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HIGH IMPACTS ON EDUCATION, RESEARCH AND PRACTICE AROUND HEALTH INFORMATICS: LONGITUDINAL CASE ANALYSIS FROM SRI LANKA

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High Impacts on Education, Research and Practice around Health Informatics: Longitudinal Case Analysis from Sri Lanka

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Abstract:
In achieving sustainable development goals, capacity development around health informatics is an essential prerequisite. However, in developing contexts, there tends to be a significant disconnect between these capacity development efforts and health information system (HIS) developments – leading to multiple, unimplemented, non-scalable systems. This paper attempts to overcome this disconnect by choosing to answer the questions what capacities need to be developed and how this should be done – within the contexts of networks-of-action and innovation ecosystems. In doing so, the paper presents a longitudinal analysis of a successful education and research initiative hosted at the University of Colombo, Sri Lanka where more than 100 medical doctors have acquired education in health informatics. Through an interpretivist approach, the paper argues that capacity development cannot be treated in vacuum but need to be framed and integrated with ongoing educational processes, research and practices. It proposes that capacity development around health informatics should be considered an ecosystem that supports both creation of human resources and HISs with transformative potential. The said ecosystem consists of four designated interacting spaces; academic; innovation; development; and work – defined based on the relationships formed by students at different points in time. Enabling these relationships nurture multiple transformative HISs with broader health system and development impacts. The paper's primary contribution is the articulation of this model illustrating the inter-connectedness of education, research and practice. By applying this model in developing contexts, it would be possible to transform capacity development around health informatics into impactful information systems within the health-domain.

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1. Introduction

In 2014, then United Nations Secretary General Ban Ki-moon, in an address to the World Summit on Information Society (WSIS+10) High-Level Event, emphasized that "*We must do everything in our power to increase access to information and communication technologies and broadband connectivity across the world…. This will empower millions of people and enable us to meet our development goals in the post-2015 era*" (United Nations, 2014). The development goals referred to by Mr Ban Ki-moon are the Sustainable Development Goals (SDGs), which have now come into effect in the form of 17 goals and 169 targets. While Goal 3 refers to 'health and well-being', almost all other goals directly or indirectly contribute toward better health outcomes (Buse and Hawkes, 2015). It is perceived that Information and Communication Technologies (ICTs) have a major role to play in fast-tracking the attainment of these goals (International Telecommunication Union, 2017). If ICTs are to play a major role in developing country contexts, this would require such contexts to shift from manually gathering, storing, processing, and utilizing health data to automating these processes through electronic health information systems (HIS) (Haux, 2006) and building value-adding information products on top of these processes. This would also mean that developing country contexts now need to build and evolve their own capacity in terms of designing, developing, adopting, and applying ICT-based solutions in health care service delivery, management, and planning — the very definition of health informatics (U.S. National Library of Medicine).

Thus, as part of broader, SDG-driven health reforms, many developing countries are being encouraged to formulate plans for capacity development in health informatics, which is often done without much direction and in a rather ad hoc fashion. In other words, apart from emphasizing that "we need more training," not many research and practice-based recommendations provide enough insights into what capacities need to be developed and how should this be done. Thus, there is a need for us to go beyond the standard recommendations and become more specific about what human capacities we need to develop with respect to the broader development agendas such as SDGs and the mechanisms to try and move in that direction.

Building capacity in developing country contexts is a nontrivial challenge, as there are many technical and institutional challenges that need to be addressed. We argue that understanding these challenges needs to be supported by high-impact research, which combines both research and practice to address a larger societal problem — in our case it relates to building capacity toward strengthening public health information systems. The research and practice are inextricably tied to ICT, as technology is both an object of study and also a vehicle to enable the development of capacity, as our case study and its analysis will demonstrate.

In this paper, we present a successful capacity development program in public health informatics from Sri Lanka, which has evolved over eight years. It has been contributing to the country's HIS development and has helped strengthen the overall health systems in a significant way. One of the unique features of this program is its focus on developing health informatics–related capacities among medical doctors with the aim of bridging the domains of ICT and health. It is also unique in terms of its approach to capacity development, which recognizes the importance of the need to merge individual training

with ongoing developments in HISs. Thus, by undertaking an in-depth longitudinal study of the Sri Lankan case, our aim is to develop a model that will illustrate how capacity development in health informatics in developing contexts can be better aligned with the SDGs and other global health-reform imperatives.

2. Literature review

In this section, we will evaluate the literature around capacity development in health informatics with the aim of identifying the key themes under consideration. For clarity, we structure this section using the derived themes; North-South and South-South collaborations and the role of higher education institutions, gaining legitimation in capacity development, multidisciplinarity in health informatics, and the notions of networks of action and innovation ecosystems. The themes recognized will shape the research questions in relation to capacities to be developed and how this should be done.

2.1 North-South and South-South collaborations and the role of higher education institutions

When progressing toward the SDGs, North-South and South-South relations and other triangular regional and international collaborative efforts have been recognized as enablers of ICT adoption and capacity development (UN Open Working Group on Sustainable Development, 2015). Through technology adoption and capacity development, the post-2015 development agenda aims to increase significantly the availability of high-quality, timely, and reliable data that can be disaggregated by various relevant parameters (Gupta and Vegelin, 2016). Even before the post-2015 agenda took effect, it has been recognized that North-South collaboration is a necessity in terms of multilevel capacity development around HISs (PEPFAR, 2012). The multiple levels as perceived by PEPFAR include individual, organizational, and policy-level capacity development. However, similar to most donor-funded HISs that fail to sustain beyond the piloting phase (Kimaro and Nhampossa, 2005), capacity development initiatives that depend on external experts alone may also fail to sustain beyond a certain point – particularly when donor support seizes to exist (Lucas, 2008; Khang and Moe, 2008; Cibulskis and Hiawalyer, 2002). Therefore, it is important for North-South collaborations to be reinforced with regional and national-level efforts to better strengthen sustainability of the systems being developed.

In developing country contexts, capacity development in health informatics has been approached typically by way of individual researcher training, learning by doing, North-South partnerships, and establishing centers of excellence in the Global South (Lansang and Dennis, 2004). Among these approaches, North-South collaborations, as in the case of institutions in the Global North undertaking technology transfer initiatives in the Global South, seem to dominate (Chu et al., 2014; Lansang and Dennis, 2004). However, Hersh et al. (2010) recognize a possible challenge in sustaining these initiatives when such approaches do not align with one another and are not sensitive to the contextual requirements. Braa and Muquinge (2007) recognize the lack of South-South collaboration in terms of health informatics capacity development and its weak linkages with North-South collaborative efforts as the potential reasons for this perceived challenge.

2.2 Gaining legitimation in capacity development

In our view, the phenomenon just described is explainable by Ridgeway and Berger's (1986) and Suchman's (1995) view of 'legitimacy'. According to Ridgeway and Berger,

legitimacy refers to certain practices or processes becoming acceptable to a particular social group as normative practices. In Suchman's view, legitimacy is "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman, 1995: 574). In information systems (IS) research, legitimation is increasingly recognized as an alternative to the technology acceptance theories and as being at the forefront of IS and also information and communications technologies for development (ICT4D) research (Bergek et al., 2008; Hussain et al., 2004; Prakash and De, 2007). In terms of capacity development and the role played by higher education institutions such as universities, legitimation would entail satisfying all stakeholders, including those who would ultimately utilize the services of those being trained (Luna et al., 2014; Frenk et al., 2010). The question, however, is how stakeholders can be made to recognize capacity development efforts as being legitimate in terms of contributing to national interests such as achieving the SDGs.

With regard to this question, we draw from Shidende et al. (2014) who described the role of the universities as creating 'implementation mediators' who can communicate better, convey requirements, conduct capacity development, and cope with contextual challenges. At the same time, Klerkx et al. (2009) have elaborated on the role of innovation brokers who would merely be taking part in building appropriate linkages in innovation systems, and facilitating multi-stakeholder interaction. In terms of HISs, however, the complexity dictates the necessity for having mediators who would be able to move between health and ICT domains in addition to playing the role of an innovation broker (Shidende et al., 2014; Bayardo et al., 1997). From a legitimation point of view, mediators could therefore be thought of as both the result of and the contributor toward the legitimation of capacity development efforts undertaken by higher education institutions, or any other organization for that matter.

