Open Innovation: Transforming Health Systems through Open and Evidence-Based Health ICT Innovation

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Abstract: For many years the full potential of creating and leveraging integrated health ICT systems such as electronic health records to improve healthcare delivery, reducing its cost and promoting prevention has been elusive. Traditional health ICT business, innovation, development and adoption models have failed to address chronic road blocks to realizing its full potential and have led to many high profile failures. The chronic symptoms include persistent barriers to integration and interoperability, high cost, duplication of effort, and poor, to no support for collaborative, "evidence based" medicine. This paper provides a review of case studies and analysis on how open innovation, or open source processes, can break the grid lock and bring the fundamental paradigm shift needed to exploit the full potential of health ICTs. The paper will discuss how the open innovation model, as applied to health ICT, provides a framework for harnessing the naturally occurring "bottom up" forces and emergent behaviour found in complex adaptive systems such as healthcare. It does this by describing a model and context for collaborative, open, peer reviewed, evidence-based innovation and technology transfer processes. Evidence from case studies are presented on how open ICT innovation in healthcare provides essential feed backloops for supporting, researching, developing and disseminating while driving continuous quality improvement at a global scale.

Key words: open innovation, open source, ICT, healthcare.

■ The pressing need for effective ICT solutions in health

Health systems throughout the developing and developed world face tremendous pressure to improve health quality, accessibility to care and outcomes, while at the same time they are striving to contain and cut costs. Examples of significant challenges facing health systems everywhere include:

- Healthcare costs as a share of GDP are rising inexorably in many countries, and increases in health care spending are projected to continue outpacing the rest of the economy;

- Costs of health insurance is rising at a faster rate than inflation (FREKING, 2007);

- There is a persistent and unacceptably high rate of medical error in health systems. The Institute of Medicine's (IOM) report "To Err is Human" (IOM, 2000) first drew widespread attention to the scope of medical errors in health systems. A 2007 follow-up study to the IOM report found that medication error is the most common medical error harming at least 1.5 million Americans yearly at a cost of over $3.5 billion a year not taking into account lost wages and productivity or additional health care costs (ASPDEN *et al*., 2007);

- Chronic, non-communicable disease is a major, yet potentially manageable burden on health systems (DAAR *et al*., 2007);

- Demographic profiles and trends, such as high birth rates pose a growing set of unique and dynamic challenges.

It should come as no surprise then that for many years now, there has been a global consensus that deployment and adoption of effective and affordable information and communication technologies (ICT) in health systems is essential to overcoming the faced quality and cost challenges. Developed countries such as the United States (US), United Kingdom (UK) and Canada have sought to leverage the promise of ICTs and have established programs and incentives to speed the widespread adoption of solutions such as integrated electronic health records (EHRs). The US American Recovery and Reinvestment Act of 2009 (ARRA) has allocated $30 billion in incentives for hospitals and family physicians to encourage the adoption of certified EHRs. An additional $2 billion in grants are available through the US's Department of Health and Human Services (HHS) for projects such as telemedicine initiatives [1]. In Canada similar incentive and EHR certification programs have been established at the provincial level such as Ontario's $386-million EHR incentive program (WEBSTER, 2011a) and British Columbia's Physician Information Technology Office (PITO) [2]. Yet in the face of this consensus and serious investment there is clear and compelling evidence that fundamentally new approaches are needed to ensure that ICT investments will yield the clinical and financial promise that everyone is counting on.

1 http://bphc.hrsa.gov/recovery/

2 http://www.pito.bc.ca/programs/

■ It's time for a paradigm shift

> "There's only one thing more painful than learning from experience, and that is not learning from experience." (Archibald MacLeish)

In spite of the clear and pressing clinical and financial need for effective and affordable health ICTs, the reality is that most of the evidence to date shows a disappointing return on investment, both clinically and financially. At a program level, there has been a spate of high profile failures and scathing critiques of several high cost, long-term initiatives. At the technical and architectural level, software solutions continue to demonstrate chronic symptoms of health ICT ineffectiveness such as a lack of interoperability, vendor lock-in and poor integration. These patterns strongly suggest that there are fundamental flaws in traditional approaches to the development and adoption of health ICTs and that a paradigm shift is desperately needed.

