

The nature and value of healthcare professional virtual communities: an exploration of the ICUConnect listserv

Kaye Rolls

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Certificate of Original Authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative doctoral degree and/or fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Acknowledgments

'It takes a village to raise.. a doctoral student'.

Over the eight years that it has taken me to arrive here, my village, including family and friends, professional colleagues and employers, research students at UTS, the Academy, ICUConnectors and supervisor/mentors, have provided the bedrock upon which I have built this thesis. But first a story

In early 2004 my intensive care unit had a problem. In our enthusiasm to evaluate a patient's Glasgow coma score (i.e. how awake they were) and elicit the best motor response we had caused significant injury to the skin covering their sternum (breast plate). The collective wisdom was that sternal rub was the best method because orbital pressure (i.e. pressure to the upper bony part of the eye socket) was out of the question and, well, her nail beds were not in good shape either.

What were we to do?

I had recently joined a virtual community called ICUConnect. I posted an email and Wow the feedback was amazing! Within 24 hours I had 12 responses which included a complete lesson in how to do a Glasgow coma score and what it meant.

And so I was caught in ICUConnect web, hook line and sinker

My first thankyou goes to my ever-enduring husband Colin and sadly neglected children, Jack, David and Erin. Your willingness to put up with a wife and mother, often absent in mind if not body, enabled me to get through the hard work of these past eight years. A big thankyou to my parents for being my cheer squad even if they were

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List of Abbreviations

CoP	Community of practice
VCoP	Virtual community of practice
VC	Virtual community
DoI	Diffusion of innovations
EBP	Evidence based practice
HCP	Healthcare professionals
KB	Knowledge broker
KM	Knowledge management

Glossary

Word	Definition
Absorptive capacity	(in relation to an organisation) ability of an organisation to acquire, assimilate and exploit new knowledge for organisational advantage (Ehin 2004)
Actors 1	Are distinct individuals or collective units within a network (Hawe, Webster & Shiell 2004)
Boundary spanners	Individuals who have links across social systems including organisations or organizational units (Rogers 2003)
Centralisation	(in relation to an organisation) degree to which power and control are concentrated in few individuals (Rogers 2003)
Child email	Replies to an email (Kerr 2003)
Complexity	(in relation to an organisation) degree to which members possess a high level of knowledge and skill (Rogers 2003)
Cosmopile	An individual who has extensive communication channels outside usual social system (Rogers 2003)
Cosmopolitan	Individual positioned across multiple external communities (Dahlander & Frederiksen 2012)
Culture	'customs, traditions, heritage, habits, ways, mores, values' p 176 (The Australian Concise Oxford Dictionary 2004)
Digital immigrant	Person born before 1980 (Helsper & Eynon 2010; Margaryan, Littlejohn & Vojt 2011)
Digital native	Person born after 1980 (Helsper & Eynon 2010; Margaryan, Littlejohn & Vojt 2011)
Discussion thread	'as a collection of individual messages related to each other by the reply function in email' (Kerr 2003) p1
Emojis	A small digital image or icon used to express an idea or emotion (Dictionary 2017) https://en.oxforddictionaries.com/definition/emoji
External Orientation	(in relation to an organisation) Where organisational leaders have professional networks external to their workplace (Aarons, Hurlburt & Horwitz 2011; Purcell & McGrath 2013)
Flaming / trolling	Hostile and insulting online behaviour deliberately designed to offend and /or generate argument. Individuals who habitually engage in this behaviour are referred to as trolls. (Burnett 2000)
Formalisation	(in relation to an organisation) degree to which an organisation emphasises rules and regulation (Rogers 2003)
Heterophily	The degree to which two or more individuals who interact are different in certain attributes (Rogers 2003)

Word	Definition
Homophily	The degree to which two or more individuals who interact are similar in certain attributes (Rogers 2003)
Innovation	Process whereby disconnected chunks of knowledge are integrated & combined into novel products, concepts and practices to create value (Dahlander & Frederiksen 2012) p989
Inter-connectedness	(in relation to an organisation) Degree to which separate units within an organisation are linked by social networks (Nieves & Osorio 2012)
Knowledge broker	Are individuals who occupy positions across more than one knowledge network that affords them access to new knowledge(Burt 2009; Ziam, Landry & Amara 2009)
Knowledge worker	An individual who transfers, discovers or creates knowledge (Paul 2006)
Lurker	Silent majority, one who never or rarely posts (Neelen & Fetter 2010; Nonnecke, Andrews & Preece 2006)
Maven	High level of broad based market knowledge (Walsh, Gwinner & Swanson 2004)
Moderator	Individual/s who manage all or some aspects of a virtual community including authorization of new members, technology
Netiquette	A formal or informal list of rules governing acceptable online behavior(The Australian Concise Oxford Dictionary 2004)
Netiquette	accepted conventions of online behaviour for the purposes of promoting polite and civil interactions; Combination of 'networks' and 'etiquette' (Scheuermann & Taylor 1997)
Opinion Leaders	Individuals who are able to influence others within their social system (Rogers 2003)
Organisational slack	(in relation to an organisation) degree to which uncommitted resources are available (Rogers 2003)
Parent email	The message to which a reply is sent (Kerr 2003) p1
Social network	'Finite set or sets of actors and the relation or relations defined on them' (Wasserman & Faust 1994) p20
Thread thwacking	introduction of an unrelated subject or topic into a discussion thread
Watercooler	location in workplace where informal opportunistic conversations occurs(Siu 2015; Zhao & Rosson 2009)

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Abstract

Current organisational structures and cultures limit the social networks of healthcare professionals (HCPs) who facilitate translation of evidence into practice and consistency of patient care standards. ICUConnect, a listserv for intensive care clinicians, was explored as an exemplar to evaluate whether HCP virtual communities (VC) facilitate knowledge and clinical expertise exchange within a broader professional social network. A series of studies using multiple methods, underpinned by the Diffusion of Innovations and Community of Practice (CoP) theories, was conducted to address the thesis aim, focusing on 'who', 'what' and 'why' of VC membership and activity.