2.3 Multidisciplinarity in health informatics

In a recent book, Sahay et al. (2017) have argued strongly for the need of a multidisciplinary approach in research and practice to strengthen health informatics in developing countries. They trace historically why this approach has not been adopted in both the rich countries of the North and also in developing countries. While in the North, the origin for health informatics was driven by the PC revolution in the seventies and eighties, the medical profession dominated, and systems were driven largely for decision support applications focusing on the individual human body. While in the South, driven largely by donors, the statisticians dominated in the building of population-facing systems, largely to support monitoring and evaluation. Sahay et al. (2017) argue that a focus on the human body without considering the social context or focus on the larger population without accounting for individual care is each incomplete by itself. In the contemporary context of Universal Health Coverage and rising threats of Non-Communicable Diseases, etc., there is a need to merge both these domains of HIS. This would enable us to focus on individual continuity of care, and from data of these individual encounters, generate population-based statistics — for example mortality and morbidity statistics for the population.

After laying out this problematic, Sahay et al. (2017) argue that a key ingredient to developing this integrated perspective is to evolve a multidisciplinary approach that can

lead to the articulation of socio-technical methods. They use the metaphor of 'airplanes don't fly, airlines do', to argue that technology cannot do anything on its own, unless it is seen as part of complex and heterogeneous networks involving people, institutions, practices, history, and culture. Building such networks then necessarily requires a multidisciplinary approach involving informatics, statistics, medicine, public health, and in the modern context, even disciplines such as finance, governance, and politics.

Developing this multidisciplinary perspective has been historically a deep challenge for reasons both institutional and individual. University departments, especially in developing countries, are notoriously difficult to innovate, and they have many hurdles in modifying curriculum and developing joint programs involving computer science and medical faculties. Institutionally, donors tend to adopt singular perspectives that typically promote disease-specific interventions involving medical doctors, and in some cases ICT experts, but rarely both integrated together. Similarly, at the individual level, we tend to be resistant to change, and tend to protect our individual domains of expertise. Doctors tend to believe they are also experts in technology and can build useful systems independently. Similarly, ICT experts wonder why they need disease experts to help design systems, as they can easily access such knowledge. Breaking down these barriers at institutional and individual levels becomes a great challenge that current health informatics developments face.

2.4 Networks of action and the innovation ecosystems

In the face of such multidisciplinarity, we are convinced that there are multiple actors involved in capacity development efforts around health informatics — particularly in developing country contexts where donors play a prominent role. It is also apparent, however, that capacity development efforts and the products of such efforts — recognized herein as the mediators — should gain a desirable legitimation for capacity development efforts to sustain. What is unclear to us at this point is how different actors involved in capacity development around health informatics should organize themselves in order to gain the desirable collective legitimation.

Braa, Monteiro, and Sahay (2004) provide us with some clarity as they recognize that actions toward sustainability and scaling of HISs in developing contexts should be situated within a network — the Networks of Action — to enable collective learning as against being singular units that must continuously reinvent the wheel of learning. They bring to the forefront more than a decade of experience emanating from the organization of the Health Information Systems Program (HISP) — an extensive South-South-North network with a focus on open-source-based information systems for public health care (Braa et al., 2007). The network in this case is formed around the open-source HIS — District Health Information System (DHIS).

DHIS was first developed and introduced in the mid-nineties in South Africa with the intention to improve health data quality and its subsequent use (Braa et al., 2007). Following its successful implementation in South Africa, DHIS has evolved into its current version – DHIS2 – which has now become the backbone of many HISs in more than 50 countries. DHIS2 has helped to bring together through the HISP network multiple actors from the domains of both practice and research at both local and global levels (Braa et al., 2007). This would mean that capacity development around DHIS2 could also

take place at both local and global levels, feeding into the interests around the successful development, evolution, and adoption of DHIS2.

Thus, Braa and Sahay (2012) have extended the notion of networks of action into being an innovation ecosystem around DHIS2. This conceptualization emphasizes the importance of enabling innovation within networks of action and its role in sustainable development as described by Mansell and Wehn (1998). Innovation within an innovation ecosystem would take place when different actors within the ecosystem share their expertise and experiences with all others to enable cumulative learning around the reference technology. Thus, from an innovation ecosystem perspective, capacity development efforts should provide enough opportunities for those who are trained to interact with a recognized innovation ecosystem.

However, what's lacking in current literature is how aspects such as North-South and South-South collaborations, the higher educational institutions, legitimation, and multidisciplinarity in term of health informatics could support networks and innovation ecosystems. We perceive this to be a gap in IS literature and we consider fulfilling this gap a means of accelerating IS developments in developing contexts.

Thus, the research questions that we will be answering through this paper can be elaborated as follows:

- What capacities around health informatics would contribute toward the propagation of health information systems taking aim at sustainable development goals?
- How should developing contexts model their capacity development efforts in health informatics within the contexts of networking and innovation ecosystems aimed at fast-tracking sustainable development goals in health?

3. Research Approach

In this section, we elaborate how we conducted this study as an in-depth longitudinal study spanning over eight years. In doing so, we first present the case context and argue for its relevance in answering our research questions. Next, we present the research design before elaborating on the data collection methods, analyses of the gathered data, and the role of the researchers.

3.1 Case context

Among South Asian countries, Sri Lanka is a leader in terms of many of the health indices (WHO, 2015). It can boast of a free education system up to university level, and even up to postgraduate level in the case of medical professionals. This is in addition to Sri Lanka having a free health system, thus paving way to achieving universal health coverage (Tangcharoensathien et al., 2015). During the last decade, Sri Lanka has seen rapid growth in its ICT and telecommunication infrastructure, mobile and internet penetration, and computer literacy, as well as in its focus toward improving quality of the health care received by its people (Brahmanage and Weerasekera, 2011). However, the country lacked the necessary capacity to use these favorable conditions to facilitate HIS innovations and their implementation. It is in such a backdrop that the Postgraduate Institute of Medicine (PGIM) of the University of Colombo in collaboration with the University of Oslo (UiO) embarked on an ambitious program to educate medical doctors in becoming health informaticians.

In Sri Lanka, training of specialist medical doctors in all specialties is carried out by PGIM. The institute offers Postgraduate Diploma, Master's, and Specialist qualifications (Doctor of Medicine (MD)) in over 50 medical specialties and subspecialties, thus fulfilling the total requirement of specialist and non-specialist doctors within the public health sector. Doctors at the Ministry of Health (MoH) attend postgraduate training programs at PGIM with full-paid study leave. Following completion of the training, all doctors are re-absorbed into the MoH, either into a specially designated cadre position or as general medical officers. In addition, given that PGIM is the only institution in the country authorized to grant specialist qualifications (Board Certification) to doctors, the MoH becomes PGIM's main client. Thus, capacity development efforts undertaken by PGIM, by default, will include representations from the MoH along with other state and non-state sector stakeholders such as professional colleges.

From the side of the UiO, the collaboration was facilitated by a Norwegian Masters (NOMA) grant from Norad managed by the Norwegian Centre for International Cooperation in Higher Education (SIU). Norad's financial support made it possible for the UiO to become the technical partner in the design, development, and implementation of the master's program in health informatics that is the analytical focus of this paper. The financial support offered through the NOMA program was distributed to PGIM over four years beginning 2010, to support scholarships, for development of infrastructure, and for enabling study tours and participation in international conferences. The funding also supported practical systems development as a part of student thesis work in an effort to better integrate research, education, and practical systems development and implementation.

A multidisciplinary multi-stakeholder committee — the Specialty Board in Biomedical Informatics ('the Board') — developed the curriculum to cater to local needs and managed the delivery of the program using a multispecialty faculty drawn from the health and IT domains in collaboration with UiO. Since 2010, the Board has overseen the completion of five batches of postgraduate students comprising over 90 medical doctors. Table 1 depicts the status of each batch up to December 2016.