Big is too big

The recent failure of the 9 year, multi-billion pound UK NHS's National Program for IT (BALLARD, 2011), the goal of which was to provide every patient in the UK with an electronic health record (by 2010) stands out as the most costly example. In a recent report the UK's National Audit Office (NAO) concluded that "the £2.7 billion spent so far on care records systems does not represent value for money. And, based on performance so far, the NAO has no grounds for confidence that the remaining planned spending of £4.3 billion on care records systems will be any different" (NAO, 2011). The NAO goes further to say that "where systems have been delivered, they are not yet able to do everything that the Department intended, especially in acute trusts." (NAO, 2011) The systems delivered so far provide administrative functionality rather than the much needed clinical functionality such as prescribing and administering drugs. The NAO attributes the failure in part to "fundamentally underestimating the scale and complexity of a major IT-enabled change programme." (NAO, 2011)

Canada has also experienced what seems like an epidemic of critical government auditor reports of health ICT initiatives. Ontario's auditor general reported in 2009 that "Ontario taxpayers have not received value for money for this $1 billion investment" and that Ontario "is near the back of the pack" compared to other provinces in implementing electronic health records, having wasted millions on underused computer systems (CBC News, 2011). Across the country in British Columbia, the province's auditor general

reported in February of 2010 (Office of the Auditor General of Canada, 2010) that the $222 million Canadian dollar (CAD) initiative was "behind schedule, over budget, not well planned and still failing to deliver promised benefits to patients." (BRENT, 2010) A key criticism of the program was that "key stakeholders such as health professionals were not effectively engaged to ensure the proposed EHR system would meet the needs of its users" and the report recommended the guidance and direction of the EHR initiative through an "open planning process."(DocLounge, 2010). Lastly, at the national level Canada Health Infoway, which was chartered in 2001 and received $1.6 billion CAD to facilitate the adoption of an interoperable electronic health record for all Canadians was also criticized in 2009 by the federal auditor general. The auditor found that after eight years in operation, only 17% of doctors in Canada had implemented electronic health records (CBC News, 2009).

In the United States, the US Department of Defence's AHLTA EHR has come under severe criticism for failing to meet the needs of users and alienating health professionals. In the summer of 2008 a groundswell of provider dissatisfaction prompted a meeting with a Military Personnel sub-committee. Testimony from senior officials concluded that "the state of the current system was unacceptable [in fact] intolerable" and Rear Adm. Thomas Cullison, the Navy's deputy surgeon general, stated that there were "reliability and performance issues" with AHLTA with weekly system failures and a software interface that is "clunky and awkward for doctors." (U.S. Government Printing Office, 2009)

Chronic symptoms of ICT paradigm paralysis

While poor project management and administration have played a key role in health ICT failures, other recurring symptoms point to key fundamental weaknesses in traditional approaches to software innovation, development and deployment. The following is a summary of several of these key recurring symptoms:

- Health system-wide ICT solutions are too expensive when considering the aggregate cost of implementing most integrated health ICTs at a national level. The price tag for large-scale adoption of proprietary systems is too high to be considered affordable even by the richest countries. Kaiser Permanente for example has spent $4.2 billion implementing the Epic EHR system in 431 medical offices and 35 hospitals (ANDERSON, 2009).

- It is difficult to measure effectiveness of health policies and investment in IT and therefore to navigate toward the right choices. Lack of fully integrated systems and consistent implementation of standards have made it difficult and in many cases impossible to establish databases and feedback loops necessary for scientific evaluation of the impact of ICTs.

- In spite of standards such as HL7 (aimed at enabling integration of disparate systems) being in existence since 1987, it continues to be very difficult to share medical information and implement unified medical records at local, regional and national levels. Projects such as Canada Health Infoway's "Blueprint" and the US's National Health Information Network (NHIN) initiatives [3] would not be necessary if health ICTs were truly "plug and play" in terms of integration and interoperability.

- Re-invention of the wheel is pandemic and duplication of efforts is common both within countries and globally. In Canada for example, each province has its own software certification program and there is little to no collaboration to ensure a common set of standards for EHR solutions (WEBSTER, 2011a).

