Integrated Framework of Knowledge Management and Knowledge Discovery to Support E-health for Saudi Diabetic Patients

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Abstract--**In the last decade, the government of Saudi Arabia has given high priority to developing and implementing e-healthcare services and technologies. However, it has met a number of barriers in implementing its healthcare initiatives. This paper describes these barriers and proposes an e-health knowledge management framework to overcome these barriers by integrating developments from knowledge management with knowledge discovery techniques. This framework should assist in the delivery of competitive e-healthcare services and improve intellectual capital to provide smart health services in the country. The proposed framework will be applied to the domain of diabetes mellitus address the difficulties that diabetic patients encounter.**

Keywords - knowledge management; knowledge discovery; Saudi Arabia; diabetes mellitus; self-management; diabetes education.

I. BACKGROUND

The integration of knowledge management and knowledge discovery can play an important role in supporting e-health [1]. Eysenbach defines e-health as 'an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the internet and related technologies' [2]. According to the World Health Organization (WHO) e-health refers to'...the use, in the health sector, of digital data - transmitted, stored and retrieved electronically- in support of healthcare, both at the local site and at a distance'.

In the last few decades, the Saudi Arabian government has given a high priority to improve its e-health services. A number of new initiatives have emerged focusing on many aspects of healthcare, ranging from creating electronic files for patients, statistical monitoring of infectious diseases, connecting all hospital systems using technologies of cloud computing and monitoring the arrival of pilgrims and vaccines given to each pilgrim in their home country [3]. However, the implementation of these initiatives has been impaired by many problems outlined as illustrated in Figure 1:

- ***Non-connectivity of information systems***. Though some regional directorates and central hospitals are using information systems [4], there is no effort to connect these information systems in order to build up a national healthcare system [5].
- ***Lack of technical expertise and computer skills***. Computer skills of healthcare staff and professionals are deficient due to their lack of experience in using computer applications [6]. No guidelines are provided to handle electronic medical records (EMRs), and the staffs complain about poor maintenance of computers, networks, slow computers and old terminals.
- ***Failure of adoption Health Information Services (HIS).*** There are critical issues associated with planning and adopting HIS, and its implementation in Saudi Arabia; some of these are caused by the poor technical support and over running with respect to time and budget [6][7].
- ***Human barriers.*** This problem has been considered as the major reason for failing to adopt health information systems in Saudi hospitals [8]. Human barriers include negative beliefs of healthcare professionals towards technologies and lack of trust by medical staff towards computer based medical solutions. Therefore, many medical staff resists the change from traditional to computer based healthcare services.
- ***Cultural barriers.*** Cultural factors contribute to the failure in adopting e-health because of limited human interaction [7]. Aldraehim and Edwards [9] explain that Saudi Arabian people are extremely influenced by their culture and, therefore, they prefer physical interaction to virtual contact.
- ***Medication safety***. According to Aljadhey et al. [10], medication safety raises two major e-health issues. The first issue refers to communication gaps among healthcare institutions, which contribute to medical mishaps and patients' medical historical issues. The second issue is limited use of technology whose consequences occur in illegible handwriting. Computerised Provider Order Entry (CPOE) can solve this problem; however, this is being adopted slowly.
- ***Financial barriers***. Transmitting traditional paper medical records to electronic system can be very costly [11]. Such high expenditure, which needs to be spent on the adoption of IT in health, may lead to the slow uptake of e-health applications.
- ***Security and privacy***. This focuses on the easiness in accessing EMRs of patients due to the fact that some medical records of patients can be disseminated to others without permission of the patient or the doctor [6].

Figure 1. E-health Barriers in Saudi Arabia

This paper is structured as follows. Section I presents the background regarding e-health barriers in Saudi Arabia. Section II explains the role of knowledge management and knowledge discovery in healthcare. Section III provides insights regarding barriers that can hinder the SECI model utilization in the Saudi Arabian context. Section IV introduces the proposed framework to overcome e-health barriers in Saudi Arabia. Section V introduces the domain of application. Section VI describes the difficulties faced by diabetic patients. Section VII discusses the self-management and education approach to overcome these difficulties. Section VIII describes the feasibility of the internet in diabetes self-management and education. Section IX explains how an integrated framework can be used to help patients of diabetes and their health careers in managing those difficulties. Finally, Section X summarises the main directions adopted by this project.

II. KNOWLEDGE MANAGEMENT AND KNOWLEDGE DISCOVERY

Nowadays, patients and health practitioners are connected to hospitals, clinics and pharmacies; they share knowledge in order to reduce administrative costs and improve the quality of care. Although the focus tends to be on managing health records and interoperability of IT healthcare systems, knowledge management plays an important role in providing high quality and effective healthcare system. It also allows the capture, representation and dissemination of knowledge of healthcare professionals such as their strategies, practices and insights. This knowledge is the power that enables organisations and individuals to select the best actions and strategies [12]. Utilisation of best practices provides significant advantage for organisations in term of competition and efficiency. Individuals keep their knowledge in their brain and those individuals have the brainpower or intellectual capital that every organisation desires [13]. Furthermore, their knowledge helps identify current problems as well as achieve desired results [14]. Consequently, many top managers have recognised the importance of capturing and managing knowledge of its healthcare professionals and developing systems to improve their services.

Knowledge management is a useful mechanism to capture the intellectual capital of organisations, and healthcare establishments, in particular, so that they can deliver the best quality of care. It can help healthcare professionals cope with the fragmented and distributed nature of medical knowledge, the challenges caused by information overload and the importance to access local knowledge in making clinical decisions [15]. Additionally, it can provide healthcare practitioners with educational and training initiatives in terms of professional development and changing environment preparation [20][21][22]. Finally, dissemination of medical knowledge and best practices enable social learning initiatives where evidences can be disseminated to clinicians, nurses, and other healthcare workers [23][24][25] at national and international levels as well as to rural areas.