Table 1. Evolution of the health informatics master's program at PGIM — status as of December 2016

Batch	Year of enrolment	Funding source	No. of students applying	No. of students per batch	Current state
Batch 1	2008	NOMA/MoH	54	33	Already graduated
Batch 2	2010	NOMA/MoH	66	31	Already graduated
Batch 3	2010	NOMA/MoH	52	21	Already graduated
Batch 4	2012	NOMA/MoH	26	14	Already graduated
Batch 5	2014	MoH	10	9	Already graduated
Batch 6	2015	MoH	22	22	In training (2nd year)
Batch 7	2016	MoH	49	32	In training (1st year)
Total			279	162	

Thus, the empirical data for this research originated from the activities around the conduct of this health informatics program (officially titled 'Master's Programme in

Biomedical Informatics') at PGIM. From the point of view of this research, there were several reasons for selecting this program and Sri Lanka as the study context. First, the strong linkage between the university and the MoH meant that we as researchers would gain the ability to follow the students into their work practices with minimum hindrance. Second, the information technology and telecommunication infrastructure development and increased mobile and internet penetration in Sri Lanka also enhanced the government's interest in health informatics. Third, the health informatics program at PGIM is among one of the many programs implemented in developing countries with support from NOMA — and perhaps one of the most successful. Last but not least, three of the four authors of this paper are originally from Sri Lanka with strong ties to its educational and health care domains. This meant that Sri Lanka became the obvious choice for this paper as it provides the potential to become a model for other developing countries.

3.2 Research design

Given the case context and our focus on the evolution of the health informatics program over eight years (2008 to 2016), we considered in-depth longitudinal case study methodology (Yin, 1994) as a suitable research approach. This approach also allowed us a systematic way of observing events, collecting data, analyzing information, and reporting results over a prolonged period of time (Zainal, 2007; Yin, 1994), drawing upon the expertise and experience of the authors of this paper.

All the authors of this paper have been involved in the program since its inception. Two of the authors pioneered in establishing the initial collaboration between the two universities and with the funding agency. Thereafter, they have been involved in the management of the program at the highest level and were also part of the faculty throughout the period of this study. The other two authors of this paper have also been part of the program since its very inception and were actively involved at the operational level of the program, including teaching courses and supervising student projects. More importantly, both these authors undertook doctoral studies around the program focused on teaching, learning, capacity development, governance, and innovation ecosystems. Thus, their work allowed us ready access to data gathered at different points in time throughout the research period.

3.3 Data collection

Given the study design, the data collection for the purpose of this paper also took place at different points in time throughout the eight-year period, employing methods such as semi-structured interviews, participant observations, field notes, focus groups, and document analysis.

Data relating to the early stages of the program, from 2008 to 2012, were largely gathered from archives, which included notes from significant meetings of the Board, and through other forms of document analysis. As suggested by Walsham (2006), historical accounts by study participants and impressions of various events noted by the authors themselves were also considered as data for analysis. From 2012 onward, our data collection methods were largely driven by semi-structured interviews conducted by two of the authors as part of their doctoral studies. These interviews enabled the interviewees to express their views and interpretations regarding the conduct of the master's program, its influence on practice, and ways and means of sustaining the program, and in terms of aligning the

program with SDG-driven health sector reforms. Many of the interviews were conducted face-to-face at PGIM, at the Ministry of Health, or in institutions associated with the master's program. In some instances, Skype was used to conduct distant interviews. In general, each interview lasted about 30 to 45 minutes and was digitized using an audio recorder after obtaining the interviewee's consent.

Focus groups were conducted on two occasions, first in 2013 and then in 2016. The participants of these focus groups were students of the master's program who later took up informatics-related posts at the MoH. Each of the focus groups consisted of 18 and 22 students respectively and the meetings were used to derive their perceptions of the ongoing program and its impact on their own practices. The focus group discussions were also digitized. These records were supplemented by observatory notes made by one of the authors while the other moderated the discussion.

Another means of data collection was the online learning platform based on the Moodle learning management system. The online platform was designed for training students on DHIS2 and it included online discussion forums where students, tutors, and local and global HIS professionals exchanged ideas. These discussions not only gave insights into various themes being discussed but also indicated how communities were being formed among the students and within the wider network (Siribaddana, 2015). At the same time, the alumni of the program, the tutors, and the students were also brought together by a mailing list, thus facilitating ongoing interaction.

In addition, the paper was also contributed to by observatory notes made by the authors at different instances involving student interactions, laboratory sessions, training programs, and prototyping sessions of the emerging HISs. These notes were valuable in giving us the insights into planned and unplanned manifestations of the program and community formation among students, and in gathering evidence into how learning transformed into actual work practices. A summary of the data gathered is presented in Table 2.

Table 2. Summary of data collection methods

Method	**Activities**
Semi-structured Interviews	32 student interviews in total in 2012, 2014, and 2016 3 interviews of Specialty Board members 14 interviews in 2014 and 2016 among stakeholders of the program, including HIS managers, institutional administrators, and policymakers
Participant observations	Observatory notes amounting to around 120 pages
Online discussion forums and electronic mailing list	Around 600 posts made by students, tutors, and HIS professionals within the Moodle discussion forums and around 200 e-mail posts made through the mailing list
Focus groups	Two focus groups consisting of 18 and 22 students respectively, conducted in 2013 and 2016
Document analysis	Notes made of significant meetings of the Board from 2010 to 2016 (approx. 70), two publications, four newspaper articles, and one report in relation to IS developments emerging from the program

3.4 Data analysis

Our approach to analyzing data was inductive and was interpretive in nature. The approach enabled themes, concepts, and models to emerge from the raw data (Strauss and

Corbin, 1998). In doing so, we made several assumptions in line with a general inductive approach as described by Thomas (2003). One assumption is that the data analysis would be determined by both multiple readings and interpretations of raw data in light of the context being studied. Second, we accepted the fact that our interpretations would be influenced by our own experiences and assumptions. Third, we relied on a multiplicity of interpretations (of the authors) rather than build on a singular perspective.

In line with these assumptions, the interpretive process adopted by us involved all the authors who collectively came up with categories and themes. These were refined and developed using an iterative process (Miles and Huberman, 1994) that also took into account the experience and the understanding gathered by us throughout the study period. The developed themes along with the relevant categories are summarized in Table 3.

Table 3. Summary of the categories and the themes derived from the analysis

Themes	**Categories**	
	Research question 1	**Research question 2**
Gaining legitimacy	Intercultural communication	• Capacity to participate • North-South/South-South collaboration • Multidisciplinarity
Coupling training and professional practice	Action learning	• Control over evolution • Creating organizational buy-in • Resource pooling
Institutionalization of unique capacity in MoH	Contextual expertise	• Symbolic acceptance, revenue model, and valuable social activity • Policy backing
High-impact research and development	Macro-level focus	• Transformative effect • Contribution to science and practice
Ensuring sustainability	Networking skills	• Workforce retention • Entrepreneurship • Evolving community

3.5 Role of the researchers

In qualitative research, there is always the possibility of the experience, understanding, and presumptions held by the researchers influencing the interpretations made on research data (Walsham, 2006). From our point of view, being part of the same case that is being investigated made us more aware of the potential for our interpretations to be influenced by our own presumptions and judgments. However, the collective approach toward forming, refining, and developing themes emerging from the data provided us with the ability to come up with interpretations that are theoretically driven and are well grounded in the empirical observations (Myers, 1997). Furthermore, the team of researchers involved in this paper was itself multidisciplinary, representing areas of public health, medical education, medical informatics, social sciences, and bioinformatics. Thus, these insights enriched the interpretations made and facilitated an in-depth analysis.

4. Case description and analysis

In 2008, when two of the authors negotiated with PGIM to host the Health Informatics program, there were questions regarding its acceptability by the medical community — MoH in particular. This could be inferred from statements such as "the ministry doesn't see the value of allowing doctors to perform the role of an IT person" and "the government should not waste money on training doctors to do someone else's job" (Extracted from historical accounts of an early collaborator). In our view, these statements pointed to an issue of 'legitimacy' (Ridgeway and Berger, 1986), as discussed in the Literature Review section of this paper.

