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Digital health innovation ecosystems: From systematic literature review to conceptual framework

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Abstract

This paper reviews existing literature on digital health innovation ecosystems. It aims to explore the terms digital health, innovation and digital ecosystems to identify components towards presenting a conceptual framework for a digital health innovation ecosystem as part of a larger study. A systematic literature review was conducted on four academic databases: ACM, ScienceDirect, IEEE Xplore and SpringerLink. Due to the dearth in initial search results, the search was broadened to include non-academic publications and practitioner case reports. The study identified components of digital health, components of innovation relevant to the healthcare domain and components of digital ecosystems. It further suggests, within the context, a comprehensive definition of digital health innovation ecosystems. A conceptual framework for digital health innovation ecosystems is proposed. The findings from this study could conceivably be a step towards enabling a common understanding of practitioners, professionals and academics within the digital health domain as well as a basis for further studies on digital health innovation ecosystems.

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1. Introduction

Innovation is described as the ability to create new ideas¹⁻³. Innovation has been applied in different contexts⁴⁻⁵ and the healthcare sector is no exception⁶⁻⁷. Recent trends in healthcare innovation explore user participation in the healthcare delivery process^{8-9,55}. Digital health is an example of healthcare innovation, as it provides a platform in which digital technologies facilitate patients' participation in the healthcare delivery process⁹. Studies have identified innovative approaches to improve existing health models, for example, incorporating innovation ecosystems into providing digital health services^{10-12,32,33}.

Although digital health is a trending topic¹⁵, and digital ecosystems are being discussed in academic literature^{34,61,62}, the term *digital health innovation ecosystem* is rarely discussed¹² and has not been clearly defined in academic literature. Furthermore, there is limited theoretical research that focuses on the components that constitute digital health innovation ecosystems. This paper aims to explore the terms digital health, innovation and digital ecosystems to identify components towards presenting a conceptual framework for a digital health innovation ecosystem as part of a larger study. Therefore, this study contributes to the emerging body of literature on digital health innovation ecosystems.

2. Research method

Petticrew and Roberts¹³ describe a systematic literature review as "literature reviews that adhere closely to a set of scientific methods that explicitly aim to limit systematic error (bias), mainly by attempting to identify, appraise and synthesize all relevant studies (of whatever design) in order to answer a particular question (or set of questions)". Furthermore, Okoli¹⁴ recommends that studies which aim to make a contribution rather than summarise existing literature should adopt a systematic literature review approach. As this study aims to explore the terms digital health, innovation and digital ecosystems and contribute to the emerging body of literature on digital health innovation ecosystems, a systematic literature review was applied.

A systematic literature review was conducted on the following topics: digital health, innovation and digital ecosystems. A systematic literature review was conducted on four academic databases: ACM, ScienceDirect, IEEE Xplore and SpringerLink. In order to broaden the search, non-academic publications and practitioner case reports were also used. Search keywords include digital health, innovation, and digital ecosystems. The search was conducted between February and March 2016.

Books, book chapters, journal articles, conference papers, non-academic publications and practitioner case reports related to digital health, innovation, and digital ecosystems were selected. Only publications written in English were included. Duplicate publications were excluded from the search. Title and abstracts were first screened for relevance before full-text documents were screened.

The findings are categorised under different themes: definition of digital health, definition of innovation, definition of digital ecosystems, components of digital health, components of innovation and components of digital ecosystems. The components are presented in a tabular format with a description of each component identified. A comprehensive definition of digital health innovation ecosystems is also presented.

3. Results

In total, 65 publications were included in the current review, with (n=35) publications on digital health, (n=18) publications on innovation and (n=12) publications on digital ecosystems. The results of the study are provided in subsequent sections.

3.1. Definition of digital health

Different authors agree that digital health involves the use of different healthcare technologies in administering healthcare services to enhance patients' health¹⁵⁻¹⁸. In addition, while Sonnier¹⁸ and Baumann¹⁷ believe that digital health helps in monitoring patients' health, Sonnier¹⁸ emphasises that digital health not only enhances patients' health but also enables families to assist in the process by monitoring patients' health. In contrast to existing

definitions of digital health, Robinson et al.¹⁹ insist that digital health “lacks theoretical definition”. However, Robinson et al.¹⁹ suggest that digital health is the “use of digital media to transform the way healthcare provision is conceived and delivered”.