Knowledge management can provide a dynamic process of capturing, storing, sharing and creating both types of knowledge, explicit and tacit [22]. Explicit knowledge is communicable in systematic language whereas tacit knowledge is obtained through experience and cannot be articulated [23]. Nonaka and Takeuchi [23] suggested that knowledge changes from explicit to tacit and vice versa in two dimensional learning environments through four processes, namely Socialisation, Internalisation, Externalisation, and Combination, known as SECI (as illustrated in Figure 2), and represented in the form of a spiral. Socialisation enables the conversion of tacit knowledge via interaction among individuals, and can be achieved through shared experience. Internalisation enables converting explicit knowledge to tacit knowledge, while externalisation enables tacit knowledge to be converted to explicit knowledge. It makes tacit knowledge understandable and can be recorded or saved by visualising it in an explicit form. Combination is the process of 'systematizing concepts into a knowledge system' [23]; for example, people synthesise different sources of explicit knowledge through meetings, conversations and exchange of documents [16][27]. Nonaka concluded that knowledge is continuously created a third dimension, which account for restructuring the existing knowledge through the synergy of these four processes. However, a number of issues have been raised regarding Nonaka's premises; consequently, other models have been developed and/or extended Nonaka's basic ideas. For example, Nissen [24] developed the knowledge flows model to capture the organisational knowledge dynamics and added two further dimensions to Nonaka: life cycle and flow time. Harsh [25] proposed a third dimension, which accounts for knowledge reusability and where technology and human interaction can play a significant role in management of data, information and knowledge. Yao et al. [26] argued that SECI assumes that the only source of corporate knowledge originates from the staff within the organisation.

Figure 2. SECI Model [23]

In the healthcare sector, patients as well as healthcare workers significantly contribute to knowledge creation and knowledge sharing. However, tacit and explicit knowledge, which are embedded in people, are constantly updated and new knowledge is acquired from external sources through the analysis and knowledge discovery of patients data and databases, and scientific documents Knowledge discovery is another emerging discipline aimed at identifying valid, novel, understandable and useful patterns in data, texts, images, and other media [27]. It uses statistical and artificial intelligence techniques to analyse and process large amount of data [28] without or/at least less human intervention [29]. Data mining is a subfield of knowledge discovery, which discovers novel and valid trends/associations using machine learning techniques [30]. Typical applications of data mining in healthcare include monitoring high risk of diabetic individuals, so that appropriate messages can be communicated to them [31], predicting length of stay of patients with spinal cord injuries [32], and predicting hypertension from patient medical records with eight other diseases [33]. According to Berger and Berger [34] data mining is a useful approach for dealing with the rapid expansion of medical knowledge and healthcare data.

Whilst knowledge discovery can support the discovery of new knowledge from patients' healthcare data, knowledge management provides a forum to share and disseminate this new acquired knowledge and to combine it with the explicit and tacit knowledge acquired from healthcare practitioners. Such integration can address some of the problems discussed above and improve the quality and performance of healthcare services. Furthermore, it can assist healthcare organisations in making strategic effective decisions [35]. Hwang et al. [36] demonstrated how association rules can be applied to extract knowledge from patients' medical records along with medical rules of tumor associated diseases, and to develop guidelines for clinicians. Then, these guidelines can be shared among healthcare practitioners through a knowledge management system and deliver a better quality healthcare to patients.

III. SECI MODEL ISSUES

Even though the SECI model has always proved to be powerful tool to manage and share knowledge, it has been widly criticised and has been suggested that the model is not universally valid. Nonaka and Takeuchi [23] and other scholars suggested that each mode can take place by specific tools and conditions need to be there to make the knowledge conversion processes happen. For example, socialisation can take place via observation and experience when individuals are willing to share knowledge. According to Tyagi et al. [37], trust, respect and mutual understanding among resources during communication are important requisites for socialisation. Moreover, M. Glisby and N. Holden [38] mentionned other factors that must be provided in order to perform socialisation. Those factors are strong affiliation to the organisation, cooperative working environment instead of competitive, developing relationships with those who share the same fate, external sharing of knowledge facilitated by networks of partnerships between organisations and close interrelationships. To externalise knowledge, on the other hand, group commitment must occur among individuals in their workplace. In addition, participation of internal competent members and external experts in the training programs and seminars with little external control (i.e., minimal pressure from shareholders) are required for successful completion of externalisation [37] [38]. For the combination mode, Nonaka and Takeuchi stressed the importance of lack of interdepartmental rivalry, polychromic task orientation, high personal commitment and permanent occupancy. Internalisation mode can take place where there is minimal risk of mistakes occurring among individuals. This stage of knowledge conversion can be performed via job rotation, which encourages movement of members of staff in the organisation and thereby innovates knowledge transfer and increases motivation [39].

The overwhelming success for the SECI model in Japanese organisations is well-documented. However, the SECI model when applied to other countries does not necessarily indicate success as there are different cultural factors, which can influence the outcome of the knowledge conversion of the model; According to Schein [40], Nonaka and Takeuchi insist that the knowledge creation process needs social interaction, which is influenced by cultural norms. Factors of organisational culture, such as trust and the style of the organisation structure, are important to ensure knowledge sharing [39]. When considering factors suggested by Nonaka and Takeuchi for SECI model implementation it is important to appreciate how much these factors are influenced specifically by Japanese culture. Close interrelationships between organisations, which is significant factor for socialisation, is a specific characteristic of the Japanese culture only [38]. Low external control and group commitment, which are necessary requirements for externalisation, are features of the Japanese culture [76][79]. High personal commitment, permanent

occupation and other conditions essential for combination are typical Japanese practices and, therefore, combination may have difficulties when implemented in other cultures [42]. The same concept also applies to internalisation. Intensive job rotation is a typical Japanese practice because Japan focuses on developing generalists rather than specialists in particular domains. So, the experimental learning or 'learning by doing' is widely accepted in the Japanese organisations, which constitute the context of internalisation [38].

Several studies have examined the validity of SECI model in different cultures. T. Andreeva and I. Ikhilchik [42] analysed the implementation of this model in the Russian context. Dialogues with senior management were seen to be problematic in Russian companies because of the authoritarian leadership style and the prevalence of top-down communication, where employees do not directly communicate with senior managers or they are inhibited for fear of reprisal. These issues constitute a barrier for utilising the externalisation mode successfully in the Russian context. Furthermore, more effort is needed to perform combination in Russian organisations because of the presence of the concentrated authority and decision-making. In another study published by Weir and Hutchings [43], combination and internalisation do not work in the Chinese culture, in the way suggested by Nonaka and Takeuchi, due to the presence of interdepartmental rivalry and the risk of making mistakes.

