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Knowledge Management Theory and the Evidence-Based Healthcare Model to Guide the Design for an Australasia Open Biomedical Repository

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Abstract:

This paper reports on research that fills a unique gap on investigating the concept, viability and potential for an open Australasia biomedical repository, by drawing upon PubMed Central International (PMCI) as a case example. PMCI is the full text article repository for the US National Library of Medicine's PubMed. An Australasia open biomedical repository could mirror and contribute to other world repositories and include research output with an Australian and New Zealand focus. The research output in an Australasia biomedical repository could include journal literature, guidelines, conference proceedings, reports, patents, books, images, grant details and could link to research data, such as the world clinical trial registries.

Major funding bodies in Europe, the USA, the UK and Australia have mandated open access publishing over recent decades. This research focuses on the knowledge management (KM) processes related to open biomedical research and innovation. KM processes are important throughout key research activities. Examining the theoretical KM processes such as knowledge discovery, capture, sharing and application gives an understanding of the importance each of these processes towards the success of open biomedical repositories.

Institutional repositories exist throughout Australian universities and the National Library of Australia TROVE harvests the research output from these systems. This paper reports on the KM theories to explain the role of open biomedical repositories as a means to manage and disseminate the results of research. The Evidence-Based Healthcare pyramid is another model used as a lens to give meaning to the array of information resources for finding clinical evidence that are stored in a repository such as

PMCI. This paper expands on the role of open biomedical repositories to help transform societies. Lessons from the closure of PMC Canada and the success of Europe PMC have informed this research.

Keywords: knowledge management, open biomedical repositories, open science, PubMed Central International, PMC, scholarly publishing

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Introduction

Open repositories throughout the world have become a trusted platform for storing and accessing scholarly research outputs. The ultimate aim of biomedical repositories is to help make the route from basic research results to healthcare solutions as effective as possible. In 2000, the US PubMed Central (PMC) commenced as an open disciplinary repository of full-text biomedical research literature, making the results of the National Institutes of Health's research freely and permanently accessible (US National Library of Medicine National Institutes of Health). PubMed linked to PMC makes research evidence in the biomedical sciences accessible worldwide, with over one billion visitors to the site annually (Koprowski, 2004; US Department Health and Human Services, 2017). In late 2000, in Europe and Canada, PMC nodes as 'children' of the US PMC were established as PubMed Central International (PMCI) (Europe PMC Consortium, 2015) to address the problems of fragmentation, accessibility, discoverability and permanency of biomedical research outputs. However, in the Australasia region there has not been a similar concerted effort.

For over 350 years, scholarly journal articles have been the chosen means to disseminate new knowledge, register research findings, review and certify results, preserve a record, add to the existing body of knowledge and as a measure for determining academic promotion (Fyfe, McDougall-Waters, & Moxham, 2015). In a climate of widespread disruptive technological change mixed with rapid development of digital publishing, it is timely to investigate the viability and potential of open biomedical literature repositories from a KM perspective.

Over the period 1970 until the 1990s, there was a shift from personal subscriptions towards library provided journal access (Tenopir & King, 1998). Around this time sales of large portfolios of electronic journal content sold through consortia arrangements to libraries was the major means to acquire research collections. Academic libraries throughout Australia spend approximately $AUD300 million annually on collections to support students, researchers and practitioners (Gerrity, February 2016). Over the past decade, many academic libraries have needed to cancel subscriptions in order to free up funds for new titles. In addition to the struggle to maintain subscriptions, library management are required to sign contracts that forbid them disclosing publisher fees (Sample, 2012); therefore the costs of the existing scholarly publishing system are not transparent.

A digital repository is a set of systems and services that ingest, store, manage, display, retrieve and allow reuse of digital objects (Pinfield et al., 2014). Institutions, subject communities and research funders predominantly set up repositories to provide access to digital objects (Pinfield, 2009). Aggregators actively harvest data from multiple sources, such as repositories and make repositories searchable and available in a uniform way (Przybyła et al., 2016). Open access (OA) literature is content that is online, digital, free of charges and without most of the copyright and licensing restrictions (Suber, 2015). In early 2000, around the time of the Budapest Open Access Initiative, the focus was on making peer-reviewed scholarly journal articles accessible via the Internet from institutional and subject repositories such as PMC (Sequeira, McEntyre, & Lipman, 2001). By late 2000, in addition to journal articles, the content of books and book chapters, conference papers, theses, working papers, preprints, learning objects and rich media files were becoming openly accessible from repositories. The fundamental goals of opening up content relate to transparency of research methods, reusability, transparency of communication and public accessibility via the Internet (Gezelter, 2009).