An integrative review (1990-2015) of findings from 72 studies demonstrated that HCPs primarily used VCs to exchange domain specific experiential knowledge with colleagues in their clinical specialty. Reliance on readily available data however meant that the perspective of the non-posting majority of users had not been explored.

A retrospective descriptive study of 'who' belonged to the social network revealed that 78% (n=1042/1340) of HCPs who joined remained members, with 'ICUConnect' evolving from a single state nurse-specific network to an Australian-wide multi-disciplinary and multi-organisational intensive care network.

A retrospective qualitative descriptive study explored the nature of 'what' knowledge was exchanged. Over ten years (2004-13) 133 members from 80 organisations posted 326 emails in the 40 discussion threads with nurses in clinical leadership roles contributing 55% of data. Knowledge exchanged was categorised as: experiential

(34%); experiential and explicit (20%); explicit (21%); know-how (20%); know-why (5%); no knowledge (6%). Thematic analysis revealed the central construct of virtual community work with six elements identified that worked synergistically to develop a collegial professional online environment, reflecting the activities of a virtual CoP.

A naturalistic qualitative study developed an understanding of 'why' HCPs belong to the VC. Twenty-three members participated in three asynchronous online focus groups (frequent-posters: 3; low-posters: 13; non-posters: 7) and four frequent posters were interviewed. The major emergent theme was that these participants joined and remained members because this broader community of intensive care clinicians provided them with enhanced access to credible best practice knowledge.

This evaluation of ICUConnect demonstrated that members belong to a virtual CoP with a diverse professional network to support their professional development and enable access to innovations in practice. It is recommended that healthcare organisations consider using virtual CoP to improve internal clinical practices. Further research is required to demonstrate if patient care and outcomes are improved by HCP participation in virtual CoPs.

Chapter 1 - Introduction

Ensuring clinical practices reflect best practice and evidence is a significant concern for healthcare organisations globally; however despite more than twenty years of evidence based practice (EBP) attaining this goal remains a challenge (Oborn, Barrett & Racko 2010). Long before Facebook made online social networks popular the academic world understood the pervasive influence that an individual's social network had on behaviours (Borgatti & Foster 2003; Granovetter 1982; Rogers 2003) and learning (Wenger 1998). This chapter introduces a multiple methods research program that examined whether a virtual community for intensive care clinicians facilitated knowledge and clinical expertise exchange within a broader professional social network. The following sections are presented below: 1) background to the research; 2) purpose of the research; 3) brief description of the research approach; 4) the context of the research; 5) publications and presentations resulting from this work; and 6) an overview of the thesis structure.

Background

Healthcare organisations need to address two significant challenges if patients are to experience optimal outcomes; delivery of best clinical practices based on contemporaneous evidence, and supporting the professional development of clinicians, so that patients receive the best clinical care. The current reality however is that there is significant clinical practice variability, leading to suboptimal patient outcomes (Braithwaite & Donaldson 2016). Contemporary understanding of Diffusion of Innovations acknowledges that the social network of an organisation or group

exerts a powerful influence on individuals as well as the organisation (Fleuren, Wiefferink & Paulussen 2004; Greenhalgh et al. 2005a; Grossan & Apaydin 2010).

There are several conditions which contribute to ineffective social networks that currently impact on delivery of best clinical practice. The hierarchical structure of healthcare organisations isolates clinicians and restricts knowledge flow across wards and between facilities (Braithwaite, Debono & Travaglia 2009). Professional boundaries between members of the multi-disciplinary team restrict development of a shared understanding of specialty knowledge and inhibit inter-professional cooperation (Dopson et al. 2003). Workplace socialisation forces clinicians to comply with currently accepted practices (Copnell 2008; Mooney 2007) and without disconfirming information (Duncan et al. 2014; Lerman, Yan & Wu 2015) normalise and entrench ineffective and outdated practices. Finally healthcare professionals (HCP) from a range of disciplines prefer knowledge sources that are homophilous, human, easily accessible and perceived to be credible; including nursing (Curran et al. 2013; Ebenezer 2015; Estabrooks et al. 2005; Marshall, West & Aitken 2011; O'Leary & Mhaolrunaigh 2011; Spenceley et al. 2008) physicians (Curran et al. 2013; Hughes, Wareham & Joshi 2010; Kostagiolas et al. 2014; Tagliaventi & Mattarelli 2006), social workers (LaMendola, Ballantyne & Daly 2009), pharmacists (Curran et al. 2013), and public health practitioners (Meagher-Stewart et al. 2012). Importantly, there is emerging evidence that these ineffective social networks contribute to inferior patient outcomes (Creswick & Westbrook 2014; Evan Pollack et al. 2014; Hollingsworth et al. 2015; Mackintosh 2012; Rangachari et al. 2010; Weller, Boyd & Cumin 2014). The

impact of social networks on clinical knowledge and practices will be explored further in Chapter 2 – Frames of Reference

Healthcare organisations are viewed as knowledge intensive environments where the management of knowledge is a significant concern (Drucker 1992; Sorrells-Jones & Weaver 1999; von Nordenflycht 2010; Wickramasinghe 2006). An effective knowledge management strategy develops the social and intellectual capital of an organisation and establishes successful internal and external social networks so that organisational members have sustained access to innovation and best practice (Kothari et al. 2011; Rau, Neyer & Möslin 2012). There is increasing interest in the use of social media to create these social networks as virtual communities (VC) which can overcome any professional and organisational barriers (Leimeister & Rajagopalan 2014).