In the Kingdom of Saudi Arabia (KSA), the culture is formed by three factors: religion, tribal or family systems and the Arab culture [7]. Islam influences the Saudi Arabian culture by setting moral principles among people in the country. Family is extremely valued in the Saudi Arabian culture as it provides security to its members. Members of the KSA family are expected to have good relationships with their relatives and this collectivism style ensures assistance, such as job opportunities, to be given to family members through the family leaders. Their belief is also influenced by the Arabic culture, which implies that all members in the family perform their roles in order for the family to continue its standing in society. Furthermore, the father in this culture is responsible for the family and always has the authority [44]. It is also a high power distance culture and has high level of uncertainty avoidance, collectivism and feminism [45]. In another study, cultural dimensions such as extreme power distance, masculinity, low uncertainty avoidance, and extreme individualism hinder the process of knowledge sharing [46]. Therefore, the process of externalisation and internalisation may be hindered in the Saudi Arabian culture. Weir and Hutchings [43] reviewed the utilisation of the SECI segments and concluded that socialisation and combination can be achieved in the Saudi Arabian world although there is tendency to keep knowledge among themselves unless there is a need for communication and if they trust their colleagues. This can impact the sharing of tacit knowledge and its externalisation. Internalisation does not work effectively because of the lack of confidence and trust from the information outlined from the knowledge holder because work life is still influenced by Saudi family culture and is not completely separated from the work environment. Although, job rotation is adopted in KSA, it is not widely practiced and tends to focus on developing deeper experience in the same field rather than widening an employee's competence in different domains.

Solutions have been suggested to adapt the SECI model to the Arabic culture at the organisational and national levels [39]. These suggestions can be used to improve successful utilisation of Nonaka's' model in KSA.

- ***Socialisation***. KSA citizens are seen to be pre-socialised [43]. Accomplishing strong relationships between top managers and employee will emphasise socialisation in Saudi Arabian organisations. Trust is important in this stage of the SECI model. Therefore, religious and social events, such as Ramadan festivities, graduations and weddings, can reinforce trust among colleagues. Establishing a reward system has also an impact on the socialisation mode. It reinforces knowledge sharing when considering the employees' different needs and objectives [47]. Rewards for knowledge sharing can be tangible or in incorporeal forms. Self-worth is an example of an incorporeal reward which means the individual who shares knowledge has the feeling of being valued and it includes personal acknowledgement and recognition in applying shared knowledge [47].
- ***Externalisation***. Improving office design in the organisations in the Saudi Arabian context will allow higher interaction and communication between staff. This will give the opportunity for discourse in the work environment. Motivation can play its significant role to encourage knowledge discourse among colleagues in organisations. Rewards such as incentives should consider knowledge sharing behaviour among individuals. As group commitment is prerequisite for externalisation, workshops and seminars can be used to improve loyalty to work place among members. This will help to separate private life from work life. Likewise in socialisation, organisations can take advantage of the religious and social events to enhance trust and accomplish good relationships among members in order to strengthen externalisation.
- ***Combination***. As an Arabic community, KSA culture is seen to have concentrated authority and decision-making. A useful solution to overcome this barrier would be to expand the level of participation in decision-making. This action will enable information flow vertically among all

members regardless of their importance or position in the organisation.

- ***Internalisation***. The literature review has suggested that job rotation has been adopted slowly in the Saudi Arabian culture. Increasing the adoption of such a solution by moving individuals in the organisation, can improve knowledge transfer, expertise, and increases motivation. Saudi Arabian organisations normally give their members opportunities to engage in training courses, which is distributed equally among members in the organisation to ensure internalisation is being implemented.

IV. E-HEALTH KNOWLEDGE MANAGEMENT FRAMEWORK

It is important here to recognise that despite significant advantages in applying knowledge management in the healthcare sector, there are a number of barriers primarily caused by the absence of clear knowledge management strategy related to deficiency of effective team working, cultural barriers, poor IT infrastructure, degree of sectorial professionalisation, and political conflicts [41][42][43]. Finn and Waring [51] illustrated the importance of effective team working and stated that 'architectural knowledge' is fundamental for efficient team practice to ensure the delivery of safe and effective care to patients. As mentioned earlier, cultural barriers play also a negative role as some cultures do not encourage knowledge sharing; this constitutes an obstacle to knowledge management processes [52]. The healthcare sector tends to be mono-disciplinary and relationships of professionals within this sector are highly standardised, hence there is a resistance among doctors to share their findings and initiatives [49]. Strong governmental regulations and political and management conflicts can also hinder knowledge sharing among healthcare practitioners [53]. Guven-Uslu [50] described the clinician-managerial conflict as one of the important obstacles; the priority of managers is to minimise cost whereas the first priority of clinicians is to provide best care for patients.

To address the above issues, we propose a holistic framework approach to the healthcare knowledge management; this approach is still inspired by the SECI model of Nonaka, although we are aware of the critical issues associated with the two dimensional approach to knowledge management. One of those issues relates to the fact that the SECI model is embedded within the Japanese context and culture. Similarly, our framework must take into consideration the Saudi Arabian context, which is strongly influenced by the Arabic culture when applying the SECI model of Nonaka and Takeuchi [24][43]. Some of these issues are discussed later in this paper.

This framework is primarily designed to address the barriers highlighted above from the four perspectives: Business, Human, Financial and Technology. By integrating knowledge discovery into knowledge management we aim at identifying, extracting and organising tacit and explicit knowledge related to problems and solutions from multiple sources and at providing a forum for generating and sharing current and new knowledge by linking tacit and explicit knowledge to a specific medical domain. The proposed framework, referred herewith as e-health knowledge management system, is initially tailored to address the healthcare issues in Saudi Arabia and is dedicated to the diabetes mellitus domain, described in Section IV; this will allow us to evaluate the viability and performance of the proposed e-health knowledge management system.

This section describes the four components of our framework (as illustrated in Figure 3). The *Business* component focuses on organisational issues and aims at extracting and managing the barriers associated with the failure of adopting health information services and medical safety, such as poor technical support and unrestricted access to medications.

The *Human* component deals with the human barriers in relation to the use of technology from the healthcare workers and the cultural barriers from the patient perspectives; this will address the negative beliefs of healthcare professionals and patients towards the use of virtual contact and interaction with technological devices. The role of patients in the process of knowledge production and the computing skills of both, the healthcare professionals and patients, are critical to the success of our framework. To this end, the *Technology* component manages the non-connectivity issues and focuses on the technical expertise and computer skills, security and privacy issues. This component includes training aspects to address the limited/lack of computer skills among healthcare staff and professionals and their patients. Finally, the *Financial* component attempts to elicit the constraints and policies associated with the implementation, maintenance and monitoring of healthcare information services, namely the high cost of transmitting from traditional patients' paper records to electronic records. The proposed framework will elicit some of these problems and propose solutions and made available to the community via a dedicated knowledge management system (as illustrated in Figure 4).