A subject repository is defined as a repository "that collects and provides access to the literature of a single subject or a set of related subjects"; PMC is commonly cited as an exemplary subject-based repository (Huber, 2014).

Overview of an Australasia PMC and theorectical framework

An Australasia PMC could consolidate biomedical research findings and become a basis for linking clinical trials, genomic data, patents and clinical guidelines. It could be a permanent repository for present and future generations. The starting point of an Australasia PMC could be the US PubMed and PMCI. There are various options available to populate an Australasia PMC. Harvesting citations from existing repositories and inviting Australasian researchers to deposit their research papers directly in an Australasia PMC are options for consideration. Translational medicine could benefit from an Australasia PMC based on the integration of biomedical data and research.

Knowledge management (KM) is getting the right knowledge to the right user, and using this knowledge to improve organizational and/or individual performance (Jennex, Smolnik, & Croasdell, 2009). KM is doing what is needed to get the most out of knowledge resources (Becerra-Fernandez & Sabherwal, 2015).

There is a prolific amount of research literature on KM with a focus on achieving competitive advantage for organisations (Argote & Ingram, 2000; Halawi, Aronson, & McCarthy, 2005; Martensson, 2000). This paper focuses on the significance of KM processes in relation to biomedical research and innovation. According to Tuomi, when we explicitly address processes that underpin the establishment of shared understanding, it is then we develop KM systems (Tuomi, 1999).

In addition, the Evidence Based Healthcare (EBHC) pyramid model, developed by Haynes, is the lens adopted to explain the use of biomedical repositories for retrieval of quality research findings (Haynes, 2001, 2006).

Research Design

The research design involved participatory research approaches with a focus on action research (Williamson, 2013). The aim of action research is to simultaneously produce new general knowledge and address practical problems. It is particularly relevant for practitioner research, such as library science, because it involves the people who are experiencing the organizational or social challenges being addressed (Elden & Chisholm, 1993).

Action research entails an interlinked, cyclical approach to research. It is a means to combine practice and theory. The steps in action research usually include 'diagnosing a problem situation, planning action steps, and implementing and evaluating outcomes' (Lewin, 1946).

The discovery, creation, storage, retrieval and application of knowledge management processes aligned with the key research activities, is the theoretical lens used to investigate the purpose and role of open biomedical repositories. The EBHC pyramid is an additional model to help explain the design and purpose of biomedical repositories.

Literature Review

Based on a thorough search of the literature and discussions with leaders in healthcare, biomedical research and open access fields, there are no previous academic studies on the concept, viability and potential for an Australasia PMC repository from a KM perspective. A vast amount of academic research on more generic open access publishing and repositories is available.

KM processes are important throughout key research activities (Saito, Umemoto, & Ikeda, 2007). The conduct of clinical trials is a major biomedical research activity that requires registration of data and report planning at an early stage of the research. While KM is generally not directly concerned with data, the exception to this is when knowledge discovery occurs through data mining techniques (Becerra-Fernandez & Sabherwal, 2015, p. 40). KM is concerned with the discovery of tacit and explicit knowledge from data and information or from the synthesis of prior knowledge (Becerra-Fernandez & Sabherwal, 2015, p. 59). The discovery activity of research involves iterations of searching and reading (Kramer & Bosman, 2017).

Knowledge creation modes identified by Nonaka, include:

1. Socialization, involving conversion of tacit knowledge to new tacit knowledge through social interactions and mutual experiences, such as participating at conferences;
2. Externalization, entailing the conversion of tacit knowledge to explicit knowledge, such as procedures;
3. Combination, organising and integrating knowledge; and
4. Internalization, converting new tacit knowledge from explicit knowledge, such as new learning from reading (Nonaka, 1994).