A significant potential exists within multi-disciplinary VC to facilitate transfer of research knowledge and best practice (Burrell, Elliott & Hansen 2009; McGowan 2012) and support the professional development of clinicians (Barnett et al. 2012).

Healthcare professionals currently use a broad range of social media platforms in practice, although understanding the extent is limited by the study methods used and a lack of population data. Current evidence suggests that HCPs view VC as valuable knowledge portals where craft knowledge is exchanged. Given that a number of the current challenges of transfer of research into practice are related to a lack of inter- and intra-professional communication channels, there is significant potential within multi-disciplinary virtual communities to facilitate the transfer of experiential and research knowledge by breaking down professional and organisational boundaries.

Purpose

The purpose of the thesis research program was to evaluate whether HCP VCs facilitate knowledge and clinical expertise exchange within a broader professional social network by examining an exemplar practice based VC, ICUConnect.

Research approach

The research program was a qualitatively driven multiple-methods design underpinned by pragmatism. The over-arching research question was 'what is the nature and value of HCP VCs', based on the need to understand complex symbiotic relationship between the VC, members and online participation. This approach was selected as both the problem and nature of HCP VC was complex and multidimensional (Creswell 2013; Johnson & Onwuegbuzie 2004; Morse & Niehaus 2009).

Three concurrent original studies examined three interrelated aspects that contributed to emergence and development of the exemplar VC: 1) the social network of the VC; 2) knowledge exchange or online participation; and 3) why HCP join and remain members of the VC. Findings from all studies were integrated using a parallel-results convergent synthesis design (Bt Maznin & Creedy 2012; Hong et al. 2015; Thomson et al. 2014).

Relevance

Given the increasing use of social media across populations and within professional groups, developing an understanding of the essential nature of HCP VCs will enable HCPs, clinical specialities, healthcare professions and organisations to recognise how these specific types of VCs may contribute to knowledge distribution, translation of research into practice, and professional development.

Context of research program

The thesis was positioned within the context of Australian healthcare, a universal health care system publically funded by the Federal government and delivered by independent state governments. In the context of intensive care practice, the New South Wales (NSW) health department established a clinical network, the Intensive Care Coordination and Monitoring Unit in early 2003 (ICCMU). The initial role of ICCMU was to provide the NSW health department with accurate data regarding the provision and outcomes of care delivered to adult intensive care patients. ICCMU is now part of the Agency for Clinical Innovation, one of the seven functional pillars of NSW health (Lyons 2015). During introductory meetings with the management team of ICCMU senior intensive care clinicians described perceptions of professional isolation and were concerned about the potential impact on patient care. A method of easy and effective inter-professional communication was therefore needed.

ICUConnect

In December 2003 ICCMU created 'ICUConnect' to facilitate communication and knowledge sharing between clinicians of the 43 adult ICUs in NSW, Australia (Rolls et al. 2008). ICUConnect was an integral component of ICCMU's aim to promote excellence in the standard of care through clinical networking (Kelly 2016). Central to this aim was for ICCMU to be perceived as a collegial resource rather than as a bureaucracy (Rolls et al. 2008). A listserv (mailing list) was chosen as the communication platform at the time because of the:

- Ease of use by clinicians with varying levels of information technology skills; it was essentially a list of email addresses maintained on a server by the listowner (moderator);
- Technology was available at no cost through the NSW Health Department; and
- Workload burden for the moderator or list owner was minimal.

The first cohort of members was 130 senior nursing clinicians, an academic and several health department managers. To develop a sense of ownership and create a culture of sharing, a schedule of weekly contributions by each ICU was established. Additionally, ICCMU staff posted news updates from state, national and international organisations and bimonthly newsletters with relevant project and education information.

ICUConnect was therefore viewed by ICCMU as a non-hierarchical network facilitating bi-directional communication between them and frontline clinicians and locating ICCMU with the clinical community rather than a distant faceless bureaucracy. This was seen as highly effective with an early member survey (May 2004 – 197 members; unpublished) demonstrating that ICUConnect was fulfilling its function of facilitating knowledge exchange via a professional network.

A formal evaluation in May 2005 revealed the membership base had grown to 433, and in the preceding 12 months 662 on-list emails had been exchanged with 60% related to clinical topics, 21% management and the balance pertaining to information only. A member survey revealed that ICUConnect was fulfilling its function as a communication network for clinicians that was highly valued by members. Moreover a community of practice appeared to be emerging where members openly shared their knowledge and local unit clinical policies and procedures (Rolls et al. 2008). As of June

30 2016 there were 1800 members of ICUConnect mainly from Australia and New Zealand.

ICUConnect was therefore selected as the exemplar VC to explore the study purpose.

Publications from thesis

Three peer-reviewed manuscripts have been published to date, as well as three peer-reviewed conferences presentations.

Literature review

Rolls, K., Hansen, M., Jackson, D. & Elliott, D. 2016, 'How healthcare professionals use social media to create virtual communities: an integrative review', *Journal of Medical Internet Research*, vol. 18, no. 6, p. e166, viewed 24 February 2017, <<http://dx.doi.org/10.2196/jmir.5312>>.

Social Network study

Rolls, K., Kowal, D., Hansen, M. & Elliott, D. 2010, 'If you build it they will come: growth of an online community for intensive care', poster presented to The Annual Scientific Meeting of the Australian and New Zealand Intensive Care Society and Australian College of Critical Care Nurses, Melbourne, 14-16 October.