At the heart of these symptoms is the common pattern of closed, proprietary ICT solutions, methodologies and business models. Competitive strategies based on loose interpretation of standards, vendor lock-in of data or expensive interfacing licenses have led to disintegrated systems. In addition traditionally closed, linear, top down development and implementation methodologies are not congruent with the bottom up, evidence-based, user driven innovation that is an essential basis for continuous improvement in health systems. These are all common characteristics of the closed system paradigm, which has dominated the health ICT industry. A paradigm that has fostered inflexible, high cost solutions and insufficient speed in evolving to meet the rapidly changing demands of healthcare. It is clear from the examples cited in the previous section, that the opportunity lost in both human and financial terms of adhering to a closed ICT innovation and implementation paradigm has become too large to ignore.

[3] https://healthit.hhs.gov/portal/server.pt/community/healthit_hhs_gov__hitech_programs/1487

■ Health systems are complex, adaptive ecosystems

Open innovation processes in health ICTs such as those found in the open source software model represent the most significant paradigm shift in ICT in the last 20 years. There is mounting evidence that open innovation fosters improved effectiveness, affordability and innovation in the health sector. Before examining the evidence through a number of case studies it will be valuable to explain why open innovation is such a natural and synergistic fit for health systems.

> "Healthcare organizations have traditionally been viewed as if they were like machines that operate in accordance with the Newtonian laws of cause and effect, with linear relationships between actions and results. However, it is increasingly evident to administrators and researchers that healthcare organizations do not meet such mechanistic expectations – they are much 'messier' and more complex than this model suggests." (Australian Primary Healthcare Research Institute, 2004)

Health systems are in effect ecosystems that require ICT strategies, which are congruent with their complex and adaptive nature in order for them to be effective (DAL MOLIN, 2007). They behave like natural ecosystems in which user driven "bottom-up" processes and innovation strategies are critical to success (PLSEK, 2001). Key complex system characteristics exhibited by healthcare ecosystems include the following:

- Non-Linear, Emergent Behaviour - Behaviour and workflow is seemingly chaotic, unpredictable and non-linear with patterns and structures emerging over time. A good example is a patient visiting his or her doctor to attend to a sore throat. The initial diagnosis is often not definitive and the potential approaches to address this problem are numerous. Several weeks may elapse, with many more seemingly unrelated incidents, before it becomes clear that a flu outbreak has begun.

- Unpredictable - Relationships between providers are inherently complex, fluid and adapt dynamically to address a health goal or problem, as it becomes better understood.

- Numerous Interacting Components – Agents, processes, etc. (JOSLYN & ROCHA, 2000)

- Self-organizing Local Control - Control and decision-making in health care is widely distributed and localized to those working at the point of care.

- Nested Interacting Systems – The healthcare ecosystem is holistic in its scope and is composed of systems within systems, which interact with each other at various levels of policy setting, funding and delivery.

The traditional top down and closed ICT innovation paradigm is sub-optimal in creating and implementing the types of continuously improving, fluidly integrated systems, which are essential to responding to the complex adaptive nature of health systems. Traditional approaches to ICT innovation are not efficiently aligned with or sufficiently responsive to user needs in these ecosystems as they are designed to support competitive strategy and the sustainability of existing business models above all else. In complex systems such as healthcare, tackling and solving difficult challenges is best accomplished by enabling multidisciplinary groups of experts to self-organize and work collaboratively across organizational boundaries (WEAVER, 1948).

Open innovation model – evidence based medicine for health ICTs

In contrast to the traditional closed paradigm that characterizes the health ICT industry, open innovation based ICT paradigms such as open source share the same bottom up, complex adaptive DNA found in health ecosystems. It is this fundamental symmetry that makes open innovation natural and more effective for health ICT development and implementation. Other key characteristics include:

- Open innovation is congruent with, and in many ways mimics the evidence-based medicine paradigm, which makes it a more natural fit for healthcare software innovation;
- There is minimal to zero innovation friction caused by the need to recover R&D costs before releasing new features or products which make current versions of software obsolete;
- Competition is based on services rather than ICT license royalties which reduces cost;
- Improvements are shared across the global community and added to the public "gene pool" where they can rapidly and efficiently be continuously improved by a potentially huge number of highly motivated adopters and entrepreneurs;