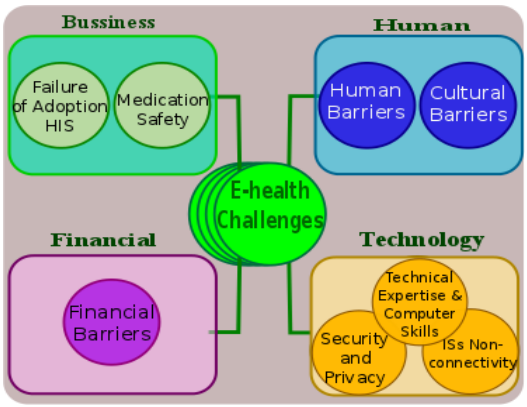

Figure 3. Components of e-Health Knowledge Management System

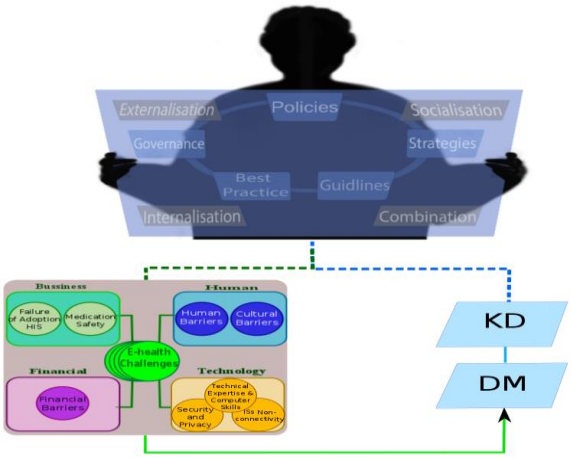

Figure 4. E-health Knowledge Management System

This approach is to be applied to support the diabetes community, which is increasing at an alarming rate in Saudi Arabia. Elicitation of their problems and issues faced is to be accomplished through interviews and protocol analysis, and via statistical data mining analyses extracted from the World Health Organisation (WHO) dataset. Using machine-learning techniques such as association rules and decision tree we can elicit typical issues and problems faced by the diabetes community and relate them to the four components presented in Figure 3. The new discovered knowledge can then be expressed in terms of recommendations and best practices to support both, healthcare professionals and the diabetes community.

The aim of the knowledge management system is to provide relevant knowledge not only to healthcare professionals who may be seeking or sharing best practices, strategies, guidelines and policies, but also to patients who need to contact specific healthcare services or professionals for advice or help. The proposed system will also provide access to academic papers related to specific problems to keep healthcare professionals up-to-date with new findings.

V. DOMAIN OF APPLICATION

Diabetes mellitus, which is one of the highest chronic diseases that affect patients from different genders, ages and weights, is to be used to validate our proposed framework. It can have severe complications such as stroke [47][48], heart attack [55], heart failure [56], kidney failures [55], Alzheimer disease [57] and mortality [58].

It is estimated that 382 million people have diabetes in the world, and by 2035, this will rise to 671 million. The number of patients who are suffering from diabetes mellitus is increasing in the Kingdom of Saudi Arabia (KSA). According to Shaw, Sicree, and Zimmet [59], KSA is in the third place among the top 10 countries for diabetes prevalence. In 2010, the prevalence percentage for diabetes mellitus in Saudi Arabia was 16.8% among adults in the ages of 20-79 years old. This percentage is expected to rise in 2030 to reach 18.9% [59]. In another statistics, there were 3.8 million cases of diabetes in Saudi Arabia in 2014, this number represents 20.5% of the prevalence of this disease among adults in the country [60].

There are twenty health regions distributed among all regions in KSA, providing services to more than 3 million diabetic patients, belonging to different ages, gender, and weight. The number of diabetic outpatients visiting the healthcare centers (HCC) is 1,891,765. This number of diabetic patients represents 6.4% of the overall number of visits to all HCC in KSA and put diabetic patients in third place in the scale of all outpatients visits in the kingdom [61].

Over 96% of all Saudi medical healthcare budgets are attributed to diabetes by Saudi citizens and 4% incurred by non-Saudi nationals. The national healthcare financial burden has reached $0.87 billion, excluding (i) indirect costs such as absenteeism, lost productivity, unemployment from disease-related disability, lost productivity due to early mortality by disease, and (ii) healthcare system administrative costs, cost of medications, clinician training programs, and research and infrastructure development [62]. The proposed framework will include the financial costs and its impact on human and barriers components into the framework. It will also attempt to overcome the barriers by utilising technology components.

A number of data mining applications have focused on diabetes. For example, Meng et al. [63] produced a model to detect diabetes using 12 risk factors and Chang, Wang, and Jiang [64] used risk factors to identify hypertension and hyperlipidemia. Suh et al. [65] developed the WANDA system to remotely help monitor blood glucose, weight, and blood pressure. HealthOrg is an application to monitor high risk diabetic individuals so that appropriate message can be communicated to patients [31]. Roch et al. [66] recognise the need and the challenges that healthcare professionals and researchers face in developing a much needed comprehensive knowledge management support system for diabetes care. To the best of our knowledge, no integration of data mining and knowledge management for diabetes has been attempted.

VI. DIFFICULTIES FACED BY KSA DIABETIC PATIENTS

Beside the many health related complications associated with this disease, diabetic patients also face difficulties and challenges related to the control and the management of diabetes, and adherence to appropriate dosage of their medication. As Péres et al. [67] report, some of these challenges include difficulties in controlling their eating habits, doubts in time schedules and correct usage and dosage of their medications, leading sometimes to their refusal to take insulin [68]. For example, most patients are not able to remember their blood glucose and blood pressure target. They also face problems in identifying medications and understanding prescriptions, especially when patients asked to change medication [69]. In addition, indicated patient deficiency in adherence to lifestyle measures and pharmacologic therapies as one of

the most common reasons cited for failure to achieve glycaemic goals. According to Onwudiwe et al. [69], inadequate health literacy can lead to an inefficient use of health services.