Each of the knowledge creation modes identified by Nonaka is vital to the transformation of research by health practitioners, industry, or consumers to adopt the findings as knowledge. A social process, which often involves checking with other practitioners and gaining insight from a range of sources occurs to form part of a 'mindline,' the knowledge in context that is used in practice. This social activity underpins the constant and repeated process to transform research into knowledge (Gabbay & le May, 2010, p. 102).

Information systems that support collaboration, coordination and communication processes can increase a researcher's contact with colleagues. These information systems underpin knowledge creation activities (Alavi & Leidner, 2001). Conception, planning and commencement of research (National Health and Medical Research Council (Australia), 2016a) and preparation and analysis (Kramer & Bosman, 2017) are key activities in knowledge discovery and creation processes.

KM processes align with biomedical knowledge creation activities. For example, there is correlation of the KM storage and retrieval processes with the biomedical research activities: data collection, processing, analysis, storage and management (National Health and Medical

Research Council (Australia), 2016a) and writing and publication (Kramer & Bosman, 2017). Four groupings of KM processes and their alignment with biomedical research activities are summarised in Table 1.

References	**Knowledge Management processes**			
Grouping	1.	2.	3.	4.
Alavi and Leidner, 2001	Creation	Storage and Retrieval	Transfer	Application
Nonaka, 1994	Socialization	Externalization	Combination	Internalization
Becerra-Fernandez, I & Sabberwal, R. 2015	Discovery	Capture	Sharing	Application
Maier, 2007	Discovery	Publication	Collaboration	Learning
	Biomedical research activities			
NHMRC (Australia)	Conception, planning and commencement of the research	Data collection, Processing, analysis, storage and management	Dissemination of results and data access	[Translation of research]*
Bosman and Kramer	Preparation, discovery and analysis	Writing and publication	Outreach	Assessment

Table 1 Summary of KM process models aligned with biomedical research activities
*Translation of research into healthcare policy and practice is one of the NHMRC's primary responsibilities (National Health and Medical Research Council (Australia), 2016b).

See also: Figure 1 NHMRC biomedical knowledge creation stages and Figure 2 Research workflow model

The National Health and Medical Research Council (NHMRC) is an Australian government authority that funds and maintains a strong integrity framework for research processes, from basic science through to clinical, public health and health services (National Health and Medical Research Council (Australia), 2017).

Bosman and Kramer from Utrecht University Library in the Netherlands derived their model based on a global survey to "chart the changing global landscape of scholarly communication (Kramer & Bosman, 2015)." The survey undertaken from May 2015 to February 2016 received more than 20,000 responses. The seven most important elements in research workflow, identified by Bosman and Kramer from the data include Preparation, Discovery, Analysis, Writing, Publication, Outreach and Assessment; see Figure 2. Research workflow model (Kramer & Bosman, 2015).

Open biomedical aggregators and repositories, such as PubMed and PMC, exemplify sophisticated KM processes and work as platforms for researchers worldwide to access biomedical research evidence.