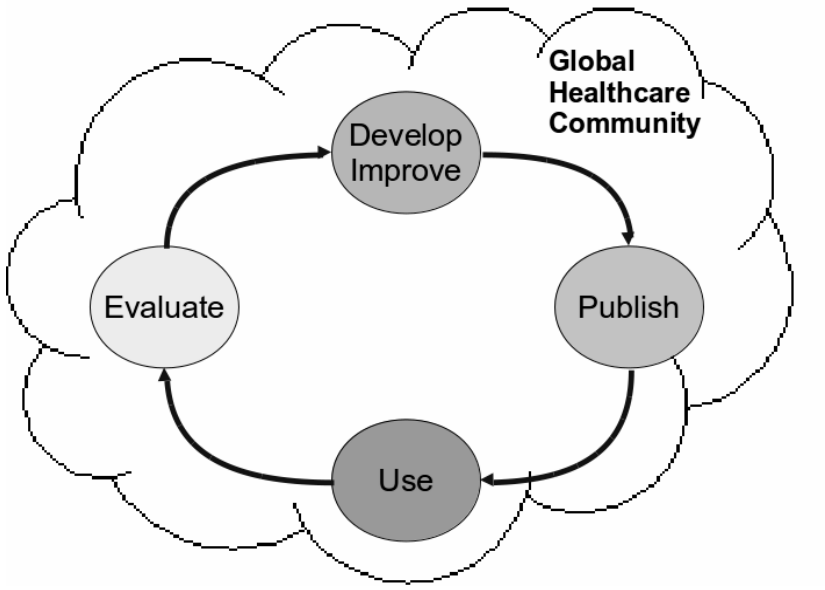
- Ineffective or inferior solutions are identified and dealt with sooner through open, peer reviewed processes thus minimizing potential negative impacts and waste;
- There are stronger incentives to adhere to open standards as this encourages widespread software adoption, community participation, and eliminates "lock-in" through proprietary interpretation of standards.

As one would expect, there are some potentially negative aspects to open innovation. Negative aspects can include greater real and perceived risk of employing externally developed technologies, the possibility of free-riding by others, and the risk of internal resistance to adoption or the "Not Invented Here" syndrome (CHESBROUGH *et al*., 2006).

Furthermore, in sectors such as healthcare, where knowledge is widespread, effectively leveraging open innovation implies adopting disruptive change in business processes (CHESBROUGH, 2003). Organizations need to reorganize as the locus of innovation shifts to external sources.

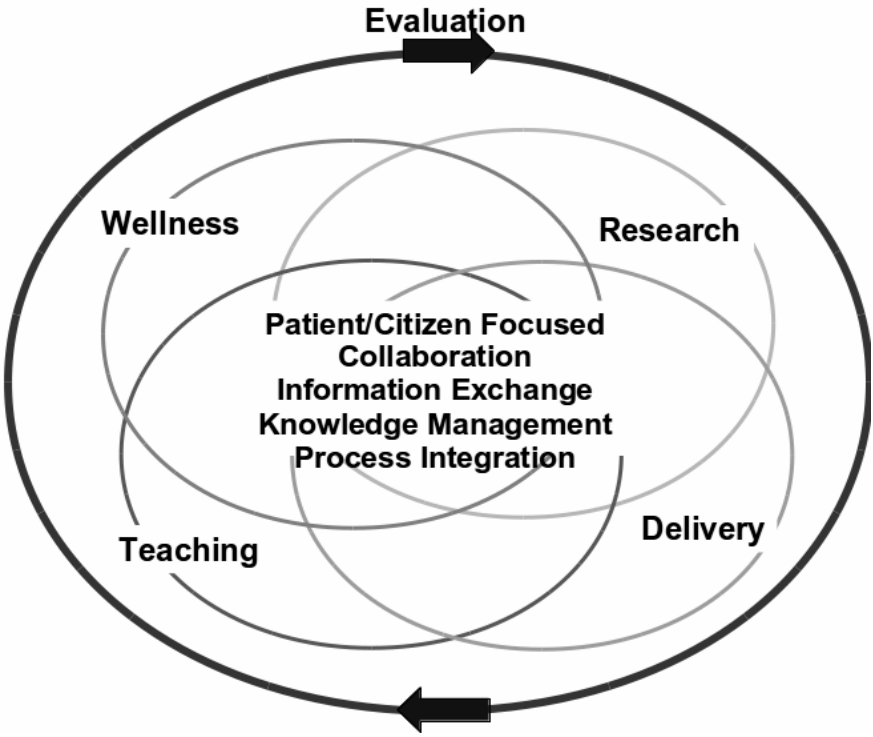
The following diagram provides a simple illustration of the open-source process model, which is a proven foundation for open innovation in health ICTs.