VII. DIABETES SELF-MANAGEMENT AND EDUCATION

Diabetes education and self-management are two research studies which have been highly studied to understand the difficulties and issues that diabetic patients may encounter every day. Funnell et al. [70] defined diabetes self-management education as the constant procedures for facilitating the needed knowledge, skills and ability for diabetes self-care for the overall purpose of supporting self-care behaviour. Diabetes education aims at increasing the knowledge of diabetic patients about their disease and health condition and at empowering them to have control over their condition [71]. In addition, diabetes self-management education have other objectives including supporting informed decision-making, problem-solving and active cooperation with the healthcare team, and to improving clinical outcomes, health condition, and quality of life [70]. Blonde [68] stresses the importance of ongoing medical nutrition therapy and self-management education which must be made available to all patients with diabetes. Furthermore, Onwudiwe et al. [69] claimed diabetes education, knowledge and self-management as the key to successful diabetes management. Funnell and Anderson [72] stated that patients are to be responsible for 95% of diabetes management, which should be carried out at patients' home through self-care. Therefore, patients of diabetes are to be given sufficient knowledge about their disease and guidelines to control it.

Self-management of diabetes includes guidelines and activities related to diet control, exercise, blood glucose testing, foot care and reduction of smoking [73]. Such knowledge can assist patients in dietary habits, enable self-monitoring of accurate glucose and weight [74]. In other words, self-management of diabetes and diabetes education can not only reduce the risks of diabetes complications and enhance patients' health and life but also it can bring financial benefits such as reducing patients' visits to hospitals and minimising healthcare professionals' consultations.

Successful utilisation of diabetes self-management and education has been implemented in some developed countries. In the United Kingdom, for instance, the National Institute of Clinical Excellence (NICE) guidelines recommend diabetes education programs to be offered to diabetics and their healthcare providers, to assist them in best managing the condition [75]. For example, DESMOND [76] offers short courses through presentations and workshops and provides diabetics patients with the skills and knowledge needed to enable them to control their conditions. The Canadian Diabetes Association (CDA) offered diabetes self-management program for people with diabetes in Canada. This program offers many services to diabetic patients to help them self-manage their condition and live healthier with diabetes. Examples of the services CDA provides are virtual health coaching, educational events about diabetes such as exhibitions and keynote speakers, learning series about diabetes risk factors and symptoms, and food skills to guide different ethnic groups in Canada in how to prepare healthy food [77].

Such programs are required to be introduced to healthcare centres and support diabetic patients in KSA. We believe that our knowledge management system can play a significant role in eliciting the best practices from various healthcare organisations and disseminating them through appropriate means to patients and healthcare providers.

VIII. E-HEALTH SELF-MANAGEMENT EDUCATION SUPPORT

Internet is used increasingly by people who suffer from chronic diseases in order to self-manage their illnesses and learn from other patients' experiences [78]. The literature review conducted by Ziebland and Wyke [79] revealed seven domains for accessing health experiences of others on the internet; (1) searching for information, (2) feeling supported, (3) maintaining contacts with others, (4) undergoing health services, (5) learning to communicate the story, (6) visualising disease, and (7) affecting behaviour. In terms of diabetes mellitus, Ramadas et al. [80] discuss the intervention of web-based technology for managing type 2 diabetes. They review 13 web-based results on positive impact of such intervention on the management of the disease. Another study showed how web-based diabetes management system helped its users reduce their glycated haemoglobin (HbA1c) [81]. It offered educational programs related to diabetes management, exercise, nutrition and recommendations for the patients with type 2 diabetes based on the information they enter such as their medications and glucose levels.

Official report shows promising indication for using internet services for health related issues in KSA. Internet penetration in KSA has risen from 13% in 2005 to 63.7% in 2014 and the number of internet users has reached over 19 million [82], showing common use of the internet in search for health associated information [83]. However, the literature review does not provide evidence of internet usage by Saudi diabetic patients. This confirms the critical need to provide self-management education not only to support diabetic patients to cope with their daily difficulties but also help healthcare professionals provide quality and consistency of care to their diabetic KSA patients.

IX. KNOWLEDGE MANAGEMENT FRAMEWORK FOR DIABETES

The above difficulties and challenges is the motivation behind the development of the proposed e-health framework, which can help address the gaps of diabetes self-management and education in KSA. This framework is to be implemented in a web-based (portal) system to provide a tailored knowledge management approach to

(i) help diabetic patients self-manage and monitor their health conditions and (ii) support healthcare providers to share best practices.

To this end, a survey is carried out to analyse and understand the current difficulties and issues of KSA faced by both, diabetic patients and healthcare providers at the healthcare centres. The results of the survey are ~~to be~~ data mined to elicit useful trends and discover crucial issues and needs that need to be addressed through the knowledge management framework. The proposed framework is based on the SECI model aimed at converting and disseminating both types of knowledge: tacit through the data mining approach and explicit through the elicitation of problems via the survey and face-to-face interviews with both stakeholders: patients and healthcare professionals. The framework is designed to provide a web-based assistance to patients in monitoring and providing tailored guidelines and support related to diet, medication usage and schedule, and recommend appropriate exercises. Patients, through the internalisation model, are "learning by doing" and through externalisation healthcare providers are disseminating their best practices. Socialisation and combination modes aim at facilitating the exchange of knowledge, practices and concerns among diabetic patients and healthcare professionals through a dedicated web-based forum to help diabetic patients meet with others sufferers, discuss various issues and learn from each other.

The framework that integrates data mining and knowledge management can become the vehicle for social media for diabetics and their health carers; it can also reduce isolation and depression, which are often faced by diabetic patients. The feasibility of social media and its contribution to knowledge management is identified by Ray [46]. Twitter, Facebook, Blogs and other means of communication, which have become extremely popular in among citizens in KSA, can be easily integrated into the proposed framework.

X. CONCLUSION

Knowledge management and knowledge discovery are two well-developed disciplines. However, to the best of our knowledge, there has been no methodical attempt at integrating them within the SECI model to address critical healthcare issues in KSA. The aim of this research project is to bridge this gap and consequently improve the healthcare services and provide a forum for both, healthcare professionals to deliver the best healthcare to their patient, and diabetic patients to overcome their problems and difficulties in managing their medical condition. The first stage of this research has focused on eliciting the barriers associated with the KSA diabetic patients and their healthcare providers. The development of the proposed integrated framework requires the need to understand any issues and challenges faced by IT specialists in KSA in developing the system across the healthcare centres. The specific domain of diabetes mellitus is used to validate the ambitious proposed e-health knowledge management framework. The paper has outlined the difficulties of applying Nonaka's SECI model to other countries as the model is based on Japanese organisations. It has suggested practical solutions for use in KSA for knowledge transfer within the segments of the SECI model. The proposed framework is designed to meet the recent government initiatives of the Saudi Ministry of Health in improving the national healthcare of its citizens.