4.1 Gaining legitimacy

In terms of higher educational institutions such as PGIM, legitimation is the outcome of different institutional processes (Hybels, 1995). The aim of these processes is to align the activities of the educational institution with socially defined standards and market expectations (Anderson and Smith, 2007). Thus, it was imperative from a capacity development point of view that the health informatics program gain acceptance from the relevant stakeholder groups. The challenge, however, was to develop legitimization processes that catered to the different interests of different stakeholder groups (Radu Lefebvre and Redien-Collot, 2012). While for the MoH these interests could relate to how the graduates fit into their existing cadres, for the doctors the concern could be how embarking into the informatics domain eroded or built upon their medical careers.

4.1.1 Capacity to participate

One approach adopted by PGIM that seems to have facilitated the legitimization of the Health Informatics program was to set up a committee that brought together the key stakeholders of the program. Within the structure of PGIM, this was possible by establishing a Specialty Board, referred hereafter as 'the Board'. The aims of setting up this Board were multiple and according to an early collaborator and a Board member:

> Setting up the Board will allow us to keep all parties informed of what we are doing and get their consent before making any training related decision. It will also help representatives from other specialties to recognize our work as not encroaching on their own professions…. Hopefully this will avoid future conflicts. (Board member, 2012)

In terms of capacity development, the Board may be considered as a means of mitigating the unequal social relationships that may be existing between different actors and organizations involved in education, IS design, and health. As pointed out by Puri et al. (2004), in terms of IS design, it is imperative that participation of stakeholders be facilitated from the very onset. To an extent, the Board seems to facilitate this requirement in relation to HISs in the Sri Lankan context at a higher level. It also created multiple channels of communication between the academic environment of the students and their prospective work settings. From an innovation ecosystem point of view, this potentially fulfills one of its requirements for facilitating communication between different stakeholders through multiple channels (Estrin, 2008). Not only does such communication facilitate a culture of innovation (Ahmed, 1998) but it also contributes to maintaining trust between the said stakeholders (Ellonen et al., 2008).

4.1.2 Multidisciplinarity and intercultural communication

Essentially, health informatics has been recognized as a multidisciplinary subject that requires inputs from different fields of science (Wyatt and Liu, 2002; Dalrymple, 2011). In line with this understanding, early collaborators also recognized the necessity for multidisciplinary inputs as evidenced in statements such as:

> ...the program is multidisciplinary and this means that we need others apart from doctors to come and teach our students and also for our students to engage with students from other universities. (*Early collaborator and Board member, 2012*)

Thus, while the Board consisted of members representing multiple stakeholder groups, the teaching panel also was multidisciplinary as it consisted of public health experts, medical educationists, project managers, health experts, and IT experts including bioinformaticians. Such inputs may have helped health informaticians to avoid potential conflicts with other professional groups representing IT, administration, public health, and even clinical sciences within the MoH. This was later apparent as trainees expressed their ability to work closely with other specialists by stating

> ...others [specialists in other clinical and nonclinical streams] recognize us as supplementing their work and are willing to work with us and make use of our skills. *(Student from batch 2, 2016)*

At the same time, the multidisciplinary inputs in the program seem to have expanded the competencies among the doctors who are undergoing training. This was evident as those who have completed training indicated that they have been contributing as project managers, developers, implementers, policymakers, and even as information security experts either alone or with other professionals in relation to e-health projects at the MoH (Focus group, 2016). Thus, the multidisciplinarity within the program seems to have provided legitimacy to the capacities being developed, as desirable by the relevant stakeholder groups. At the same time, multidisciplinarity at the level of program management and execution would impart the competency of intercultural communication among the students (Brillinger and Kagolovsky, 2008). Given that health informatics projects are diverse endeavors with complex mosaic of ‘cultures’ (Murphy, 2009), the competency thus developed would help the students to perform the task of ‘mediator’ better.

4.1.3 North-South/South-South collaboration

The affiliation with UiO and HISP, in our view, provided another mechanism toward legitimization not only in terms of the program’s quality, but also in terms of its ability to produce someone who could support the development agenda set forth by the MoH. This became apparent to us through statements such as

> We have recognized HISP to be a global leader in health information systems and therefore we are sure that the PGIM program can support us in developing the health sector. *(MoH representative in the Board, 2011)*

> Oslo not only provided us with funding but it enabled us to be part of the HISP network that benefits us even at present. *(Board member, 2016)*

However, we also noted that the affiliation with UiO was never intended to be a dependent relationship but instead a collaboration that would empower PGIM and the MoH to sustain the program independently over time.

> We [UiO] want you [the PGIM] to take over this program as we realize there's enough potential to do so locally ... *(Representative from the UiO, 2009)*

From a capacity development point of view, we interpret this partnership as a scaffold for the capacity-strengthening efforts to be embedded within the network of actions (Braa et al., 2004). The network of actions in this case does not necessarily limit to North-South collaboration but also facilitates South-South collaboration as any one node can connect with any other within the global HISP network. For example, Sri Lanka is actively collaborating with HISP India for DHIS2 development and capacity strengthening, and this includes a strong and vibrant student internship program.

4.2 Coupling training and professional practice

When looking into the health informatics program thus formed, there have been many instances where board members and even students have discussed the necessity for coupling classroom teaching with professional practice. In relation to health informatics, Wyatt and Sullivan (2005) recognize hands-on training in real-life situations as facilitating knowledge translation. Thus, workplace-based learning and skills, in our view, became an important consideration for capacity-building efforts.

The health informatics training program was designed in such a way that from the second semester of the two-year program, the students are attached to various state sector institutions and units within the MoH. During these attachments, students are expected to come up with suitable research projects that aim at resolving practical issues. As pointed out by one of the Board members, it was believed that

> training should not happen without them being placed in their future work settings as we need to link their learning with actual practices ... *(Board member, 2010)*

Thus, the program by design has been supporting workplace-based learning as desirable in a professional training program. However, the learning as perceived by the Board and by the stakeholders alike was not necessarily an apprentice type of learning (Raelin, 2008). The learning in this instance became action learning where students engage in real-life problems and actual implementation (Billett, 2001). Thus, the aim was to develop desirable capacities among the students to such a level that they would reduce the required lag period once they start working on their own in the MoH post their studies (Board member, 2012).

However, in order to facilitate action learning, it was necessary to create opportunities for the students to engage with real-world problems through appropriate work placements. This, and creating appropriate cadres of engagement, required active negotiation by the PGIM authorities with the MoH.

4.2.1 Control over evolution

The initial placement of students in the work setting did not follow specific criteria. With time, it was recognized that the MoH and its various units, which receive the services of students, cannot sustain some of the initiatives when the students leave these places at the end of their training (Meeting notes, 2012). Thus, it was decided by the Board to align the

student projects with the ongoing needs of the MoH, which was conveyed to the Board by its MoH representatives (Meeting notes, 2012). While this may have impeded the natural evolution of an innovation ecosystem as perceived earlier (Estrin, 2008), it does contribute toward maintaining focus on the more important development agendas of a particular context (Chen et al., 2008). In other words, strategic placement of students in this case can be interpreted as a way of 'control' in terms of what capacities are best needed to enable IS evolution.

4.2.2 Creating organizational buy-in

To align capacity development with national agendas, PGIM decided to invest in potential training units facilitating student training and project implementations (Meeting notes, 2011). The investments came in the form of student support through the NOMA project and the funds allocated to student projects were allowed to trickle down to their training units in fulfilling infrastructure, software, and other needs that are important in creating an effective and proactive health informatics learning environment.

These investments have created a binding link between work settings and the academic environment at PGIM, as stated by one of the MoH administrators (2014):

> It was the PGIM that supported us in developing our unit and therefore we welcome BMI students anytime and will do our bit to provide them with the necessary resources.