Figure 1 - Open source process model



In order to maximize the impact and value of this kind of open innovation process in health systems it is essential to apply it using a holistic, evidence driven ecosystem model such as the one illustrated below in Figure 2.

Figure 2 - Health ecosystem model



The health conceptual framework in Figure 2 provides a holistic "ecological" perspective on health IT innovation, research, development and dissemination, which is sensitive to the naturally occurring "bottom-up" forces and emergent behaviour of health systems. This health ICT "ecosystems" model consists of the following interrelated components:

- Evaluation – ongoing evidence-based, peer reviewed, continuous improvement processes;
- Research – covers portal support of healthcare research. Examples include clinical trials and other forms of health research.
- Delivery – encompasses portal support of the delivery of care, such as primary care and chronic disease management, including both relevant administrative and clinical processes.

- Teaching and Learning – encompasses knowledge transfer to healthcare providers, other health professionals and consumers.
- Wellness – addresses prevention, as well as the surveillance, evaluation and monitoring of population health status.

Accordingly, the model, when applied in conjunction with open collaboration, can be used to establish a holistic framework for ICT innovation that harnesses the bottom-up, creative power of healthcare ecosystems. In part, this is due to the greater involvement and participation of users and the blurring of the usual boundaries between users and developers compared to traditional commercial software development (ZHAO & DEEK, 2004). This framework can be used to align and drive Information Communication Technology (ICT) innovation and adoption toward more effective continuous improvement of healthcare processes and outcomes.

It is important to note that with the increased freedom inherent in open innovation and open source processes comes greater responsibility of the ICT community as a whole to ensure quality control and quality assurance of software solutions. Many software applications are "life critical" in healthcare and it is essential that formal testing and certification processes be implemented as part of the software development life cycle before applications are deemed acceptable to be used with real patients. There are now several good examples of how this can be achieved in open innovation communities such as the successful certification of medical imaging software like OSIRIX [4] and O3 [5].

■ Evidence from the VA VistA [6] software ecosystem

The most comprehensive and scientific body of evidence supporting the remarkable value of open innovation applied to health ICTs is that associated with the US Veterans Health Administration (VA) VistA electronic record and health information system. The VA represents the largest integrated healthcare delivery system in the United States serving over 5

4 http://pixmeo.pixmeo.com/

5 http://www.o3consortium.eu/

6 The colourful history of VistA is beyond the scope of this paper and has been documented in LONGMAN, 2007.

million veterans across 1,400 sites of care. In spite of the fact that its patients on average have more health problems, are older, and have lower incomes the VA outperforms other health systems based on objective, standardized quality measures (ASCH *et al*., 2004; KERR *et al*., 2004; JHA *et al*., 2003). What is more remarkable is that the VA used to be considered one of the worst performing health systems in the US. The dramatic transformation achieved in the VA is "in part related to VA's leadership in the development and use of the electronic health record, which has fostered veteran-centered care, continued improvement, and research. Human and system characteristics have been essential to the transformation of VA care" (KUPERSMITH, 2007).

VistA began its life as a user driven, collaborative, skunk works project in the VA over 25 years ago. It has evolved primarily through a user driven, distributed, bottom up, open, evidence-base innovation model. VistA's contribution to patient safety, health quality improvement and cost management/reduction in the VA has become legendary and serves as a benchmark example for the benefits of open innovation in health ICTs. A very recent study of the value of the VA's health IT investments is estimated at $3.09 billion in cumulative benefits net of investment costs (BYRNE *et al*., 2010). One of the key findings of the study was

> "[...] that the VA's success in achieving relatively streamlined software development and a high level of system adoption which, in turn, was reflected in our cost-benefit projection was made possible by its structure." (BYRNE *et al*., 2010).

VistA's high level of integration and rich functionality facilitates clinical healthcare transformation from the point of care, to the regional, to the national system level. It accomplishes this by providing the ability to implement and support evidence based, best practices, quantifiable system-wide measurement, combined with decision support and administrative management capability. This directly affects and measurably improves both patient safety and health outcomes and reduces costs through better management information systems. Some key examples of documented and measurable clinical improvements implementing VistA include:

- Elimination of virtually all medication error through the implementation of barcode medication administration and direct physician order entry. This significant innovation in patient safety was conceived by a nurse and developed in collaboration with her local VA IT department (COYLE & HEINEN, 2005). This pioneering work using barcodes to manage medication administration earned the VA the Innovations in American Government

Award from John F. Kennedy School of Government, Harvard University in 2006.