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REFERENCES

[1] S. Almuayqil, A. S. Atkins, and B. Sharp, "Knowledge Management Framework for E-Healthcare in Saudi Arabia," in *eTELEMED 2015*, 2015, pp. 112–117.

[2] G. Eysenbach, "What is e-health?," *Journal of medical Internet research*, vol. 3, no. 2, p. E20, 2001.

[3] P. Ram, "New Strategic Initiatives–A Case Study of the Saudi Health Ministry," *International Journal of Academic Research in Economics and Management Sciences*, vol. 3, no. 1, p. 236, 2014.

[4] M. Almalki, G. FitzGerald, and M. Clark, "Health care system in Saudi Arabia: an overview," *Eastern Mediterranean Health Journal*, vol. 17, no. 10, pp. 784–793, 2011.

[5] M. Altuwaijri, "Electronic-health in Saudi Arabia. Just around the corner?," *Saudi medical journal*, pp. 171–178, 2008.

[6] M. Khalifa, "Barriers to Health Information Systems and Electronic Medical Records Implementation. A Field Study of Saudi Arabian Hospitals," *Procedia Computer Science*, vol. 21, pp. 335–342, Jan. 2013.

[7] M. Aldraehim, S. L. Edwards, J. Watson, and T. Chan, "Cultural impact on e-service use in Saudi Arabia : Results from Questionnaire," in *Information Society (i-Society), 2012 International Conference on*, 2012, pp. 230–236.

[8] M. Altuwaijri, "Implementation of computerized physician order entry in National Guard Hospitals: assessment of critical success factors," *Journal of Family and Community Medicine*, vol. 18, no. 3, pp. 143–51, Sep. 2011.

[9] M. Aldraehim and S. Edwards, "Cultural impact on e-service use in Saudi Arabia: the need for interaction with other humans," *International Journal of Advanced Computer Science*, vol. 3, 2013.

[10] H. Aljadhey, M. A. Mahmoud, M. A. Hassali, A. Alrasheedy, A. Alahmad, F. Saleem, A. Sheikh, M. Murray, and D. W. Bates, "Challenges to and the future of medication safety in Saudi Arabia: A qualitative study," *Saudi Pharmaceutical Journal*, Sep. 2013.

[11] M. Amatayakul, "Keys to successful EHR implementation," Healthcare financial management, vol. 64, no. 12, pp. 104–104, 2010.

[12] I. Nonaka, "A Dynamic Teory of Organizational Knowledge Creation.pdf." 1994.

[13] J. Liebowitz, "Knowledge management and its link to artificial intelligence," *Expert systems with applications*, vol. 20, pp. 1–6, 2001.

[14] Shu-hsien Liao, "Problem solving and knowledge inertia," *Expert Systems with Applications*, vol. 22, no. 1, pp. 21–31, Jan. 2002.

[15] D. Nicolini, J. Powell, P. Conville, and L. Martinez-Solano, "Managing knowledge in the healthcare sector. A review," *International Journal of Management Reviews*, vol. 10, no. 3, pp. 245–263, Sep. 2008.

[16] S. Antrobus, "Developing the nurse as a knowledge worker in health--learning the artistry of practice," *Journal of advanced nursing*, vol. 25, no. 4, pp. 829–35, Apr. 1997.

[17] C. Kenner and J. H. Fernandes, "Knowledge management and advanced nursing education," *Newborn and Infant Nursing Reviews*, vol. 1, no. 3, pp. 192–198, Sep. 2001.

[18] H. M. G. Martins, D. E. Detmer, and E. Rubery, "Perspectives on management education: an exploratory study of UK and Portuguese medical students," *Medical Teacher*, vol. 27, no. 6, pp. 493–498, Jan. 2005.

[19] J. Lathlean and A. le May, "Communities of practice: an opportunity for interagency working," *Journal of clinical nursing*, vol. 11, no. 3, pp. 394–8, May 2002.

[20] J. Gabbay and A. le May, "Evidence based guidelines or collectively constructed 'mindlines?' Ethnographic study of knowledge management in primary care," *BMJ (Clinical research ed.)*, vol. 329, no. 7473, p. 1013, Oct. 2004.

[21] M. R. Tagliaventi, "The role of networks of practice, value sharing, and operational proximity in knowledge flows between professional groups," *Human Relations*, vol. 59, no. 3, pp. 291–319, Mar. 2006.

[22] G. Ni, W. Wang, J. Wang, Z. Zong, and M. Xie, "Research on the Knowledge Management System of the Vicarious Management Corporation," *2010 International Conference of Information Science and Management Engineering*, pp. 62–67, Aug. 2010.

[23] I. Nonaka and H. Takeuchi, *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. Oxford university press, 1995, p. 62.

[24] C. Bratianu, "A critical analysis of the Nonaka's model of knowledge dynamics," in *Proceedings of the 2nd European Conference on Intellectual Capital*, 2010, vol. 8, no. 2, pp. 193–200.

[25] O. K. Harsh, "Three dimensional knowledge management and explicit knowledge reuse," *Journal of Knowledge Management Practice*, 2009. [Online]. Available: http://www.tlainc.com/articl187.htm. [Accessed: 22-Jun-2014].

[26] W. Yao, J. Chen, J. Hu, and Y. Wu, "Diagnosis for Nonaka: The critique of SECI theory," *Management of Technology (ISMOT), 2012 International Symposium on*, pp. 417–420, Nov. 2012.

[27] Y. Feng, "Towards knowledge discovery in Semantic era," *2010 Seventh International Conference on Fuzzy Systems and Knowledge Discovery*, no. Fskd, pp. 2071–2075, Aug. 2010.

[28] D. Delen, G. Walker, and A. Kadam, "Predicting breast cancer survivability: a comparison of three data mining methods," *Artificial intelligence in medicine*, vol. 34, no. 2, pp. 113–27, Jun. 2005.

[29] M. Grobelnik and D. Mladenic, "Automated knowledge discovery in advanced knowledge management," *Journal of Knowledge Management*, vol. 9, no. 5, pp. 132–149, 2005.

[30] U. Fayyad, G. Piatetsky-Shapiro, and P. Smyth, "From data mining to knowledge discovery in databases," *AI magazine*, pp. 37–54, 1996.

[31] H. Koh and G. Tan, "Data mining applications in healthcare," *Journal of healthcare information management*, vol. 19, no. 2, pp. 64–72, Jan. 2011.

[32] M. R. Kraft, K. C. Desouza, and I. Androwich, "Data mining in healthcare information systems: case study of a veterans' administration spinal cord injury population," in *Proceedings of the 36th Annual Hawaii International Conference on System Sciences, 2003*, 2003.