From the point of view of student projects, the investments meant that they were able to progress beyond a mere prototype design and gain wider visibility. In some instances, such visibility facilitated the gaining of a critical mass that translated student projects into national-level systems (Van Slyke et al., 2007). This became apparent from some of the comments made by students:

> It would have been impossible to convince my superiors at the unit if I wasn't able to develop the full system and made its staff use the system. *(Batch 2 student, 2014)*

> If I waited for funds to come from the ministry, even I would have given up the idea of implementing this system at a bigger scale. *(Batch 1 student, 2014)*

We interpret these findings as appropriate distribution of funding, which Braa and Sahay (2012) recognized as imperative in building networks around health informatics in the South.

4.2.2 Resource pooling

Furthermore, it was realized at the beginning of the program that lack of insight from actual practitioners during classroom teaching may distance student learning from reality. In fact, one student emphasized this point by stating,

> Although lecture sessions are useful, I cannot understand how this would be useful in my future practice and the lecturer [who is an IT expert] was not able to give me the necessary insights from a health care setting ... *(Batch 3 Student, 2014)*

Initially, the health informatics program was struggling to recruit resource personnel who could give such insights given the lack of e-health projects and health informatics expertise within the country. However, the Board created a pool of resource personnel of

students who had already graduated, who are now managing e-health and informatics-related projects in the MoH. This action, in our view, facilitated the pooling of resources, which Braa and Sahay (2012) recognized as a necessary component of effective networks of action.

Another instance where pooling of resources became apparent is the participation of the alumni of the program in the capacity development process using the electronic mailing list. This meant that insights regarding ongoing HIS developments at the ministry reached the student population, thus generating interesting discussions. The issues discussed varied from gaining ministry support for projects, securing resources, resolving technical issues, to determining the feasibility of adopting novel technologies to the local context (Gathered from the analysis of forums and e-mail list posts).

4.3 Institutionalization of unique capacity within the MoH

According to Scott (2001, p.49), institutions are "multifaceted, durable social structures, made up of symbolic elements, social activities, and material resources." In order to create long-term value, sustainability, and scalability of an action — such as capacity development around health informatics — it is necessary for such actions to be institutionalized (Scott, 2001; Kimaro and Nhampossa, 2007). While the process of institutionalization was touched upon to a certain extent in the earlier section under the theme 'gaining legitimacy', we recognize institutionalization as a multistep process in line with Madon et al. (2009). Thus, any action that contributes to gaining symbolic acceptance from a particular social group stimulates valuable and routine social activities related to the said group, creating viable revenue models, and helps enroll government support that will further strengthen the institutionalization process.

In relation to the health informatics program, it became clear to us that until sometime after the program started, graduates were not so sure as to what their roles were within the MoH post their studies. One student expressed his concern by stating:

> Although I follow this course I am not sure whether the Ministry will be able to make use of us productively ... What we have to do in some units is to create presentations and excel sheets for the seniors and that is a waste of what we have learnt ... *(Batch 2 student, 2012)*

Such assumptions, according to some Board members, were "the result of students not seeing a career path within the MoH and that they feel unsafe about their own destiny" (Board member, 2012). Thus, efforts toward the creation of a career path gained traction as the first two batches were about to enter the services on completion of their studies (Meeting notes, 2013).

4.3.1 Symbolic acceptance, revenue model, and valuable social activity

The representation of the MoH in the Board and the lobbying by different groups facilitated the creation of a special cadre position called the Medical Officer in Medical Informatics (MOMI) in the MoH (Focus group, 2014). Creation of MOMI allowed the ministry hierarchy to refer to the capacities of a health informatics postgraduate whenever the need arose, articulated by one of the graduates as follows:

> The ministry is now relying on the BMIs for coordinating and fulfilling various technology requirements including preparing tender documents, participating in

> technical evaluation committees, engaging with the ICTA [the national information and communication technology agency] and in local implementations of ICT solutions ... *(Student from batch 1, 2016)*

From an institutionalization point of view, the career path not only fulfilled the necessity for a revenue model —in terms of both earnings for graduates and cost savings for the MoH — it also fulfilled the need for a valuable social activity — to be recognized as health informaticians (Madon et al., 2009). At the same time, it may have provided for legitimation of the skills of a health informatician, and therefore, as pointed out by Suchman (1995), it would enable the students to embed themselves within the socially constructed norms, values, beliefs, and definitions of the national public health system.

4.3.2 Policy backing

In parallel, the national e-health policy also recognized the qualification of health informatics postgraduates and their contribution in national-level development programs (National e-health policy (draft), 2015). Such recognition may be considered as fulfilling the requirement to gain government support in terms of institutionalization (Madon et al., 2009). From the point of view of the students, institutionalization of their capacity has given stability and hope to their careers, as was perceived by one of the students:

> I now feel that the health sector depends on us to come up with technology solutions, which also motivates me in my work. *(Batch 2 student, 2016)*

4.3.3 Contextual expertise and harnessing the tacit knowledge

Moreover, the graduates of the health informatics program have now become a community of their own. Being part of this community through various means enables students to gain contextual expertise and the tacit knowledge embedded within the community that are necessary in engaging with administrative, socio-technical, political, and even financial challenges that come in their way (Focus group, 2016). This also implies that efforts toward institutionalizing health informatics capacity development seem to have achieved its intended objectives. To highlight this further, it would be necessary to evaluate the outcomes of the initiative in terms of development-focused research and information system implementations.

4.4 High-impact research and development

From 2010 to 2016, several national-level health informatics projects were initiated by the students and the graduates. Table 4 describes some of these projects.

Table 4: Some of the national level HISs emerging through the capacity development effort

Project	**Impact on the national health system**
e-IMMR	The electronic indoor morbidity and mortality registry provides the aggregate statistics of the curative sector. As of today, it collects more than 80% of hospital-based mortality and morbidity statistics with ICD coding through medical record officers located in health care institutions. It was the first system to be implemented countrywide.
e-Registry for the National Program for Tuberculosis Control and Chest Diseases	A DHIS2-based public health information system to capture the information related to tuberculosis and other respiratory disease management.
Hospital Information System (HIS)	In-house EMR for the State health sector developed by identifying the national needs and aligning them with the national policy. Currently being implemented in several curative health institutions, including leading

	tertiary care and specialty hospitals.
Malaria Information System	Aimed at facilitating the vector control and case identification by the Anti-Malaria Campaign of the Ministry of Health.
National Nutrition Monitoring System	National Nutrition Monitoring System is a combination of District Nutrition Monitoring System for health sector stakeholders and the Nutrition Intervention Tracking System for non-health sector partners. It is used to identify malnourished children and nutritionally at-risk households with mobile-based field-level data collection.
NCD Information system	Caters to the information need to identify noncommunicable disease (NCD) risks and assessment of effectiveness of NCD interventions.
Disaster Management Information System	An inventory management system to facilitate the emergency operations of preventive and curative health institutions during disaster situations.
Cause of Death and Smart Verbal Autopsy	The Smart Verbal Autopsy is a mobile-based solution to empower Public Health Midwives to gather community-based information to identify the probable cause of death for better national projections of underlying causes for mortality statistics.
eRHIMS	Mainly focuses on maternal and child health information needs of the Family Health Bureau.
National eHealth Base Documents	The national eHealth base documents comprise the National eHealth Policy and National eHealth Standards and Guidelines. Health sector supplements to the National eGovernment Policy of Sri Lanka. It has identified several areas of eHealth to be governed by aligning it with national needs.

High impacts related to the case will further be elaborated at the end of the analysis in Table 6.

4.4.1 Transformative effect

Almost all of projects summarized in Table 4 were aimed at automating and at the same time expanding the existing manual HIS, thus allowing timely and accurate health information to the practitioners and data managers. One of the MoH administrators stated (2016):

> Almost all health information projects in the ministry have been started and run by the BMIs and it has helped us to provide accurate health data without a delay. For instance, the annual health bulletin has been delayed by around five years and now the delay is mere one year after the introduction of e-IMMR.

Some projects also contributed in terms of empowering the health workers. This was evident in the case of National Nutrition Monitoring System (NNMS), which empowers midwives in several districts to take control of their own data. Observed another MoH administrator:

> The NNMS has fulfilled the need for accurate and timely capturing of nutritional data that would allow us to overcome the issue of malnutrition in rural areas including in areas of tea plantations.