Rolls, K., Hansen, M., Jackson, D. & Elliott D. 2014, Analysis of the social network development of a virtual community for Australian intensive care professional', *Computers, Informatics, Nursing*, vol. 32 no.11: 536-544 [citations 4]

Knowledge Exchange study

Rolls, K., Hansen, M., Jackson, D. & Elliott D. 2015, 'An exploration of knowledge exchanged in an intensive care virtual community', paper presented to The Annual Scientific Meeting of the Australian and New Zealand Intensive Care Society and Australian College of Critical Care Nurses , Auckland, 28-30 October.

Why We Belong study

Rolls, K., Hansen, M., Jackson, D. & Elliott D 2015, 'Using online focus groups to explore why healthcare professionals belong to a practice-focused virtual community'. Poster presentation to Qualitative Methods conference, Melbourne, 27-30 April .

Rolls, K., Hansen, M., Jackson, D. & Elliott D. 2016, 'Why we belong: a study protocol exploring membership of an intensive care virtual community via online focus groups', Journal of Medical Internet Research Protocols, vol. 5, no. 2, p. e99, viewed 24 February 2017, <<http://dx.doi.org/10.2196/resprot.5323>>.

Overview of thesis

This thesis is organised into eight chapters with a glossary and list of abbreviations provided to support those content in the thesis. This first chapter has provided the background, purpose and context of the research program. The research approach has been described and papers published over the candidature are listed. The relevance of the research program has also been described.

Chapter 2 – Frames of reference, introduces several key concepts and theories integral to the thesis: knowledge and knowledge management, two mid-range theories that provided the theoretical lens for the program - Diffusion of Innovations (DoI) (Rogers

2003) and Community of Practice (CoP) (Wenger, McDermott & Snyder 2002), and the concept of virtual communities of practice (VCoP).

Chapter 3 is the thesis literature review, which was published as a manuscript in 2016. The literature review was structured as an integrative review, with the aim of understanding use of social media by healthcare professionals (HCP) in developing VCs that facilitate professional networking, knowledge sharing and evidence-informed practice. The limitations of the evidence base and recommendations for research are described.

Chapter 4 provides an overview of the research methodology and methods for the three original studies, encompassed in a qualitatively driven multiple methods concurrent design. The research program was located within Pragmatism. The chapter includes an overview of the research program, the ethical considerations, the strengths and limitations and rigour of the research.

Chapters 5-7 report the three studies that were conducted. Each chapter is self-contained, providing the background, methods, presentation and discussion of findings with links to the literature and a reflection on the strengths and limitations of the methodological approach. Chapter 5 reports the Social Network study that examined how the social network of the exemplar VC evolved over the first six years (2003-2009). This chapter is structured as a journal manuscript, and published in 2014. An in-depth description of the delivery of intensive care services is also provided in this chapter. Chapter 6 reports the Knowledge Exchange study that examined the context and context of online participation between 2004 and 2013. Chapter 7 reports the

Why We Belong study which examined the experiences of members using online focus groups and interviews.

In chapter 8 findings from the three studies are synthesised using a parallel-results convergent synthesis design. The chapter is divided into three sections: a summary of major study findings, the nature and value of a VCoP, and implications for policy and practice and future research.

Chapter 2 - Frames of reference

Introduction

The last decades of the 20th century saw a global transition from the Industrial era to the Information age (Weston, Estrada & Carrington 2007), where development and management of knowledge became a central concern for organisations (Fontaine & Millen 2004). Health care organisations in particular are knowledge-intensive environments (Drucker 1992; Sorrells-Jones & Weaver 1999; von Nordenflycht 2010; Wickramasinghe 2006). Importantly, but not well understood, is that collective social processes existing within a healthcare organisation contribute to the delivery of care, including instances of over or under - servicing, over or under - utilisation, clinical practice variation or appropriateness of care (Braithwaite & Donaldson 2016).

A central tenet of healthcare organisations is to continually evolve local clinical practices and support the professional development of clinicians, so that patients receive the best clinical care. This can be achieved through a knowledge management (KM) strategy that develops the social capital of an organisation, by establishing effective internal and external social networks so that healthcare professionals (HCP) have sustained access to innovation and best practice (Rau, Neyer & Möslein 2012). There is increasing interest in the use of social media to create these social networks as virtual communities (VC) which can overcome any professional and organisational barriers (Leimeister & Rajagopalan 2014).

The purpose of this chapter is to introduce several key concepts and theories which are integral to the thesis. There are two main sections. First, KM is examined in

relation to healthcare including knowledge, knowledge work and healthcare professionals and knowledge brokering, before describing the key elements of a KM strategy. In the second section, two mid-range theories that provide the theoretical lens for the doctoral study program - Diffusion of Innovations (DoI) (Rogers 2003) and Community of Practice (CoP) (Wenger, McDermott & Snyder 2002) - are reviewed. The concept of virtual communities of practice is also introduced (VCoP)

Knowledge management

Knowledge management (KM) refers to organisational processes and/or structures that seek to provide 'the right information to the right person at the right time for the potential of attaining a greater competitive advantage' (Kothari et al. 2011,p.1). Early KM programs focused on management of explicit knowledge however latter forms have acknowledged the need to develop human capital by establishing effective communication networks among employees as well as external networks (Ferlie et al. 2012).

Knowledge

The nature of knowledge has been a central concern of scholars for millennia and the unnatural dichotomy between types of knowledge has been questioned in philosophical circles for some time (Ryle 1945). In this sub-section a brief overview of the philosophical foundations of evidence based practice (EBP) are presented followed by an examination of the different types of knowledge.