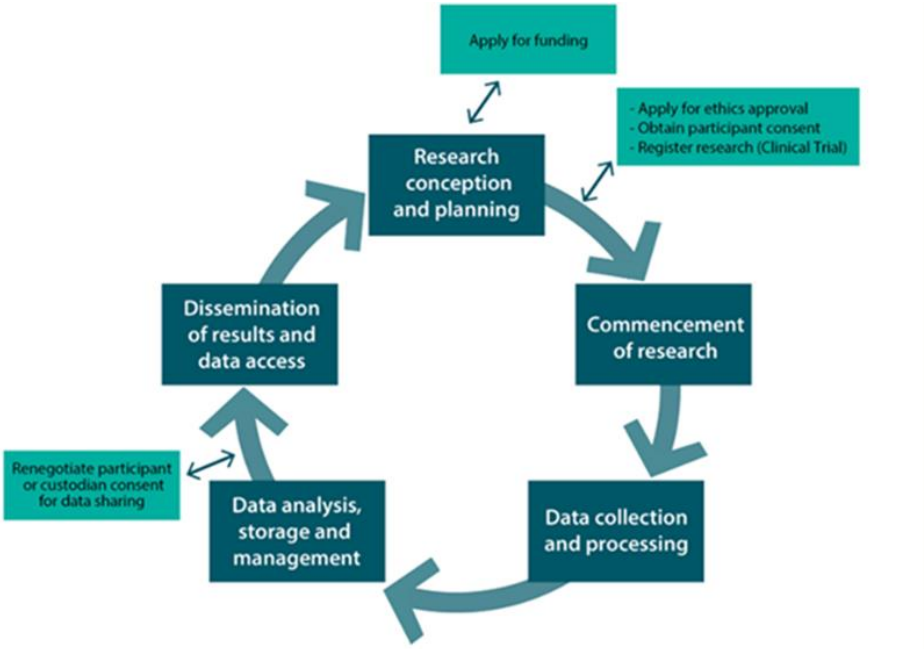

Figure 1 NHMRC biomedical knowledge creation stages

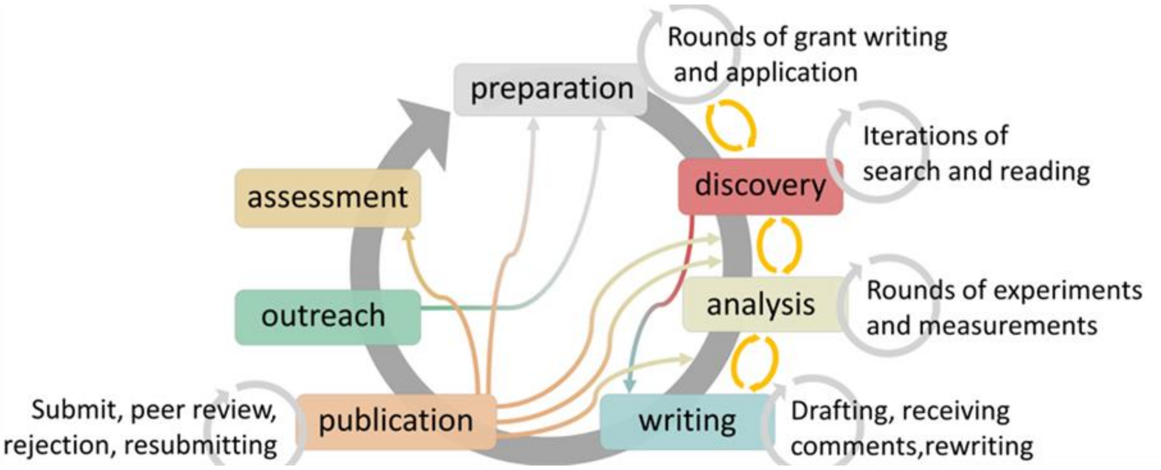

Figure 2 Research workflow model (Bosman and Kramer, 2015)

This research also explores the EBHC pyramid model to help guide the design of an open biomedical repository (Haynes, 2001, 2006).

Findings & Discussion

KM Theories

There is a strong correlation of KM processes and key research activities in the areas of creation, storage and retrieval, transfer and application (groupings 1-4) in Table 1. The conceptual design of the Australasian open biomedical repository, informed by the successful design of Europe PMC, could include integration with grant information to seal the gap between research origins through to research application.

EBHC Pyramid Model

PMC predominately comprises individual, primary research studies that are the foundation of the EBHC pyramid. For example, Europe PMC, when accessed on the 26 October 2017, comprised 4.4 million articles of which 430,168 were reviews, 11,060 were books and documents, and the remainder were primary studies ("Europe PMC ", 2017). The primary studies (Figure 4) form a pyramid within the EBHC pyramid (Figure 3). The studies hierarchy commences with laboratory research, followed by expert opinion in the form of case reports and case series, case-control studies, cohort studies, randomized controlled trials (RCT) and has systematic reviews and meta-analyses above the individual studies (Petrisor & Bhandari, 2007; Sackett, 2000; Shaneyfelt, 2016). RCTs are the gold standard in clinical research, based on a rigorous methodology that help to eliminate bias (Grimes & Schulz, 2002). Primary studies, based on the EBHC model, are located at the bottom of the pyramid (Figure 4).

Progressing beyond systematic reviews in the pyramid, the next level includes synopses, such as critically appraised primary studies. Continuing upwards in the pyramid evidence-based guidelines, and then synthesized summaries (evidence-based textbooks) and systems are at the apex. The apex represents the integration of evidence within hospital clinical decision systems, which along with digitized patient health records help to achieve individualized healthcare.

