1097/SMJ.0b013e3181f680f4.
22. Ash, J. S., Sittig, D. F., Wright, A., McMullen, C., Shapiro, M., Bunce, A., and Middleton, B., Clinical decision support in small community practice settings: a case study. *Journal of the American Medical Informatics Association* 18(6):879–882, 2011. doi:10.1136/amiajnl-2010-000013.
23. Sittig, D. F., Wright, A., Simonaitis, L., Carpenter, J. D., Allen, G. O., Doebbeling, B. N., Sirajuddin, A. M., Ash, J. S., and Middleton, B., The state of the art in clinical knowledge management: An inventory of tools and techniques. *International Journal of medical Informatics* 79(1):44–57, 2010. doi:10.1016/j.ijmedinf.2009.09.003.
24. Sittig DF, Wright A, Meltzer S, Simonaitis L, Evans RS, Nichol WP, Ash JS, Middleton B (2011) Comparison of clinical knowledge management capabilities of commercially-available and leading internally-developed electronic health records. BMC Medical Informatics and Decision Making 11. doi:10.1186/1472-6947-11-13
25. Bhattacherjee A, Hikmet N (2007) Physicians' resistance toward healthcare information technologies: a dual-factor model. In Proceedings of the 40th Hawaii International Conference on System Sciences:141–150
26. Detmer, D. E., Munger, B. S., and Lehmann, C. U., Medical informatics board certification: history, current status, and predicted impact on the medical informatics workforce. *Applied Clinical Informatics* 1(1):11–18, 2010. doi:10.4338/ACI-2009-11-R-0016.
27. Denzin NK (1989) *The Research Act: A Theoretical Introduction to Sociological Methods* (3rd Ed). In. McGraw-Hill, New York
28. Borkan, J., Immersion/Crystallization. In: Crabtree, B. F., and Miller, W. L. (Eds.), *Doing Qualitative Research*, 2nd edition. Sage Publications, Thousand Oaks, pp. 179–194, 1999.
29. Nielsen, J., *Usability Engineering*. Academic, Boston, 1993.
30. Shneiderman, B., and Plaisant, C., *Designing the User Interface: Strategies for Effective Human-Computer Interaction*, 4th edition. Addison-Wesley, Boston, 2004.
31. Liu-Sheng, O. R., Hu, P. J. H., Wei, C. P., Higa, K., and Au, G., Adoption and diffusion of telemedicine technology in health care organizations: a comparative case study in Hong Kong. *Journal of Organizational Computing and Electronic Commerce* 8(4):247–275, 1998.
32. Blumenthal, D., Launching HITECH. *New England Journal of Medicine* 362(5):382–385, 2010. doi:10.1056/NEJMp0912825.
33. Johnston, J. M., Leung, G. M., Wong, J. F. K., Ho, L. M., and Fielding, R., Physicians' attitudes towards the computerization of clinical practice in Hong Kong: a population study. *International Journal of medical Informatics* 65(1):41–49, 2002. doi:10.1016/S1386-5056(02)00005-9.
34. Noro, K., and Imada, A. (Eds.), *Participatory Ergonomics*. Taylor and Francis, London, 1991.
35. Kaplan, B., and Harris-Salamone, K. D., Health IT success and failure: recommendations from literature and an AMIA workshop. *Journal of the American Medical Informatics Association* 16(3):291–299, 2009. doi:10.1197/jamia.M2997.
36. Holden, R. J., Or, C. K. L., Alper, S. J., Rivera, A. J., and Karsh, B., A change management framework for macroergonomic field research. *Applied Ergonomics* 39(4):459–474, 2008.
37. Schraagen, J. M., Chipman, S. F., and Shalin, V. L., *Cognitive Task Analysis*. Lawrence Arlbaum, Mahwah, 2000.
38. Vicente, K., *Cognitive Work Analysis: Toward Safe, Productive, and Healthy Computer-Based Work*. Lawrence Erlbaum, Mahwah, 1999.
39. Weir, C. R., Nebeker, J. J. R., Hicken, B. L., Campo, R., Drews, F., and LeBar, B., A cognitive task analysis of information management strategies in a computerized provider order entry environment. *Journal of the American Medical Informatics Association* 14(1):65–75, 2007. doi:10.1197/jamia.M2231.
40. Rogers, M. L., Patterson, E. S., and Render, M. L., Cognitive work analysis in health care. In: Carayon, P. (Ed.), *Handbook of Human Factors and Ergonomics in Health Care and Patient Safety*, 2nd edition. CRC Press, Boca Raton, pp. 465–474, 2011.