[33] F. Huang, S. Wang, and C.-C. Chan, "Predicting disease by using data mining based on healthcare information system," in *2012 IEEE International Conference on Granular Computing*, 2012, pp. 191–194.

[34] A. M. Berger and C. R. Berger, "Data mining as a tool for research and knowledge development in nursing," *Computers, informatics, nursing : CIN*, vol. 22, no. 3, pp. 123–31.

[35] X. Li, Z. Zhu, and X. Pan, "Knowledge cultivating for intelligent decision making in small & middle businesses," *Procedia Computer Science*, vol. 1, no. 1, pp. 2479–2488, May 2010.

[36] H. Hwang, I.-C. Chang, F. Chen, and S. Wu, "Investigation of the application of KMS for diseases classifications: A study in a Taiwanese hospital," *Expert Systems with Applications*, vol. 34, no. 1, pp. 725–733, Jan. 2008.

[37] S. Tyagi, X. Cai, K. Yang, and T. Chambers, "Lean Tools and Methods to Support Efficient Knowledge Creation," *International Journal of Information Management*, vol. 35, no. 2, pp. 204–214, 2015.

[38] M. Glisby and N. Holden, "Contextual constraints in knowledge management theory: the cultural embeddedness of Nonaka's knowledge-creating company," *Knowledge and Process Management*, vol. 10, no. 1, pp. 29–36, Jan. 2003.

[39] A. I. Al-Alawi, N. Y. Al-Marzooqi, and Y. F. Mohammed, "Organizational culture and knowledge sharing: critical success factors," *Journal of Knowledge Management*, vol. 11, no. 2, pp. 22–42, 2007.

[40] E. H. Schein, *organizational culture and leadership*, 3rd ed. 2004.

[41] G. Hofstede, *Culture's Consequences: Comparing Values, Behaviors, Institutions and Organizations Across Nations*. SAGE, Thousand Oaks, London, New Delhi, 2001.

[42] T. Andreeva and I. Ikhilchik, "Applicability of the SECI Model of knowledge creation in Russian cultural context: Theoretical analysis," *Knowledge and Process Management*, vol. 18, no. 1, pp. 56–66, Feb. 2011.

[43] D. Weir and K. Hutchings, "Cultural embeddedness and contextual constraints: knowledge sharing in Chinese and Arab cultures," *Knowledge and Process Management*, vol. 12, no. 2, pp. 89–98, Apr. 2005.

[44] H. Barakat, *The Arab World: Society, Culture, and State*. Berkeley: Univeristy of California Press, c1993 1993, 1993.

[45] B. Bjerke and A. Al-Meer, "Culture's consequences: management in Saudi Arabia," *Leadership & Organization Development Journal*, vol. 14, no. 2, pp. 30–35, 1993.

[46] D. Ray, "Overcoming cross-cultural barriers to knowledge management using social media," *Journal of Enterprise Information Management*, vol. 27, no. 1, pp. 45–55, Feb. 2014.

[47] B. O. A. K.-S. INITIATIVE, "Sharing Knowledge: Problems, Root Causes, and Solutions," *Knowledge Management in Practice: Connections and Context*, p. 277, 2008.

[48] T. Sensky, "Knowledge management," *Advances in Psychiatric Treatment*, vol. 8, no. 5, pp. 387–395, Sep. 2002.

[49] E. Ferlie and L. Fitzgerald, "The nonspread of innovations: the mediating role of professionals," *Academy of management journal*, vol. 48, no. 1, pp. 117–134, 2005.

[50] P. Guven-Uslu, "Uses of Performance Metrics in Clinical and Managerial Networks," *Public Money and Management*, vol. 26, no. 2, pp. 95–100, Apr. 2006.

[51] R. Finn and J. Waring, "Organizational Barriers to Architectural Knowledge and Teamwork in Operating Theatres," *Public Money and Management*, vol. 26, no. 2, pp. 117–124, Apr. 2006.

[52] D. P. Lorence and R. Churchill, "Incremental adoption of information security in health-care organizations: implications for document management," *IEEE transactions on information technology in biomedicine : a publication of the IEEE Engineering in Medicine and Biology Society*, vol. 9, no. 2, pp. 169–73, Jun. 2005.

[53] G. Currie and O. Suhomlinova, "The Impact of Institutional Forces Upon Knowledge Sharing in the UK NHS: The Triumph of Professional Power and the Inconsistency of Policy," *Public Administration*, vol. 84, no. 1, pp. 1–30, Mar. 2006.

[54] H. S. Jørgensen, H. Nakayama, H. O. Raaschou, and T. S. Olsen, "Effect of blood pressure and diabetes on stroke in progression," *Lancet*, vol. 344, no. 8916, pp. 156–9, Jul. 1994.

[55] J. a D. R. N. Appuhamy, E. Kebreab, and J. France, "A mathematical model for determining age-specific diabetes incidence and prevalence using body mass index," *Annals of epidemiology*, vol. 23, no. 5, pp. 248–54, May 2013.

[56] S. A. Hunt, W. T. Abraham, M. H. Chin, A. M. Feldman, G. S. Francis, T. G. Ganiats, M. Jessup, M. A. Konstam, D. M. Mancini, K. Michl, J. A. Oates, P. S. Rahko, M. A. Silver, L. W. Stevenson, and C. W. Yancy, "2009 focused update incorporated into the ACC/AHA 2005 Guidelines for the Diagnosis and Management of Heart Failure in Adults: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines: develope," *Circulation*, vol. 119, no. 14, pp. e391–479, Apr. 2009.

[57] Penn Medicine, "Brain Insulin Resistance Contributes to Cognitive Decline in Alzheimer's Disease," 2012. [Online]. Available: http://www.uphs.upenn.edu/news/News_Releases/2012/03/insulin/. [Accessed: 13-Mar-2014].

[58] S. L. Murphy, J. Xu, K. D. Kochanek, and V. Statistics, "National Vital Statistics Reports Deaths : Final Data for 2010," vol. 61, no. 4, 2013.

[59] J. E. Shaw, R. a Sicree, and P. Z. Zimmet, "Global estimates of the prevalence of diabetes for 2010 and 2030," *Diabetes research and clinical practice*, vol. 87, no. 1, pp. 4–14, Jan. 2010.

[60] International Diabetes Federation, "Saudi Arabia | International Diabetes Federation," 2014. [Online]. Available: http://www.idf.org/membership/mena/saudi-arabia. [Accessed: 19-Sep-2014].