Furthermore, a proper definition of digital health should include the stakeholders involved in healthcare provision and delivery processes. In addition to the definitions of digital health provided by Kotskov¹⁶, Mellodge and Vendetti¹⁵, Sonnier¹⁸, Baumann¹⁷, Robinson et al.¹⁹ and for the purpose of this study, digital health is defined as: an improvement in the way healthcare provision is conceived and delivered by healthcare providers through the use of information and communication technologies to monitor and improve the wellbeing and health of patients and to empower patients in the management of their health and that of their families.

3.2. Components of digital health

The components that constitute digital health were identified in selected literature. The components of digital health presented in Table 1 were considered relevant for this study for two reasons:

- The components were either stated as components of digital health by the authors or
- Descriptions or the purpose of the components were in alignment with the definition of digital health for this study.

The components of digital health identified in selected literature are described in Table 1.

Table 1. Components of digital health

Components/ Sources	Description
e-health ^{20,18,21,22}	E-health refers to the use of internet and web technologies in the provision of healthcare delivery services ²³ .
m-health ^{20,18,21,22}	M-health refers to the use of mobile devices in administering healthcare services ²⁴ .
Health 2.0/Medicine 2.0 ^{20,18,21,22}	Health 2.0/Medicine 2.0 refers to “the integration of Web 2.0 in the utilization of healthcare and medicine to enable and facilitate specifically social networking, participation, apomediation, collaboration, and openness within and between these user groups” ²⁵ .
Telemedicine/telecare ^{20,18,21,22}	Telemedicine/telecare refers to the use of different information and communication technologies (ICTs) by physicians to remotely connect with patients. ²⁶
Public health surveillance ²⁰	Public health surveillance is used in gathering health information of a specific population ²⁷ to facilitate “decision making” ²⁸ regarding the health of the population in a particular setting.
Personalized medicine/patient engagement ^{18,20}	Personalized medicine refers to the provision of unique treatment to patients based on their genetic and genomic components. ³⁶
Health and medical platforms ²⁰	Health and medical platforms include online platforms such as online forums ³⁷ that help foster interaction between patients and experts.
Health promotion strategies ²⁰	Health promotion strategies refer to “the process of enabling people to increase control over their health and its determinants, and thereby improve their health”. ⁵⁰
Self-tracking (the quantified self) ^{18,22,20}	Quantified self-tracking enables patients to monitor their health status by adopting a wide range of technologies that facilitate the process ⁴² .
Wireless health/Wireless sensors ^{18,40}	Wireless sensors refer to the use of different wireless monitoring devices situated in a wireless network used for monitoring patients’ health by a physician. ⁴³
Genomics ⁴⁰	Genomics emphasizes how patients uniquely react to diseases based on their genomic components. ⁴⁴
Imaging/Medical imaging ^{40,21}	Imaging/medical imaging refers to “techniques and processes used to create images of various parts of the human body for diagnostic and treatment purposes within digital health” ⁴⁵ .
Information systems ⁴⁰	Information systems in healthcare refer to health information systems. According to Cline and Luiz ⁵¹ , these systems can significantly improve healthcare delivery services to patients.

Components/ Sources	Description
Mobile connectivity and bandwidth ⁴⁰	Mobile connectivity and bandwidth facilitate the connectivity of different digital health technologies for physicians to remain digitally connected to patients.
Internet ⁴⁰	In healthcare specifically, the use of the Internet facilitates information sharing ²³ .
Social networking ⁴⁰	Social networking platforms on which health professionals and patients can share information ⁵² .
Computing power and data universe ⁴⁰	Digital health facilitates the management of patient health information by medical practitioners, patients and their families ¹⁸ . Therefore, digital health will require information that can be accessed at different places and at different times, hence the need for high computing power and the data universe. Digital health requires high computing power and storage.
Interoperability ²²	The “ability of two or more systems or components to exchange information and to use the information that has been exchanged”. ²²
Sensors and wearables ²²	Wearable technologies are devices that inform the user when they are worn. ⁴⁹
Health and wellness apps ²²	Health and wellness apps refer to mobile applications used for disseminating health information to patients to facilitate the management of health by the patient. ⁸
Gamification ^{18,22}	Gamification in healthcare facilitates patients into performing certain activities in relation to health practices. ⁴⁸
Electronic health records (EHRs) ²¹⁻²²	Electronic health records (EHRs) consist of all the combinations of patient health information from past and previous visits to a health institution, which can be presented to a medical practitioner to make decisions regarding a patient’s health. ⁴⁷
Electronic medical records (EMRs)	Electronic medical records (EMRs) are “computerized medical information systems that collect, store and display patient information” ⁶⁵ . Furthermore, EMRs enhance eligibility of patient records and have also been used to improve decision making in emergency departments. ⁶⁶
Big data ^{21,18, 22}	Snijders, Matzat and Reips ⁴⁶ define big data as a “term used to describe data sets so large and complex that they become awkward to work with using standard statistical software”.
Health information technology ^{21,18, 22}	Health information technology refers to the “application of Information and Communication Technologies (ICT) involving both computer hardware and software that deal with the processing, storage, retrieval, sharing and use of health care information, data, and knowledge for communication and decision making” ³⁹ .
Health analytics ³⁸	The “software solutions and analytical capabilities needed to assimilate big data” ³⁸ .
Digitized health systems ³⁸	The “storage and exchange of digitized patient medical records” ³⁸ .
Privacy and security ⁴¹	Privacy and security are measures taken to ensure that patients’ health information is well protected. Patients also want to maintain privacy in the way health information is accessed in EMRs ⁶⁷
Cloud computing ¹⁸	The use of cloud computing in deploying healthcare services to patients ⁶⁴ .