From an ICT4D point of view, these projects seem to have answered the call for high-impact research and development, which are perceived as having a transformational effect on a social group within a developing country context (Robey, 2003; Agarwal and Lucas, 2005). To support the transformative effects, however, there was a need for research work to be disseminated to the right audience.

4.4.2 Contribution to science and practice

While many of these projects materialized as problem-solving initiatives, it was necessary for these research projects to contribute to the theoretical and practical knowledge domains of health informatics in developing countries in order to make a lasting impact (Agarwal and Lucas, 2005; Qureshi, 2015). One avenue for this was the Sri Lanka Journal of Biomedical Informatics (SLJBMI), which came into being as an online open journal with backing from PGIM (Meeting notes, 2010). From 2010 to 2013, fifteen issues were published and many of the articles were contributed by course graduates. At the same time, several international conferences — e-Health Sri Lanka 2010 and 2014, e-health Asia 2015 — were organized by PGIM in collaboration with the MoH and the Health Informatics Society of Sri Lanka (HISSL) to provide a platform for sharing scientific knowledge and experiences with local, regional, and international members in the IS community.

In addition to establishing a publication outlet, the Board also took the decision to invest in capacity development and knowledge dissemination by utilizing the NOMA grant to sponsor both students and the faculty to attend conferences of international repute as presenters (Meeting notes, 2011–2013). From 2010 to 2014, many BMI students (around 40) and 10 to 15 academics from the Board were able to participate in international conferences and engage in knowledge sharing with delegates from other countries. In addition, three academics including two of the authors of this study received scholarships to complete their PhDs at the UiO. The scientific contributions and the accolades received by the students of the program in relation to their projects or IS developments are summarized in Table 5. Such contributions would impact not only the ongoing or future IS developments but also the health informatics research landscape.

Table 5: Publications made and awards received by students based on their projects or program related IS developments

Year	No. of journal publications	No. of conference publications	No. of national/international awards
2010	2	1	
2011	5	3	1
2012	7	9	
2013	11	3	
2014	3	14	2
2015	5	18	
2016	4	31	7
Total	**37**	**79**	**10**

4.4.3 Competency in macro-level research focus

In order to achieve what was discussed earlier, there was a need for students to develop competencies around research and publication alongside the practical knowledge in health informatics. According to some of the graduates of the program, the motivation for them to reach for higher goals in terms of their projects manifested following being exposed to international IS conferences of the highest caliber (Focus group, 2014). Through their ability to focus their projects on macro-level issues such as e-health policy effects, empowerment of health staff, improvement of the quality of care delivery, governance, etc.,, the students were able to impart a significant impact on broader health sector development (Board member, 2015). In terms of IS research, focus on macro-level

issues is desirable as it can demonstrate the transformational impact of ICTs as against micro-level or operational issues (Agarwal and Lucas, 2005). Thus, we are able to ascertain that from a capacity development point of view, the program has given students the opportunity to look into the transformational impact of their projects in line with the national policies as against working in isolation and at a micro level.

4.5 Ensuring sustainability

During the initial discussions, there were doubts about the sustainability of the course beyond the NOMA funding period (Meeting notes, 2011). In particular, questions were asked by early collaborators and board members as to how PGIM could sustain this program when the generous funding coming from the NOMA project, such as sponsoring of projects, free laptops, foreign study tours, sponsoring of conference participation, and funding support to develop work settings, seized to exist. The financial sustainability of the program was assured, because at the end of the funding period the MoH started providing the funding for the course. That, however, was not enough for long-term sustainability of the course.

4.5.1 Workforce retention

In typical developing country contexts, health workforce retention is a recognized issue and highly specialized professionals in particular, such as health informaticians, may be compelled to seek greener pastures given the high demand in more developed settings (Willis-Shattuck et al., 2008; Anyangwe and Mtonga, 2007). According to Willis-Shattuck et al. (2008), both financial incentives and motivation may play a crucial role in terms of workforce retention.

In fact, the number of students applying for the MSc program dropped drastically four years into the course and we were unable to fill the 30 student placements in 2013. The number of students fell to 14 and 9 in 2012 and 2014 respectively (Please see Table 1) because the commencement of the MD course, which would have ensured them a successful career, was delayed due to institutional reasons. However, with the announcement of the commencement of the MD program with Board Certification as a Specialist in Health Informatics – which allows holders of master's qualification to progress into a PhD-equivalent qualification and therefore to become consultants in health informatics – the enrolment to the program increased to 22 in 2015 and 32 in 2016. The MD program commenced in January 2017 and, interestingly, there were 67 applicants for 30 places in the 2017 intake. Thus, we interpret the decision to expand the career path of health informatics graduates, which has the potential for better incentives and motivation, a move toward workforce attraction as well as retention.

4.5.2 Entrepreneurship

However, a career path alone would not facilitate a sustainment of an academic program such as Health Informatics. Creation of opportunities for entrepreneurship was also recognized as an important element of sustainability, as also emphasized by the private sector at a discussion forum:

> Sri Lanka has a unique talent in the form of medical informaticians ... They can now look beyond their comfort zones ... and become entrepreneurs themselves. If

> they do, the capacity within the country would be recognized globally and more people will become interested in getting the support of these doctors. *(Private sector representative in a health informatics forum, 2016)*

4.5.3 Evolving community and networking skills

To an extent, by collaborating with UiO and its HISP network, capacity development efforts at PGIM became part of a broader network — the network of actions (Braa et al., 2004). This meant that those who were being trained became part of a community and were able to harness the expertise embedded within this network around information systems such as DHIS2. In fact, many of the projects listed in table 4were based on DHIS2 and did not incur an initial development cost. The widespread adoption of DHIS2 by the students and therefore by the MoH also indicated to us that the capacity development initiative at PGIM has enabled those being trained and their actions to be embedded in a complex ecosystem around DHIS2; the students expressed their agreement during a focus group:

> DHIS2 seems to hold everyone together as we are now able to communicate with our colleagues, developers abroad and implementers from the region whenever we have an issue and we feel that we are not alone. *(Focus group, 2016)*

From a development point of view, by utilizing DHIS2 and being part of the innovation ecosystem, students were able to come up with rapid solutions and fulfill the requirements at the MoH (Braa and Sahay, 2012). The result-oriented nature of these projects, and the minimum funds required in their initial design and implementation, attracted the interest of the MoH and in particular its administrators who are seeking ways of incorporating technology into their own programs (as indicated by an MoH administrator, 2016).

Based on our analysis of the capacity development effort, in Table 6, we can now summarize some of the tangible high impacts of this program.

Table 6: Tangible high impacts of this program

Areas of Impact	Indicators of high Impact	Broader health systems and development implications
Students graduating with Masters in Health Informatics	• Enrolment of 162 students (2008 to 2016) • Creation of 108 medical officers in health informatics at the MoH	99% of students enrolled had medical background, and employed by the MoH, who were seconded for studies. By returning to the MoH after their studies, contributed to create strong and sustainable capacity within the MoH
Students graduating with PhDs or equivalent	• 3 PhD's • 22 (registered for the MD)	PhD scholarships were enabled through the North-South (Oslo-Sri Lanka) collaboration, and their thesis topics directly contributed to research, education and practical HIS development for the MoH, Sri Lanka. The MD program is the highest qualification for a doctor in Sri Lanka and specialist qualification equivalent to a PhD. This provided a clear career path for doctors, and strong motivation for them to stay in the country and