The basis for western healthcare knowledge has been shaped by rationalism and the Cartesian mind-body split (Nonaka & Takeuchi 1995) and empiricism (Garrett 2014).

Central to these philosophical positions is that there is 'A' truth or in the case of health, 'A' treatment. Meaning that it is possible to: separate knowledge from context and person; codify 'best practice'; and easily transfer this knowledge for use by other HCPs or in different settings. The advent of the EBP movement in the late 20th century, where clinicians made decisions by combining best scientific evidence, patient considerations and clinical expertise was in response to the failure of clinicians to translate evidence into practice (TRIP) (Sackett et al. 1996). The subsequent evolution of EBP, including development of evidence hierarchies where randomised controlled trials (RCTs) are privileged while de-emphasising clinical expertise, appears to have maintained the rationalist paradigm (Wieringa & Greenhalgh 2015). At present these hierarchies are being challenged by narrative and qualitative forms of evidence (Ferlie et al. 2012).

The rationalist and empirical knowledge claims are hard to sustain in the real world of clinical practice. Dominant views of EBP are contestable, including good scientific evidence can be applied across multiple patients and contexts, and that an RCT will always provide the best evidence (Blunt 2015; Wieringa & Greenhalgh 2015). In practice EBP conforms more to a pragmatic epistemology where the basis of truth is found in evidence of achieving desired outcomes and that there may be more than a single solution (Garrett 2014; James 2013). Further, pragmatism is reflective of the mindlines developed by groups of clinicians who deliver practices based on a combination of theoretical, explicit or codified and collective tacit knowledge, reinforced through interactions with other clinicians and patients (Gabbay & Le May

2004). As indicated in the Introductory chapter Pragmatism underpinned the thesis program and is explored further in Chapter 4 – Overview of Methods.

Knowledge has been often been conceptualised as a continuum with explicit knowledge on one end and tacit or experiential knowledge at the other, however in practice it is a more complex multidimensional iterative phenomenon (Nonaka & Takeuchi 1995; Panahi, Watson & Partridge 2013; Ryle 1945). Explicit knowledge is knowledge that has been externalised from an individual and can be transmitted to another, and is therefore codified into an understandable language. Conversely, experiential knowledge is that which has been learnt through experience or practice (Brown & Duguid 1991; Smith, McKeen & Singh 2007). Though often used as a synonym for experiential knowledge, tacit knowledge does differ. Polanyi (1983) described 'tacit' knowledge as having three essential elements: (1) unconscious or subordinate awareness gained through education and experience; (2) the skilful or competent performer; and (3) a specific and unique occasion or focal target. Tacit knowledge is an important component of all applied knowledge (Panahi, Watson & Partridge 2013; Polanyi 1983) and therefore to view knowledge as two dimensional or on a continuum is erroneous (Virtanen 2013). An alternative view is the knowledge creation cycle where an expert transfers their expertise via phases of socialisation, externalisation, combination and internalisation (Nonaka & Takeuchi 1995). These processes emphasise the importance of the social and human aspects of knowledge and development of professional competence through experience within a community and interaction with experts (Brown & Duguid 1991; Duguid 2005; Eraut 2004).

When considering the application of knowledge to professional practice the know-what, -how and –why taxonomy reflects both the evolution of professional competence and how different forms of knowledge come together in action (Garud 1997). Know-what knowledge is explicit or codified knowledge (Ryle 1945) which prepares a practitioner to know what actions are appropriate for a limited number of situations (King 2009). Future HCPs attend university to learn the fundamental know-what knowledge, that is scientific and theoretical discipline knowledge that enables them to practice as novice professionals. This ‘know-what’ knowledge needs to be developed or built upon through ‘learning by doing’ or practice experience so that know-how knowledge is accumulated, enabling the novice to function more independently (Garud 1997) and in the presence of distracting information (King 2009).

Know-how knowledge also develops during interactions with professional colleagues and thus also resides within organisational routines, processes and social networks (Garud 1997). Therefore know-how knowledge includes an articulation of the problem, solution and rationales for a specific situation. It is well accepted that novice HCPs require experience so that they develop the ‘know-how’ or specific practice (craft) knowledge of their discipline so they are able function as safe, effective and independent professionals (Eraut 2004; Kothari et al. 2012).

Know-why knowledge evolves as professionals acquire significant experience, and through reflection develop a deeper understanding of how to combine scientific (know-what) with acquired knowledge (know-how) and apply this to novel and complex situations (King 2009). This is learning-by-studying where a professional

actively examines or experiments to develop a deeper understanding of how the underlying principles and theories interact in given situations (Garud 1997). Know-why is embodied by an understanding of the problem, working through alternative solutions, rationales and application of scientific evidence to a specific situation. In health, clinical expertise is analogous to 'know-why' knowledge and is central to original articulation of EBP (Sackett et al. 1996) and providing quality patient care (Manley et al. 2005; McHugh & Lake 2010). Integral to expertise are both mastery of a specific bounded knowledge and practice domain, and the ability to span boundaries and participate in other networks (Akkerman & Bakker 2011). Access to clinical expertise is becoming an imperative for nursing because there is variability in quantity and quality of empirical evidence to guide basic practices (Rolls & Elliott 2008) and the aging workforce is reducing availability of this scarce commodity (Cioffi 2012). Table 1 maps these knowledge types to examples of healthcare knowledge.

The know-what, -how and -why knowledge categories should not be viewed as a continuum, rather as an iterative process as new knowledge is introduced or develops in practice and through interactions between colleagues (Garud 1997). Further the know-what and -how of a clinical unit or organisation reflect negotiated norms that become embedded within local and organisational practices and routines (Atherton 2013). This view of knowledge therefore emphasises the importance of the social and human aspects of knowledge and development of professional competence through experience within a practice community (Brown & Duguid 1991; Duguid 2005; Eraut 2004). Importantly, inter- and intra-organisational networks are central to knowledge

creation and diffusion as much knowledge is experiential, implicit or tacit (Newell & Swan 2000), particularly in healthcare organisations.