- Support of preventive care such as immunization, cancer screening (breast, cervical, colorectal, prostate), diabetes monitoring, and smoking cessation programs – Using VistA to support preventive care, the VA showed improvement in the number of patients treated from approximately 35% of eligible patients in 1996 to over 82% by 2003 (PERLIN *et al*., 2005). This has in many instances translated into improved health outcomes (PATERSON *et al*.; PIETTE *et al*., 2001).

- Significant improvement in chronic disease management through the use of evidence based clinical reminders – "Utilization of VA's EHR has yielded tremendous benefits to clinical care and permits VA to capture data for virtually every clinical performance measure. For instance, a comparison of VA patient care quality data from 2003 with Medicare data from 2003, and with the best reported performance of other health care systems in the U.S., shows that VA care sets the benchmark for every one of these clinical performance indicators." (THOMPSON, 2004)

- Improvements in postoperative morbidity and mortality rates – From 1991 to 2008 the VHA has experienced declines in 30-day postoperative morbidity rates, from 17.4% to 8.8% and from 3.16% to 1.36% respectively (Congressional Budget Office, 2009).

- Significant reduction in waste and duplication of laboratory tests and radiology examinations – film-less operations are enabled by the VistA Imaging module; lab tests do not have to be repeated as results are available system-wide.

- Elimination of waste and cost of "prescription shopping" i.e. multiple filling of same prescription.

- Significant cost reductions by reducing inpatient admissions, increasing outpatient visits through better managed care – "It should be noted that from 1996 to 2003, the number of veterans treated annually increased by 75% from approximately 2.8 to 4.9 million. The appropriated budget to care for those increasing numbers of patients remained flat at $19 billion from 1995 to 1999, and has increased to approximately $25 billion for fiscal year 2003, or about 32% cumulatively over 6 years." (PERLIN *et al*., 2004).

Evidence from the global VistA ecosystem and beyond

Over the past ten years the availability of the VA's VistA software, documentation and educational material as public domain resources through the US Freedom of Information Act has spawned a thriving open source community. Many of the original architects and developers of VistA helped establish and are active members of the community. WorldVistA [7], a charitable non-profit organisation was established in 2000 to promote the adoption of VistA outside the VA by facilitating and coordinating open, collaborative improvement and adaptation of VistA.

To date there has yet to be similar peer reviewed studies and clinical evidence in the global VistA community to those conducted on the VA's development and implementation of VistA. Nevertheless there are some key examples, which can be cited of the significant benefits of open innovation applied to health ICTs.

The first example is the ability to adopt and adapt a high quality EHR like VistA in countries that could not normally afford or sustain the use of a system with this level of functionality and integration. In the summer of 2007, Jordan initiated the initial stages of a program to adopt WorldVistA EHR (a version of VistA adapted for use outside the VA) for use across its entire public health system. Jordan could not afford proprietary solutions on par with VistA and was keen on achieving the same kind of clinical transformation experienced in the VA. Once the groundwork was completed Jordan established the public-sector, stakeholder owned non-profit Electronic Health Solutions (EHS) to build a team that could support and adapt the software for use in Jordan. An important design principle was that EHS would become an active contributor and participant in the global VistA community. It recognized that open collaboration with the rest of the community was the key to ensuring VistA's quality, affordability and ensuring local sustainability. To that end, in the space of a year and a half, with the help of the community and external consultants, EHS was able to establish a team which could adapt the software for local needs while remaining compatible with VA, WorldVistA and community software enhancements.

There are several examples of how the open innovation model and strategy has benefited both Jordan and the community in the area of collaborative software improvement. One of these was the ability to adapt a

[7] http://www.worldvista.org

graphical scheduling application developed by the US Indian Health Service (IHS), which develops and maintains another variant of VistA. The existing character based scheduling application was not acceptable to end users and the interface needed to provide better support for displaying Arabic. Developing this application from scratch was both cost and time prohibitive. Fortunately IHS releases its software as public domain software and contractors and experts who are familiar with the software are free to enhance and implement the software. Because of these circumstances Jordan was able to adapt and implement the scheduling application in a fraction of the time and cost it would have taken had the software and expertise been proprietary. Another similar example is the adaptation of the pediatric growth chart application to support WHO standards. In this case a community member had made available a growth chart add-on for the Delphi based, clinical graphical user interface. Jordan took this enhancement and modified it to support the WHO standard. In both these instances, Jordan contributed its enhancements back to the community by licensing the software as open source thus contributing to a virtuous spiral of improvement [8].