3.3. Definition of innovation

Discussions on innovation have been recorded in existing literature over a long period of time^{35,1,2}. Therefore, the concept of innovation is not new. However, innovation has been defined from different perspectives. The commonality among the different definitions of innovation is that innovation is described as the creation of new ideas to improve the output of a firm^{1,2}.

Innovation has been applied in the context of healthcare^{6,7}. Omachonu and Einspruch⁶ and Thankur, Hsu and Fontenot⁷ have provided definitions of innovation in healthcare. Thankur et al.’s⁷ definition of healthcare innovation implies that health practices that have proven to have the best approach in healthcare are used in administering health services to patients. The focus of this study is on healthcare innovation. Adopting the definitions of Omachonu and Einspruch⁶ and Thankur et al. and for the purpose of this study, healthcare innovation is defined as: the adoption of those best-demonstrated practices that have been proven to be successful and implementation of those practices aimed at improving treatment, diagnosis, education, outreach, prevention and research, and with the long term goals of improving quality, safety, outcomes, efficiency and costs.

3.4. Components of innovation

The components that constitute innovation were identified in selected literature. The components of innovation presented in Table 2 were considered relevant for this study for two reasons:

- The components were either stated as relating to innovation by the authors or
- Descriptions or the purpose of the components were in alignment with the definition of healthcare innovation for this study.

Furthermore, these components can be applied within the healthcare context. The components of innovation identified in selected literature are described in Table 2.

Table 2. Components of innovation

Components/Sources	Description
Process innovation ⁵⁸	Process innovation “entails innovations in the production or delivery method. The customer does not usually pay directly for process, but the process is required to deliver a product or service and to manage the relationship with the various stakeholders” ⁵⁸ .
Product innovation ⁵⁸	Product innovation is the product that “the customer pays for and typically consists of goods or services” ⁵⁸ . Varkey, Horne and Bennet ⁵⁸ also explain that “clinical procedure innovations belong to the category of product innovations” ⁵⁸ .
Structure innovation ⁵⁸	Varkey et al. ⁵⁸ indicate that “structural innovation usually affects the internal and external infrastructure, and creates new business models”.
Information technology ⁶	Omachonu and Einspruch ⁶ state that information technology is a component of innovation.
Closed innovation ⁵⁶	Closed innovation refers to a single entity exploring innovative ideas in isolation ⁵⁶ . An entity could include a single company, business or institution.
Open innovation ⁵⁶	Open innovation refers to an entity participating in sharing and gaining ideas from other entities ⁵⁶ .
Open innovation 2.0 ⁵⁹	Open innovation 2.0 is referred to as a “new paradigm based on principles of integrated collaboration, co-created shared values, cultivated innovation ecosystems, unleashed exponential technologies and extraordinarily rapid adoption” ⁵⁹ .
Innovation networks ecosystems ⁵⁷	Spruijt ⁵⁷ defines an innovation ecosystem as a “dynamic system” which “contains complex feedback loops, causal links, flows, stocks, delays among the agents”.
Triple Helix system ⁵³	The concept of Triple Helix idealizes on universities, industries and government taking centre stage in the innovation process ⁵³ . Within the healthcare sector, the Triple Helix system can also be applied to include stakeholders from universities, industries and the government ⁷⁰ .
User Innovation ^{55,54,30}	This refers to a process in which users of a product participate in the innovation process ^{55,54,30} . User innovation has been applied within the healthcare domain ⁵⁵ .
Intellectual property ⁶⁰	Intellectual property rights can be used to reduce chances of intellectual properties being stolen by others on an innovation platform. Intellectual property rights can also be applied within the healthcare sector to improve innovation ⁶⁰ .