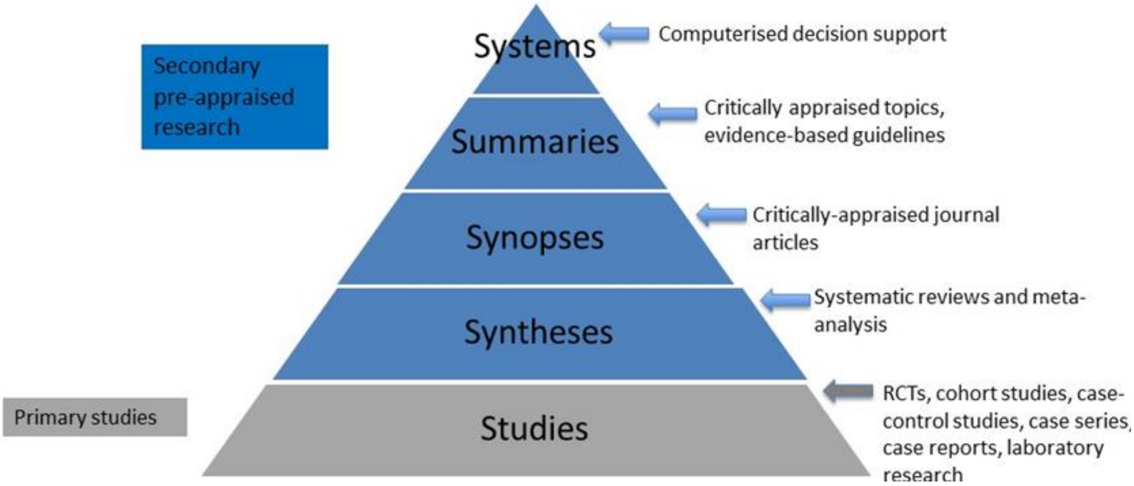

Figure 3 Evidence-based healthcare (EBHC) pyramid

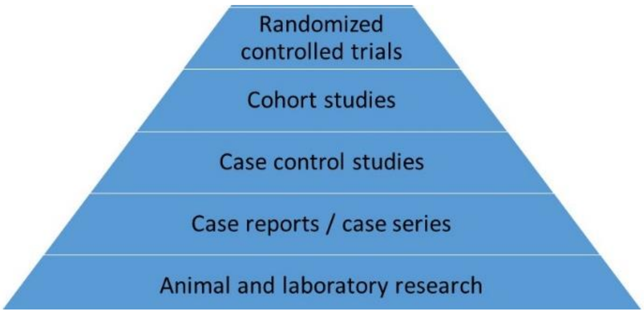

Figure 4 Primary studies, a hierarchy of study design pyramid within the base of the EBHC pyramid

Australasia Open Biomedical Respository Conceptual Design

KM & the EBHC Pyramid Model

There is an opportunity to design a successful and sustainable Australasia open biomedical repository based on KM standards and guides. The organisation of knowledge according to Standards Australia is 'an ecosystem that consists of a complex set of interactions between people, process, technology and content' (Standards Australia, 2005). The need for balance amongst the four elements is stressed by the Australian Standard and it is argued that 'one element should not be developed at the expense of another' (Halbwirth & Sbarcea, 2005).

To progress the conceptual design of an open Australasia biomedical repository the KM processes were determined as seven activities, including discovery, creation, representation, storage, retrieval, transfer and application; see Table 2 Biomedical KM processes for their definitions and examples.

As a starting point a brief description of the people, repository process, technology and content for each KM process that are critical in the conceptual design for an Australasia open biomedical repository are summarised:

Discovery

Researchers are the people element in the discovery KM process. Researchers review existing knowledge by undertaking, for example, searches in PubMed to identify literature on a topic. A disciplinary repository, such as PMC, satisfies the requirement of the NHMRC open access policy as a means to disseminate research findings (National Health and Medical Research Council (Australia), 2012 (revised 2014)). Online databases, visual knowledge gateways and automated current awareness services are the technology elements of the research discovery process. Proprietary databases for example, CINAHL, PsycINFO, the Informit Health Collection and open databases such as PubMed, clinical trials, PhD theses and other data sources contain discovery content elements.