Similar examples of leveraging and extending community innovations have taken place in the North American context. WorldVistA has twice successfully pursued EHR certification of WorldVistA EHR to meet criteria established by the US HHS. In both instances software improvements and innovations contributed by other community members were critical to successful certification. The innovations that WorldVistA was able to leverage included prescription completion software, electronic prescribing software, development of a web-based growth chart solution and software, which enabled export and import of medical history via the Continuity of Care Record (CCR) standard. Again all of these improvements would have required significantly more time and cost to develop from scratch which would have added to the overall cost of certifying the software.

In addition to examples from the VistA community, there is a growing body of evidence from other open source communities attesting to the value of open innovation and open source processes applied to healthcare ICTs. Two notable examples are the Belize Health Information System (BHIS) and OSCAR the primary care electronic health record developed at McMaster University's Department of Family Medicine. In the case of OSCAR,

[8] The growth chart software enhancements were made available to the VistA community via the WorldVistA code repository at https://trac.opensourcevista.net/

numerous testimonials by physician adopters can be found in the community discussion forum [9], which cite superior functionality and implementation costs that are a fraction of proprietary systems. Belize's BHIS is based on open source components and its national implementation has been attributed with reducing "national health budget costs by as much as 3%, and adverse drug reactions by 90%." (WEBSTER, 2011b).

■ Summary and conclusions

Investment in ICTs that have been developed, enhanced and disseminated through traditional closed, proprietary methods have yielded sub-optimal results. Traditional health ICT business, innovation, development and adoption models have failed to address chronic road blocks to realizing its full potential and have led to many high profile failures. The chronic symptoms of underachievement include persistent barriers to integration and interoperability, high cost, duplication of effort, and poor, to no support for collaborative, "evidence based" medicine. This is compelling evidence that a fundamental paradigm shift is needed to fully realize the potential of ICTs in transforming and improving health system performance.

Open innovation has all the markings of the paradigm shift that is needed to fully leverage the value and potential of health ICTs. There is significant, scientifically gathered and peer reviewed evidence that supports serious consideration of open innovation applied to health ICT development, improvement, and adaptation as a valuable alternative to business as usual. In this context it is important to re-emphasize that with the increased freedom and benefits of user-driven innovation comes, what may be for many, new and greater responsibility. Healthcare software applications are in many cases 'life critical" in that patient safety and health outcomes can be adversely affected by software, which has not been adequately tested. As mentioned before, it is critical that proper testing and quality assurance processes be integrated with the open innovation software life cycle.

There are significant real and potential broader business implications associated with this paradigm shift that are important to anticipate and consider. One fundamental implication is the disruptive nature of this business model. It will completely alter the competitive landscape and shift

[9] https://lists.sourceforge.net/lists/listinfo/oscarmcmaster-bc-users

competitive advantage away from proprietary, intellectual property to competition based on service excellence. This in turn will, for the most part, eliminate customer lock-in and negatively impact the sustainability of software suppliers that have built corporate infrastructures, which rely too heavily on software royalties. The availability of open source, royalty-free software will also impact procurement processes, as long, expensive and often ineffective tendering processes will eventually become difficult to justify or in many cases obsolete. There should be no doubt that the empowerment of the software user, brought by this paradigm shift, will fundamentally alter the healthcare ICT business landscape.

Looking forward, it is recommended that further research and collaboration be initiated to identify and share best practices in implementing open innovation and open source as an integral part of healthcare ICT development and adoption. Furthermore, with the increased adoption of open source solutions such as EHRs in low resource settings there is an increasing need to extend the open innovation model beyond software, to the knowledge bases that healthcare software depends on, such as drug interaction databases and terminology databases. Similarly, there is increasing need and value in exploring how to best apply open, continuous improvement to healthcare business process rules such as evidence-based decision support algorithms which are key to patient safety and the improvement of health outcomes. Lastly, it is recommended that above all, a holistic, ecosystem perspective be adopted in healthcare ICT innovation; one which integrates the key domains of a health ecosystem such as care delivery, research, education and prevention or wellness.

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