3.5. Definition of digital ecosystems

Over the years, different definitions of digital ecosystems have emerged. For example, Chang and West³⁴ define a digital ecosystem as an “open, loosely coupled, domain clustered, demand-driven, self-organising agents’ environment, where each species is proactive and responsive for its own benefit or profit”. This definition suggests that each species present in a digital ecosystem participates with the aim of achieving something. Similar definitions of digital ecosystems by Hadzic and Dillion³² and Serbanatti and Vasilateanu¹¹ imply that interacting components in a digital ecosystem should be connected. However, Briscoe and De Wilde⁶⁸ insist that participants in a digital ecosystem need not be in a specific location to be connected. Kolb⁶³ provides a different perspective to digital ecosystems as he defines a digital ecosystem as a “community of digital devices and their environment functioning as a whole”. Digital devices provide information to the other components in the ecosystem. The digital ecosystem simulates the actions portrayed by organisms in a natural ecosystem³¹.

Furthermore, Hadzic and Dillion³² describe a digital ecosystem as “complex”. Ion et al.⁶⁹ postulate that the complexity of digital ecosystems could be attributed to the differences in the objectives of participants who take part in the activities of the digital ecosystem.

Adopting the definitions of Hadzic and Dillon³² and Serbanatti et al.¹⁰ and for the purpose of this study, a digital ecosystem can thus be defined as: a network of digital communities consisting of interconnected, interrelated and interdependent digital species, including stakeholders, institutions and digital devices situated in a digital environment, that interact as a functional unit and are linked together through actions, information and transaction flows.

3.6. Components of digital ecosystems

The components that constitute digital ecosystems were identified in selected literature. The components of digital ecosystems presented in Table 3 were considered relevant for this study for two reasons:

- The components were either stated as relating to digital ecosystems by the authors or
- Descriptions or the purpose of the components were in alignment with the definition of digital ecosystems for this study.

Furthermore, these components can be applied within the healthcare context. The components of digital ecosystems are described in Table 3.

Table 3. Components of digital ecosystems

Components /Sources	Description
Community ²⁹	Community in digital ecosystems refers to the entire species available within the digital ecosystem environment. ²⁹
Content ²⁹	Content in digital ecosystems refers to information or services which are of use to the species available within the digital ecosystem. ²⁹
Practice ²⁹	In order for the different species to be comfortable and operate freely, practice is required. ²⁹
Technology ²⁹	Technology in digital ecosystems refers to hardware and software responsible for the information interchange within the digital ecosystem. ²⁹
Biological species ³⁴	The people who participate in the digital ecosystem. ³⁴
Economic species ³⁴	The different companies and institutions that participate in the digital ecosystem. ³⁴
Digital species ³⁴	The digital devices, software and hardware used by people and different companies and institutions that participate in the digital ecosystem. ³⁴
Digital environment ^{32,10}	The platform on which digital species interact. ^{32,10}
Security ⁶¹	The protection of resources and species in the digital ecosystem. ⁶¹
Trust ⁶²	The trust that all species in the digital ecosystems are focused on achieving the same goal. ⁶²

3.7. Definition of digital health innovation ecosystems

Working definitions of digital health, innovation and digital ecosystems have been provided. A proposed definition of digital health innovation ecosystems should contain the essence of the definitions for digital health, innovation and digital ecosystems. Based on the discussions related to digital health, innovation and digital ecosystems, a digital health innovation ecosystem can be defined as: a network of digital health communities consisting of interconnected, interrelated and interdependent digital health species, including healthcare stakeholders, healthcare institutions and digital healthcare devices situated in a digital health environment, who adopt the best-demonstrated practices that have been proven to be successful, and implementation of those practices through the use of information and communication technologies to monitor and improve the wellbeing and health of patients, to empower patients in the management of their health and that of their families.

A conceptual framework for a digital health innovation ecosystem is presented in Fig. 1, showing the underlying relationships of the different components identified in selected literature.