Table 1 Knowledge types mapped to healthcare knowledge

Knowledge type	Definition	Healthcare example
Experiential	Knowledge learnt through experience or practice (Brown & Duguid 1991; Smith, McKeen & Singh 2007).	
Explicit	Knowledge that has been externalised from an individual, or codified, and can be transmitted to another via an understandable language	<ul style="list-style-type: none"> Published research clinical practice guideline, national standards
Tacit	<p>Knowledge that emerges in a specific moment when an expert is faced with a novel situation but is able to act because of expertise. Elements included</p> <ol style="list-style-type: none"> 1. unconscious or subordinate awareness gained through education and experience 2. the skillful or competent performer 3. a specific and unique occasion or focal target (Polanyi 1983) <p>Similar to know-why</p>	<ul style="list-style-type: none"> Unconscious variation of practice during procedure where novel circumstances arise Unconscious understanding of amount of pressure to apply when inserting vascular access device based on previous experience including factors such as depth and skin type
Know-what	Scientific and theoretical discipline knowledge that enables them to practice as novice professionals. (King 2009; Ryle 1945)	<ul style="list-style-type: none"> Airway anatomy Process of central line dressing
Know-how	Practice knowledge that combines know-what with clinical experience so that practitioners are able to perform safely and independently under most circumstances (Eraut 2004; Kothari et al. 2012).	<ul style="list-style-type: none"> Insert an endotracheal tube in patient with normal airway (intubate) Dress a central line following local guidelines
Know-why	Clinical expertise developed through extensive experience and study of practice so that the practitioner is able to perform independently regardless of circumstances (King 2009)	<ul style="list-style-type: none"> Vary intubation approach when faced with a very difficult airway Vary dressing for central line because patient has poor skin integrity

In clinical practice both nurses and physicians rely on personal knowledge (both theoretical and experiential) before turning to close credible colleagues when personal knowledge stocks are unable to provide an answer (Ayers LaFave 2008; Marshall, West & Aitken 2011; O'Leary & Mhaolrunaigh 2011; Spenceley et al. 2008; Tagliaventi &

Mattarelli 2006). For nurses the decision to use a specific information source is not as simple as proximity because of the complex interplay between the problem, nurse, work setting, mediating factors, limited information sources and attributes of information sources (Spenceley et al. 2008).

For clinicians to have access to the most appropriate knowledge for practice in any given situation their professional development must be supported through local and organisational CoP (Kothari et al. 2011). Moreover the knowledge embodied within the clinician's local unit must be continually replenished by effective knowledge management activities that include effective professional networks and active boundary crossing (Akkerman & Bakker 2011; Kothari et al. 2011).

Knowledge work and healthcare professionals

Knowledge work involves evaluating data from novel situations and applying specialised information and expertise to transfer, discover or create knowledge (Drucker 1999; Paul 2006; Ramsey 2010). The success of organisations in this evolving Knowledge age hinges on effective leverage of intellectual work of their knowledge workers (Drucker 1992; Ramsey 2010; Weston, Estrada & Carrington 2007). Knowledge workers function best where they are able to interact across organisational boundaries and are empowered to make decisions.

A boundary is a 'demarcation, or a sphere of activities, that marks the limits of an area, which may include knowledge, tasks, as well as hierarchical, physical, geographical, social, cognitive, relational, cultural, temporal/spatial, division, occupational and disciplinary boundaries' (Hsiao, Tsai & Lee 2012, p.463) . Boundaries that impact on the free movement of knowledge and innovation in healthcare (Hara & Fichman 2014;

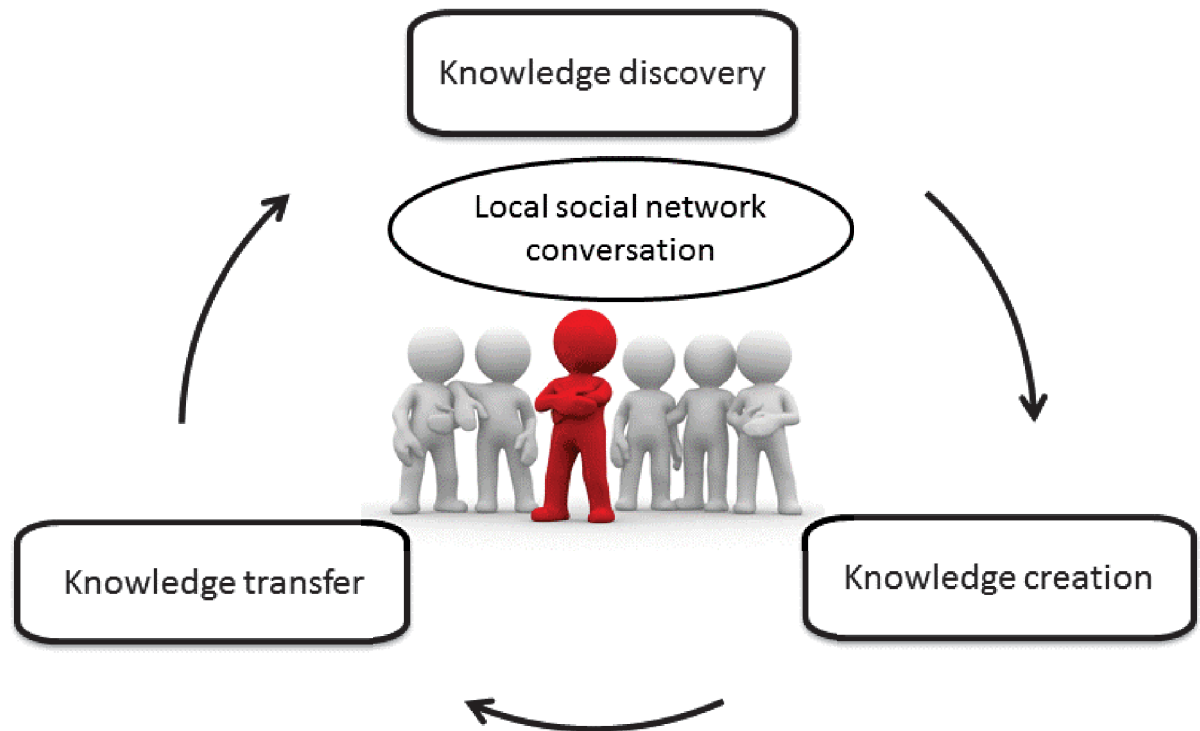
Thomson, Schneider & Wright 2012) include: 1) structural or organisational (Carlile 2004); 2) knowledge (Wright 2009); 3) social [semantic (Carlile 2004), interpersonal (Wright 2009) and cultural (Sturdy et al. 2009)]; and 4) political or pragmatic (Carlile 2004; Wright 2009).