[61] Ministry of Health, "Health Statistical Yearly Book 1432," 2011. [Online]. Available: http://www.cdsi.gov.sa/english/. [Accessed: 29-Jan-2014].

[62] A. K. Alhowaish, "Economic costs of diabetes in Saudi Arabia," *Journal of family & community medicine*, vol. 20, no. 1, pp. 1–7, Jan. 2013.

[63] X.-H. Meng, Y.-X. Huang, D.-P. Rao, Q. Zhang, and Q. Liu, "Comparison of three data mining models for predicting diabetes or prediabetes by risk factors," *The Kaohsiung journal of medical sciences*, vol. 29, no. 2, pp. 93–9, Feb. 2013.

[64] C.-D. Chang, C.-C. Wang, and B. C. Jiang, "Using data mining techniques for multi-diseases prediction modeling of hypertension and hyperlipidemia by common risk factors," *Expert Systems with Applications*, vol. 38, no. 5, pp. 5507–5513, May 2011.

[65] M. Suh, J. Woodbridge, T. Moin, M. Lan, N. Alshurafa, L. Samy, B. Mortazavi, H. Ghasemzadeh, A. Bui, S. Ahmadi, and M. Sarrafzadeh, "Dynamic Task Optimization in Remote Diabetes Monitoring Systems," *2012 IEEE Second International Conference on Healthcare Informatics, Imaging and Systems Biology*, pp. 3–11, Sep. 2012.

[66] A. Rocha, A. Martins, J. C. Freire Junior, M. N. Kamel Boulos, M. E. Vicente, R. Feld, P. van de Ven, J. Nelson, A. Bourke, G. ÓLaighin, C. Sdogati, A. Jobes, L. Narvaiza, and A. Rodríguez-Molinero, "Innovations in health care services: the CAALYX system," *International journal of medical informatics*, vol. 82, no. 11, pp. e307–20, Nov. 2013.

[67] D. S. Péres, M. A. dos Santos, M. L. Zanetti, and A. A. Ferronato, "Difficulties of diabetic patients in the illness control: feelings and behaviors," *Revista Latino-Americana de Enfermagem*, vol. 15, no. 6, pp. 1105–1112, Dec. 2007.

[68] L. Blonde, "Current challenges in diabetes management," *Clinical cornerstone*, vol. 7, no. Cvd, 2005.

[69] N. C. Onwudiwe, C. D. Mullins, R. A. Winston, F. T. Shaya, F. G. Pradel, A. Laird, and E. Saunders, "Barriers to self-management of diabetes: a qualitative study among low-income minority diabetics," *South African Journal of Diabetes and Vascular Disease*, vol. 11, no. 2, pp. 61–65, 2014.

[70] M. M. Funnell, T. L. Brown, B. P. Childs, L. B. Haas, G. M. Hosey, B. Jensen, M. Maryniuk, M. Peyrot, J. D. Piette, D. Reader, L. M. Siminerio, K. Weinger, and M. A. Weiss, "National standards for diabetes self- management education," *Diabetes Care*, vol. 32, no. SUPPL. 1. 2009.

[71] M. M. Funnell and R. M. Anderson, "Empowerment and Self-Management of Diabetes," *Clinical Diabetes*, vol. 22, no. 3. pp. 123–127, 2004.

[72] M. M. Funnell and R. M. Anderson, "The Problem With Compliance in Diabetes," *JAMA*, vol. 284, no. 13, p. 1709, 2000.

[73] D. J. Toobert, S. E. Hampson, and R. E. Glasgow, "The summary of diabetes self-care activities measure: Results from 7 studies and a revised scale," *Diabetes Care*, vol. 23, no. 7, pp. 943–950, 2000.

[74] T. Deakin, C. E. McShane, J. E. Cade, and R. D. R. R. Williams, "Group based training for self-management strategies in people with type 2 diabetes mellitus," *The Cochrane database of systematic reviews*, no. 2, p. CD003417, Jan. 2005.

[75] M. Alotaibi, "An Intelligent Mobile Diabetes Management and Educational System for Saudi Arabia (SAED)," Kingston University, London, 2014.

[76] M. J. Davies, S. Heller, T. C. Skinner, M. J. Campbell, M. E. Carey, S. Cradock, H. M. Dallosso, H. Daly, Y. Doherty, S. Eaton, C. Fox, L. Oliver, K. Rantell, G. Rayman, and K. Khunti, "Effectiveness of the diabetes education and self management for ongoing and newly diagnosed (DESMOND) programme for people with newly diagnosed type 2 diabetes: cluster randomised controlled trial," *BMJ (Clinical research ed.)*, vol. 336, no. 7642, pp. 491–495, 2008.

[77] "Programs & Support Services | Canadian Diabetes Association." [Online]. Available: http://www.diabetes.ca/in-your-community/programs-support-services. [Accessed: 29-July-2015].

[78] S. Ziebland, M. Lavie-Ajayi, and G. Lucius-Hoene, "The role of the Internet for people with chronic pain: examples from the DIPEx International Project," *British Journal of Pain*, vol. 9, no. 1, pp. 62–64, Nov. 2014.

[79] S. Ziebland and S. Wyke, "Health and illness in a connected world: how might sharing experiences on the internet affect people's health?," *Milbank Quarterly*, vol. 90, no. 2, pp. 219–249, 2012.

[80] A. Ramadas, K. F. Quek, C. K. Y. Chan, and B. Oldenburg, "Web-based interventions for the management of type 2 diabetes mellitus: a systematic review of recent evidence," *International journal of medical informatics*, vol. 80, no. 6, pp. 389–405, Jun. 2011.

[81] H.-S. Kwon, J.-H. Cho, H.-S. Kim, B.-R. Song, S.-H. Ko, J.-M. Lee, S.-R. Kim, S.-A. Chang, H.-S. Kim, and B.-Y. and others Cha, "Establishment of Blood Glucose Monitoring System Using the Internet," *Diabetes Care*, vol. 27, no. 2, pp. 478–483, 2004.

[82] "CITC Annual Reports," 2014. [Online]. Available: http://www.citc.gov.sa/English/Reportsandstudies/Reports/Pages/CITC_Annual_Reports.aspx. [Accessed: 31-May-2015].

[83] K. M. AlGhamdi and N. a Moussa, "Internet use by the public to search for health-related information," *International journal of medical informatics*, vol. 81, no. 6, pp. 363–73, Jun. 2012.