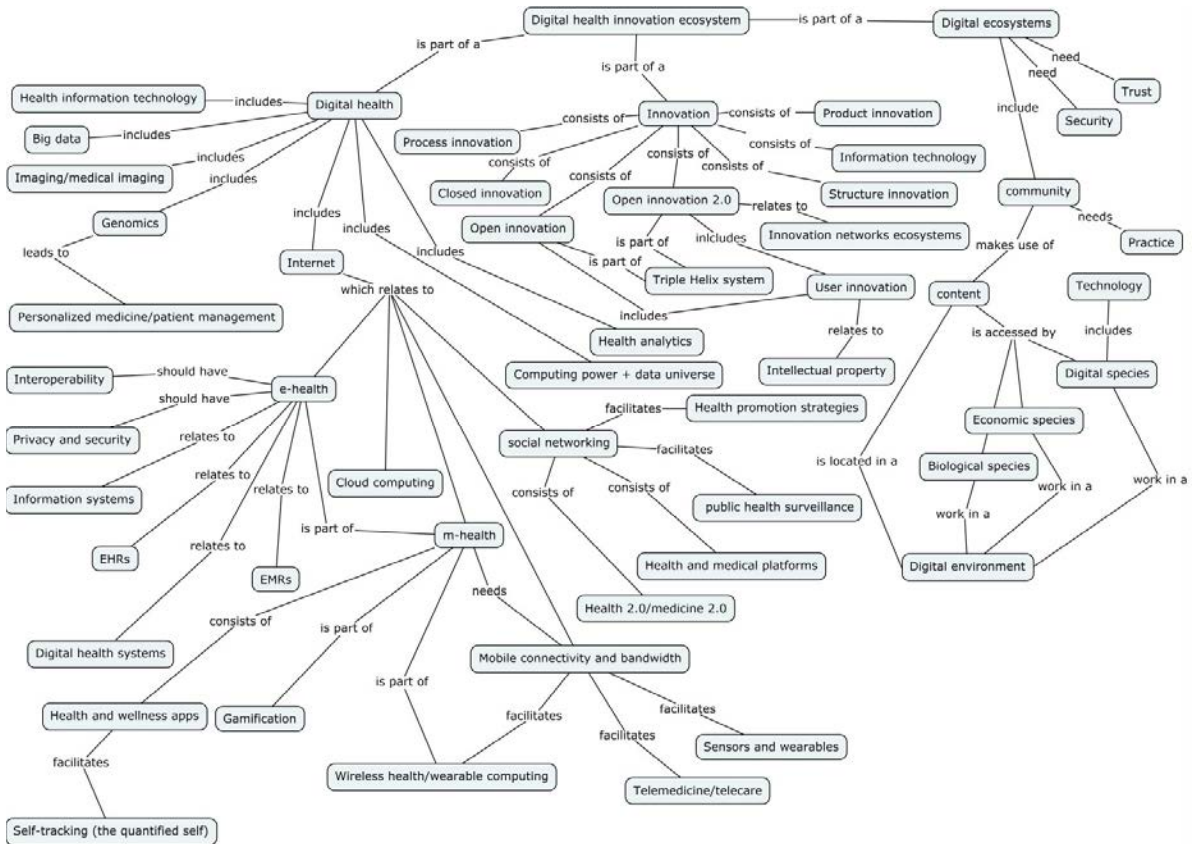


Fig. 1 Conceptual framework for digital health innovation ecosystems

5. Conclusion

This study contributes to the emerging body of literature on digital health innovation ecosystems. A definition of digital health innovation ecosystems and components of digital health innovation ecosystems is provided within the academic domain. A conceptual framework for digital health innovation ecosystems is proposed. The findings from this study could conceivably be a step towards enabling a common understanding of practitioners, professionals and academics within the digital health domain as well as a basis for further studies on digital health innovation ecosystems.

The components of digital health, innovation and digital ecosystems were selected based on their descriptions and purpose, aligned to the definitions of digital health, innovation and digital ecosystems for this study or based on the authors stating that these components were either related to digital health, innovation and digital ecosystems. As a result, other relevant components of digital health, innovation and digital ecosystems that did not match our inclusion criteria might have been excluded and hence, affected the results. However, for further studies, the inclusion criteria may be broadened to include other relevant components of digital health, innovation and digital ecosystems. Future work would be to examine how the components of the proposed conceptual framework presented in this study have been applied in developed and developing countries.

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