		contribute to public health systems strengthening
Practical HIS development contributing to broader national level health systems strengthening processes	• National/program wide HISs developed and implemented - 7 • Institution focused HIS – around 20	(Please refer to Table 4 for details.) Building effective systems and supported through in-house capacity contributed to health sector wise strengthening.
Research papers published	• Journal papers – 37 • Conference presentations - 79	(Please refer to Table 5 for more details) In addition to the building of personal capacities of the authors, this helped to develop knowledge capital in tertiary education and practice.
International conferences attended	• 7 regional and international conferences attended (e.g. APAMI, APMEC, e-Health Asia, AEHIN etc.) by students and faculty of the health informatics programme.	Participation in these conferences exposed students and faculty to the international HIS context as well as provided them with opportunities to network and share experiences with other members of the community.
International conferences hosted	• e-Health Sri Lanka 2010 and 2014. • IFIP 9.4 conference 2014 • eHealth Asia 2015 • Commonwealth Digital Health Conference 2016 • APAMI conference 2018 (awarded)	Hosting these conferences posted Sri Lanka in the global map as the site for cutting edge research, education and practice around public health informatics.
Networking and advocacy	Networks established through the educational programme and supporting activities • HISSL • HISP/DHIS2 • OpenMRS • AeHIN • IMIA • Commonwealth Medical Association Advocacy • National eHealth Steering Committee • National Foundation for Open Source Health Software • National eHealth Policy • National eHealth Standards and Guidelines • Health Identification Number	Being part of these networks meant that capacity development efforts could make use of an extensive resource pool and contributions made by the students could be shared. National bodies accepted health informatics capacity as an essential component in their decision making thus enabling industry best practices and theoretical insights to be applied in resolving national HIS needs and related development goals.
Programme evolution and sustainability	• Seven batches since 2008 • Introduction of the MD program with the first batch of 22 students. • Gradually increasing demand for the masters program since the introduction of the MD program • Government investment of around 30 to 40 million LKR on student	As a result, the PGIM has been able to equip itself to the demands of the program having its own servers and hosting capabilities supporting both student and national level HIS development. The PGIM also gained recognition as a

	scholarships since 2008 • Investment set to increase by around 100 million LKR each year to support foreign placements of MD students.	centre of excellence in health informatics both locally and regionally. Created buy-in for the program and its output from the MoH thus gaining better alignment of capacity development with national HIS needs.
Entrepreneurship contributed through capacity development	• HISP Sri Lanka was established • Multiple e-health companies were engaged with dealing with personal medical records, e-learning, social media advertising, etc. • Individual consultancies carried out for to UNICEF, WHO, USAID, Vital Strategies, and other private sector organizations.	Fostering entrepreneurship capabilities in the country helps reduce external dependencies, broadens local network thus contributing to overall sustainability and scalability of the systems and processes.

As is evidenced in Table 6, the PGIM program has had multifaceted and high impacts, which are reflected in measurable indicators. Domains of impact span systems development, research, education, policy development, and also strengthening of global networking and advocacy. This mix of impacts reflects the need for approaching capacity development with a multidimensional and multidisciplinary framework. Further, it highlights that these impacts are inextricably tied to ICT, both as an object of study, and as a vehicle to enable learning about HIS and strengthening health systems.

Challenges, too, have emerged that need to addressed in the future. For example, there may be a trend being promoted where medical graduates see themselves as informatics experts who can now independently build systems. This may be a naive view, as these doctors may lack the necessary informatics expertise relating to databases, servers, technical integration of systems, and other areas of the fast-evolving domain of informatics. The problem of doctors building their own systems for their respective units of the MoH has led to a proliferation of DHIS2 instances in the country (nearly 20 at last count), which goes against the national agenda of creating uniform and standardized systems and mitigating the challenge of fragmentation.

A key learning here is for PGIM to redefine the curriculum where medical doctors are trained primarily as business analysts (defining requirements), as users of information, and mediating the relationship between the use contexts and the team of developers. This would contribute to better-designed systems and to information generated by the systems being more effectively used to strengthen health services delivery and health outcomes. Bringing about such a shift in thinking and practice is a nontrivial challenge as it would require adjustments at both the institutional and individual levels. But the positive aspect is that we have a strong, robust, and legitimized foundation to build this change upon.

5. Discussion

We started this paper by stating that developing country contexts do not receive adequate guidance on capacity development around health informatics. Therefore, we perceived that IS scholars need to be more specific in terms of their recommendations toward what capacities need to be developed and how should this be done in light of the SDGs and other national and global health imperatives. We also recognized that although certain

issues related to capacity development in health informatics have already been highlighted, these have not been interpreted in the context of notions such as networks of action and innovation ecosystems — state of the art in open-source HIS development in developing country contexts. As a result, we saw a disconnect between capacity development efforts in health informatics and HISs practically taking aim at the SDGs. This disconnect, in our view, hinders HIS evolution in the developing contexts.

According to Braa, Monteiro, and Sahay (2004), actions toward sustainability and scaling of HISs in developing contexts should be situated within networks of action to facilitate collective learning. In other words, they argue that actors or the stakeholders of HISs would have a better chance of succeeding in their HIS-related efforts if they are part of a wider network comprising multiple actors and concerted actions. Capacity development is a collective effort that may exist at different levels (Braa et al., 2004). In a way, the Sri Lankan case is also part of networks of action — the HISP — recognized by us as the North-South/South-South collaboration in our analysis.

However, the concept of networks of action alone would not fully answer our questions as to what competencies need to be developed and how this should be done. The notion of innovation ecosystems in this regard contributes to our understanding further as it brings to the forefront the element of 'innovation' and how such innovation may take effect (Chang and West, 2006; Braa and Sahay, 2012). Accordingly, in terms of HISs such as the DHIS2, innovations take place through local actions and when actors circulate between countries and between nodes (Braa and Sahay, 2012). To an extent, the case presented gained by circulating actors through its North-South/South-South collaboration. At the same time, the DHIS2 innovation ecosystem also recognizes the challenge of institutionalizing the circulating actors, means of innovation, and the actual artifacts within a particular setting (Braa and Sahay, 2012). In our view, this is similar to what we recognized in the Sri Lankan context in terms of institutionalization of unique capacity in health informatics. However, while the DHIS2 innovation ecosystem described by Braa and Sahay focused on a single HIS platform (the DHIS2) and multiple capacity development initiatives around the same, the Sri Lankan case cannot be explained in the same vein.

In our view, what we have explored in the Sri Lankan context is an 'ecosystem of capacity development' around health informatics, not limited to DHIS2. As indicated by Liu et al. (2007) and Bosch (2009), the reason for this view is that throughout its existence, the capacity development effort evolved and has been evolving further in harmony with its environment — the Higher Educational Institution and the MoH. The evolution and the harmonization of the capacity development effort were recognized by us in our analysis under 'gaining legitimacy', 'institutionalization of unique capacity' and as 'ensuring sustainability'. The evolution has been controlled to a certain extent as the expected outcomes are clear and are oriented based on the SDGs — recognized as 'control over evolution' in the case analysis.

However, in contrast to the DHIS2 innovation ecosystem, the nodes we perceive in the capacity development ecosystem are somewhat different. While the DHIS2 innovation ecosystem and the networks of action for that matter describe nodes as well-demarcated actors (Braa and Hedberg, 2002; Barabasi, 2002) or events (Pentland et al., 2010), the equivalent in our case are formed based on a multiplicity of relationships. In fact, our

view is not so different from what Curley et al. (2013, p.19) defined as ecological approach — "the study of the relations between a person and its environment and to other collaborators within the environment." Empirically, our interpretation is supported by many of the competencies recognized as desirable among health informaticians in some way contributing toward building effective relationships with one another. For instance, competencies such as intercultural communication, contextual expertise, and networking skills are important ingredients for an effective relationship (Brillinger and Kagolovsky, 2008; Murphy, 2009; Castells, 2011). At the same time, characteristics such as multidisciplinarity, resource pooling, creating organizational buy-in, entrepreneurship, and evolving community, which we recognized in relation to capacity development, also refer to factors necessitating effective relationships (Fitchman et al., 2011; Krishna and Walsham, 2005; Siribaddana, 2014). Therefore, we argue that in an ecosystem of capacity development, circulation of actors such as the students and health informaticians would take place between 'sets of relationships' or what Foucault recognized as 'spaces' (Topinka, 2010; Foucault, 2007). Our findings also align with Nigel Thrift's view of space where it is perceived as a durable and sustainable entity that garners its meaning as a result of collectives formed with time (Thrift, 1996).