Effective knowledge work is achieved by teams of knowledge workers in organisations where: self-responsibility and autonomy is promoted; continuous learning and teaching is actively supported; both quality and quantity of outputs are valued; and knowledge workers are viewed as assets not liabilities (Drucker 1999; von Nordenflycht 2010). Healthcare professionals are identified as a subgroup of knowledge workers called 'technologists', where a personal knowledge store, initially based on formal academic education evolves through experience and professional development (Antrobus 1997; Ayers LaFave 2008; Drucker 1999).

As noted above, there are three specific modes of knowledge work:

1. *Knowledge transfer* - Any action that contributes to the disclosure, dissemination, transmission or communication of knowledge
2. *Knowledge discovery* - Search for new understanding through integration of pre-existing knowledge or information; identification of previously unseen connection items; perceive situations in a new context; present new opportunities
3. *Knowledge creation* - Development of new knowledge by modifying, transforming and changing representation of old knowledge (Paul 2006) (see figure 1).

Figure 1 Knowledge work and knowledge brokers



The knowledge work possibilities for HCPs extend from an individual patient through to building intellectual capital for their organisation (e.g. through quality or education initiatives) and/or profession (e.g. via research and publication). At an individual patient level clinical decision making embodies the knowledge work of clinicians, with individual patient data integrated with personal, professional and institutional knowledge (Carper 1978; Snyder-Halpern, Corcoran-Perry & Narayan 2001; Spenceley et al. 2008) to identify patient needs and plan, deliver and evaluate the outcomes of care. The *knowledge transfer* role includes patient specific activities, such as documentation of patient data, communication with other members of the multi-disciplinary team (MDT) and families (Edwards & Donner 2007) and coordination of patient care (Jacques 1993). This knowledge transfer or knowledge sharing mode of work is especially significant for nurses who are seen as credible knowledge sources by their colleagues (Ayers LaFave 2008; Marshall, West & Aitken 2011; O'Leary &

Mhaolrunaigh 2011; Spenceley et al. 2008). *Knowledge discovery or creation* occurs during the assessment and evaluation of treatment phases of nursing work as new understandings of individual patients are uncovered. The volume of clinical decision making by intensive care nurses (Bucknall 2000) and competency and professional standards for intensive care nurses (American Association of Critical Care Nurses 1998; Australian College of Critical Care Nurses 2002) underscore the role of intensive care nurses as knowledge workers. It is important to understand that not all nurses are able to function as knowledge workers as knowledge work requires an active reflective process (Brooks & Scott 2006b).

Current dominant healthcare organisational models are based on vertical bureaucratic or industrial designs, restricting social capital development and impact negatively upon knowledge workers ability to interact and work effectively (Manojlovich 2005; Moody 2004; Ramsey 2010). At present, mechanistic or positivist KM strategies dominate which do not take into account how prevailing cultures and / or power structures impact on knowledge sharing (Ferlie et al. 2012). This is compounded by use of information technologies that do not support effective knowledge sharing and a focus on isolated initiatives that may not be sustainable (Kothari et al. 2011). These approaches lead to silos whereby different parts of an organisation are not effectively linked, preventing the organisation from becoming an inquiring system that is able to capitalise of internal knowledge (Linden et al. 2007; Tsoukas 1996). Achieving effective knowledge work therefore requires interventions and structures at individual, unit and organisation levels (Orzano et al. 2008; Snyder-Halpern, Corcoran-Perry & Narayan 2001) that create networks to facilitate knowledge absorption (Ferlie et al. 2012) .

Knowledge Brokering

Knowledge brokering is the active human process of transferring knowledge between different groups of people (Canadian Health Services Research Foundation 2003) and furthermore are leading knowledge workers within an organisation (see figure 1. While the concept has a short history in healthcare, increasing importance is now being placed on this key knowledge management function, especially in relation to TRIP (Canadian Health Services Research Foundation 2004; Gerrish, McDonnell, et al. 2011). If knowledge to be useful it should be transmitted in an interpretable and accessible manner (Alavi & Leidner 1999; Courtney 2001). Knowledge brokers (KB) are variously described as link or connection officers, agents of change, third person, intermediary, informers, boundary spanners, bridgers, intermediaries and infomediaries (Ziam, Landry & Amara 2009). Health professionals with a KB role facilitate transfer and assimilation of new knowledge into an organisation through identification and amalgamation of new knowledge with current organisational knowledge (Ziam, Landry & Amara 2009).