41. Kroemer, K. H. E., Kroemer, H. B., and Kroemer-Elbert, K. E., *Ergonomics: How to Design for Ease and Efficiency*. Prentice Hall, Upper Saddle River, 2000.
42. Hollnagel, E., and Woods, D. D., *Joint Cognitive Systems: Foundations of Cognitive Systems Engineering*. CRC Press, New York, 2005.
43. Woods, D. D., Designs are hypotheses about how artifacts shape cognition and collaboration. *Ergonomics* 41(2):168–173, 1998. doi:10.1080/001401398187215.
44. Wyatt, J. C., Clinical data systems, part 3: development and evaluation. *Lancet* 344(8938):1682–1688, 1994.
45. Karsh, B., Beyond usability: designing effective technology implementation systems to promote patient safety. *Quality & Safety in Health Care* 13(5):388–394, 2004.
46. Breen, G. M., and Zhang, N. J., Introducing ehealth to nursing homes: Theoretical analysis of improving resident care. *J Med Syst* 32(2):187–192, 2008. doi:10.1007/s10916-007-9121-9.
47. Buenestado, D., Elorz, J., Perez-Yarza, E. G., Iruetaguena, A., Segundo, U., Barrena, R., and Pikatza, J. M., Evaluating acceptance

and user experience of a guideline-based clinical decision support system execution platform. *J Med Syst* 37(2):1–9, 2013. doi:10.1007/s10916-012-9910-7.
48. Etchells, E., Bailey, C., Biason, R., DeSousa, S., Fowler, L., Johnson, K., Morash, C., and O'Neill, C., Human factors in action: getting "pumped" at a nursing usability laboratory. *Healthcare Quarterly* 9: 69–74, 2006.
49. Rose, A. F., Schnipper, J. L., Park, E. R., Poon, E. G., Li, Q., and Middleton, B., Using qualitative studies to improve the usability of an EMR. *Journal of Biomedical Informatics* 38(1):51–60, 2005.
50. Beuscart-Zephir, M. C., Pelayo, S., Degoulet, P., Anceaux, F., Guerlinger, S., and Meaux, J. J., A usability study of CPOE's medication administration functions: impact on physician-nurse cooperation. *Medinfo* 11(Pt 2):1018–1022, 2004.
51. Or, C. K. L., and Tao, D., Usability study of a computer-based self-management system for older adults with chronic diseases. *JMIR Research Protocols* 1(2):e13, 2012. doi:10.2196/resprot.2184.
52. Ash, J. S., and Bates, D. W., Factors and forces affecting EHR system adoption: Report of a 2004 ACMI discussion. *Journal of the American Medical Informatics Association* 12(1):8–12, 2005.
53. Lorenzi, N. M., Riley, R. T., Blyth, A. J. C., Southon, G., and Dixon, B. J., Antecedents of the people and organizational aspects of medical informatics: Review of the literature. *Journal of the American Medical Informatics Association* 4(2):79–93, 1997.
54. Or, C. K. L., Wong, K., Tong, E., and Sek, A. Clinical workflow and work system assessment of private clinics in Hong Kong and implications for electronic medical record development. Human Factors and Ergonomics Society 55th Annual Meeting:665–669, 2011.
55. Dykes, P. C., McGibbon, M., Judge, D., and Li, Q., Poon, E. G., Workflow analysis in primary care: implications for EHR adoption. Annual Symposium of American Medical Informatics Association, In, p. 944, 2005.
56. Unertl, K. M., Weinger, M. B., Johnson, K. B., and Lorenzi, N. M., Describing and modeling workflow and information flow in chronic disease care. *Journal of the American Medical Informatics Association* 16(6):826–836, 2009. doi:10.1197/jamia.M3000.
57. Tan, J., Wen, H. J., and Awad, N., Health care and services delivery systems as complex adaptive systems: examining chaos theory in action. *Communications of the ACM* 48(5):36–44, 2005. doi:10.1145/1060710.1060737.
58. Eisenhardt, K. M., and Martin, J. A., Dynamic capabilities: what are they? *Strategic Management Journal* 21(10–11):1105–1121, 2000.
59. Teece, D. J., Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal* 28(13):1319–1350, 2007.
60. Wellman, J., Jeffries, H., and Hagan, P., *Leading the Lean Healthcare Journey: Driving Culture Change to Increase Value*. CRC Press, New York, 2010.
61. Trusko, B. E., Pexton, C., Gupta, P. K., and Harrington, J., *Improving Healthcare Quality and Cost with Six Sigma*. Pearson Education, Upper Saddle River, 2007.