In our conceptualization, capacity development in health informatics in the Sri Lankan context gave rise to four different spaces; the academic space, innovation space, development space, and the work space. Within this conceptualization, academic space refers to a set of relationships that are driven by academic interests and the requirements of the academic program. However, students may not necessarily arrive in this space as 'blank slates' or 'tabula rasa' as described by Locke (Pinker, 2004). In fact, students become part of the academic space after being in the 'work space' where they might have had a different set of relationships as medical officers. The relationships formed within this space are geared toward gaining the knowledge and skills required to perform various functions of a health informatician — including IS development and implementations. At one point, these students will undertake innovative research, which would make them generate a different set of relationships within the context that they are expected to work. Their innovations — including IS innovations — would undergo scientific and technical scrutiny by the research community — as they contribute to science and practice. When these innovations gain recognition, and are scaled up further, a new set of relationships will be formed thus paving the way to the creation of a 'development space'. However, there is the possibility that many would not be part of the development space during their training period. The work space, in our view, is the space within which a health informatician would operate on a day-to-day basis, which will be formed by its own unique relationships. These relationships would be different from the relationships that they formed when they were part of a similar work space before the program.

In this conceptualization, a professional student would move through these spaces — not necessarily in a sequence — becoming part of the HIS community. At each of these spaces, processes of legitimization would take place in different forms as was recognized earlier. More importantly, the spaces thus created remain open for the entire community, whether they are medical doctors, students of health informatics, or trained health informaticians. Thus, such openness, created both by design and through evolution, avoids potential disengagement of the expert practitioners from the community as a whole (Jansen et al., 2009; Chen et al., 2008).

What does this mean in terms of IS in the developing country contexts? In our view, different stages of HISs may form in relation to different stages. HISs may emerge in any of these spaces and will be supported through different sets of relationships.

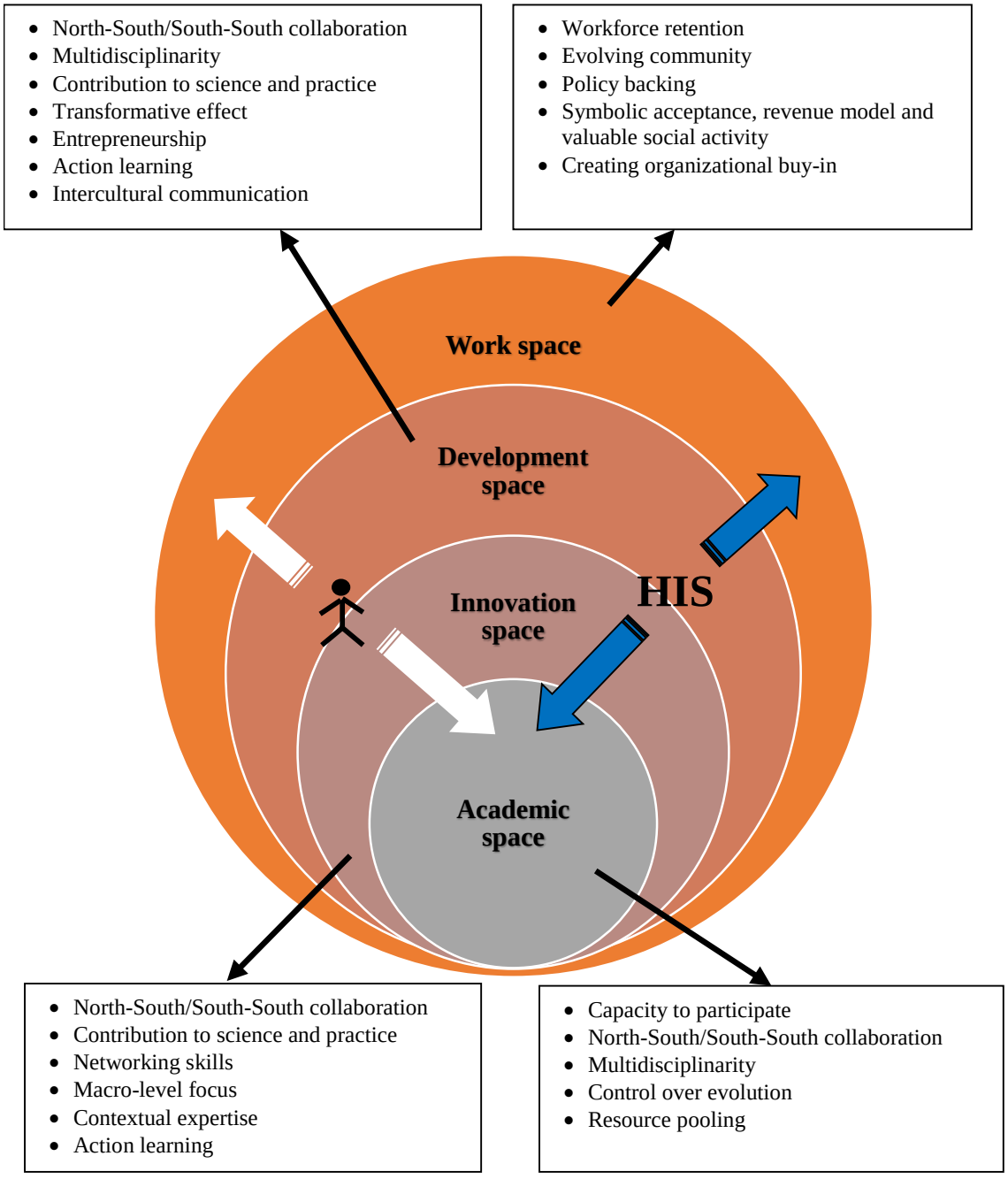

Figure 1. Capacity development ecosystem around health informatics

The ecosystem is organized in such a way that even an existing IS could evolve as it is subjected to different relationships formed according to contextual needs. The coupling of education, research and professional practice, gaining legitimacy, institutionalization of unique capacity, high-impact research and development, and sustainability would

mean that contextual needs around HISs would always be translated into capacity development needs within the ecosystem.

The capacity development ecosystem around health informatics, along with some of the key focus areas pertaining to each of the spaces, the movement of the students, and the emergence of a potential IS, can thus be illustrated as in Figure 1.

When applied to developing contexts, the model presented in Figure 1 will aid those who are engaged in capacity development around health informatics to plan such programs with a holistic perspective. The model will allow flexibility as it outlines only the broad themes or contributors that need to be thought of in facilitating the formation of different spaces — fitting each context. Therefore, practitioners and policymakers will be able to make use of suitable and feasible ways of dealing with each of the ecosystem contributors and allow the spaces to form as the formal health informatics training programs evolve. More importantly, the contributors recognized in Figure 1 will in parallel enable developing contexts to keep focus on IS developments as the model will couple capacity development with IS evolutions from the very beginning.

5. Conclusion

In this paper, we have attempted to answer two key questions essentially summarized as what capacities need to be developed and how this should be done – within the contexts of networks-of-action and innovation ecosystems.

In terms of capacities that need to be developed, this paper recognizes the importance of capacities that aid networking and innovations. These capacities can be classified into intercultural communication, action learning, contextual expertise, macro-level focus, and networking skills. It is such capacities that would lead to capacity development programs and the trained health informaticians to gain legitimacy, institutionalize their capacities and innovations, engage in high-impact research and IS developments and thereby sustain the program.

In terms of how capacity development programs around health informatics may be modelled, we recognize the usefulness of considering the same as an ecosystem. The ecosystem, we perceive, consists of four spaces; academic, innovation, development, and work — which are formed as a result of relationships formed by the students or the health informaticians. These spaces, in our view, would be the seeding grounds for IS, its evolution, and maturity.

These findings, in our view, will change the way health informatics–related capacity development has been perceived in ICT4D literature — detached from the actual work practices of the health informaticians and from the evolution of transformative ISs. This ecosystem perspective of capacity development in health informatics will thus enable future researchers, academics, practitioners, and policymakers to be sensitive to what relationships would be facilitated through their decisions and whether these relationships are appropriate to achieve the national interests driven by the SDGs.

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