Creation

The people element of creation relates to the undertaking by researchers of data analysis and other investigation activities. It also includes the role of funding bodies (Europe PMC has 29 funders) (Europe PMC, 2018b) who underpin creation. The other people include those who create the databases and repositories, such as PMCI and the publishers who copy edit and provide platforms for research output. Technology is a vital element in each step of the creation process. In relation to the process element, repository process activities can drive behaviour, for example, policies that mandate opening up research, in addition to research performance evaluation and grant application processes. The content element in creation for example, with Europe PMC, includes data sources such as Agricola, Chinese Biological Abstracts, CiteXplore, EthOs, PhD theses, NHS Evidence (UK Clinical Guidelines), PubMed, MEDLINE, Europe PMC Book metadata, biological patents and US PMC(Europe PMC, 2018a).

Table 2. Biomedical KM processes							
	Discovery	Creation	Representation	Storage	Retrieval	Transfer	Application
Definition	The process of finding information, a place, or an object, especially for the first time	The act of inventing or making something, new or bringing something into existence	The model or way something is shown or communicated	The putting and keeping of things in a special place for use in the future	The process of getting stored information from a computer	The movement of data or information or knowledge from one place, position to another	The way in which something can be used for a particular purpose
Examples	Discovery includes an analysis of what existing knowledge is already available and what knowledge is lacking	Data analysis and research activities	Publication or video or meta data or patent or conceptual model or guidelines , conference proceedings, reports, books	Entering and transfer of meta-data and content into a repository	Search commands, filters, open access, standards e.g. Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) standard	Dissemination of results	Translation and adoption of research

Definitions are from the Cambridge Dictionary available from https://dictionary.cambridge.org/

Representation

The people element of representation relates to communication of the research output, which is spoken or published and becomes explicit knowledge. As illustrated by the EBHC model the repository process includes qualitative and quantitative research outputs. Publishing requirements determine KM representation processes, such as the International Committee of Medical Journal Editors and in Australia by NHMRC guidelines. The technology element as part of the representation process is, for example, the repository software adopted to manage research outputs.

Storage

The human aspect of the storage element relates to data entry and transfer of the meta-data and related content into a repository. The repository process includes storage standards for systems such as PMC and Europe PMC. Other relevant standards for text data mining and long-term preservation of content are also important to the storage element. Efficient submission systems is another key aspect of storage design. The content element of storage processes is represented by the options available for direct entry of meta data and manuscripts, along with storage standards for open repositories.

Retrieval

The people element of retrieval entails the development of user search and retrieval skills by researchers, industry professionals and the general public. The repository process elements of retrieval encompass standards for example, the Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) standard ("Open Archives Initiative Protocol for Metadata Harvesting,"). The technology element includes search commands, filters and other technology tools leveraged from memberships to bodies such as ELIXIR (ELIXIR, 2018). Study design standards and their associated nomenclature for example, the study type descriptor randomized controlled trial, are critical to the later retrieval and future application elements. Search commands, filters and open access standards, along with the ability to ingest content from major sources, for example, The Australian National Library’s TROVE for biomedical sources and adoption of tools such as Crossref are important for making research output easy to cite and access.

Transfer

The people element of the KM transfer process involves dissemination of research output and data via presentations at conferences, personal communications and the use of systems. International referencing standards determine the research output process adopted by repositories. Search platforms such as Europe PMC, PubMed and search engines, such as Google Scholar, Academic.com, ResearchGate are examples of the technology systems used for transfer of repository content.

Application

The people aspect in application is through translation and adoption of research knowledge into changes in practice and policy to achieve improvements in society from research. Open repositories processes, that include links to grant details, help to link together the original science with details on the translation and adoption of research output. Technology has a role in the application element by providing metrics and explicit KM systems. Clinical guidelines and computerized decision support systems (at the top of the EBHC model) are examples of the content element in the application process of biomedical repositories.

Conclusion

Open biomedical repositories achieve the important goal of providing access to research output for those locked out by paywalls to online information resources. Open biomedical repositories are a means to achieve accessible, discoverable, mineable, interoperable and permanently findable research output. This paper outlines a conceptual design of a potential open Australasia biomedical repository informed by KM theories and supported by the EBHC pyramid model. Improved understanding of the role of KM in the design and operation of open biomedical repositories is important to transforming future societies.

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