Advanced practice nurses (APN), such as clinical/nurse educators (C/NE), clinical nurse specialists (CNS), nurse consultants (NC) and nurse researchers , undertake a significant knowledge brokering role by bringing in new knowledge for assimilation into organisational knowledge (Gerrish, McDonnell, et al. 2011). This is achieved by:

1. accumulating knowledge from external sources including journals, conferences or online sources such as evidence repositories and professional organisation websites

2. synthesising and translating evidence for application within their local context, and
3. disseminating this knowledge through formal organisational learning and development programs (e.g. education or clinical practice guidelines) and informally through individual and small group interactions with clinical staff (Currey, Considine & Khaw 2011; Gerrish, McDonnell, et al. 2011).

Key elements of healthcare knowledge management

The key elements of an effective KM program in health that facilitate effective knowledge work and mobilisation include:

1. A strong sense of community within the organisation, created by establishing active networks, a trusting climate, helpful relationships and effective communication structures (social capital) (Ferlie et al. 2012; Kothari et al. 2011; Orzano et al. 2008)
2. Organisation structure where time for professional development and collaboration is allocated (Kothari et al. 2011)
3. Communities of practice comprised of non-hierarchical groups to transfer best practice and maximize knowledge sharing and learning (intellectual capital) (Kothari et al. 2011)
4. A culture of reflective practice (Oborn, Barrett & Racko 2013; Orzano et al. 2008)
5. Robust information technology that is easily accessible and matches clinical work practices (Ferlie et al. 2012; Orzano et al. 2008), and

6. An empowered workforce supported by organisational leaders who facilitate the legitimacy of the knowledge workers, especially clinical leaders, to effect change (Ayers LaFave 2008; Braithwaite & Donaldson 2016; Ferlie et al. 2012; Kothari et al. 2011; Oborn, Barrett & Racko 2013; Orzano et al. 2008).

These elements, especially the social networks and social capital created, facilitate the transfer of knowledge across boundaries, especially development of a shared understanding among members of the multi-disciplinary clinical team (Bate & Robert 2002; Kothari et al. 2011; Nicolini et al. 2008; Oborn, Barrett & Racko 2013; Rau, Neyer & Möslein 2012).

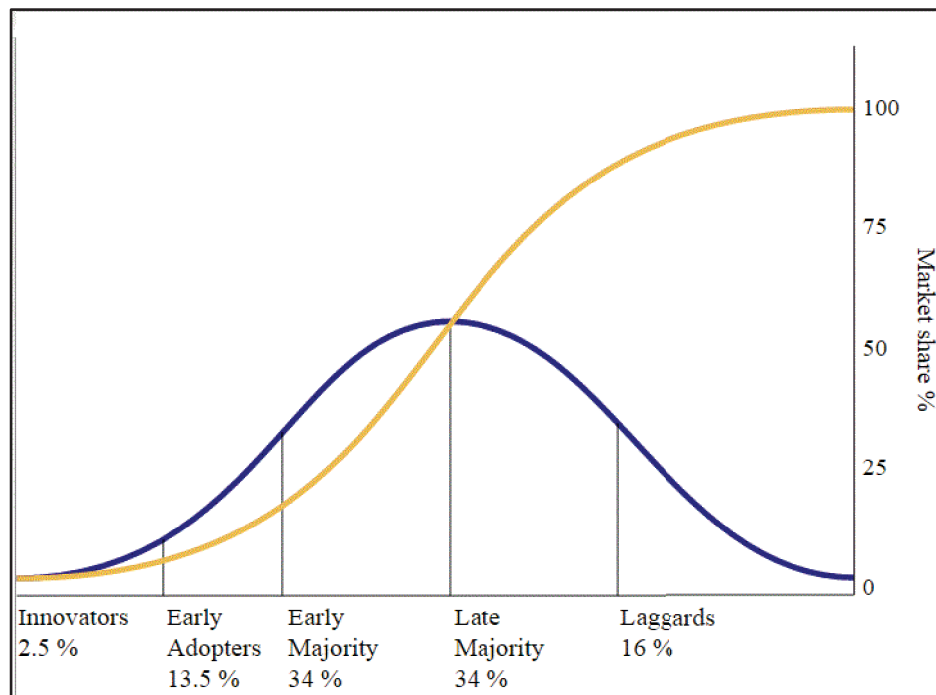
Theoretical foundations of Thesis

The study of social networks occurs across a number of disciplines including sociology, organisational management, communication and learning. For the purposes of this thesis two mid-range theories, Diffusion of Innovations (DoI) (sociology) (Rogers 2003) and Community of practice (CoP) (learning) (Wenger 1998) have been used as theoretical lens' for interpreting data and developing an understanding of the nature and value of ICUConnect. While on a superficial level these theories appear quite different, there is a shared core of how humans learn from each other through interactions within a social group. In this section an overview of each of these theories is provided, incorporating a brief examination of relevant literature.

Diffusion of innovations

Everett Rogers developed the 'Diffusion of innovations' (DoI) theory by integrating studies where researchers had examined how individuals adopted innovations over time (See figure 1) (Rogers 2003). Rogers then evolved the theory by undertaking studies across different countries and levels of economic and social development (Rogers 2003). In health, these innovations could include new equipment, research findings or practices.

Figure 2 Diffusion of Innovations (Rogers 1962)



An innovation is an idea, practice or object that is perceived to be new by an individual or work group and there are six characteristics of an innovation that influence this perception (Rogers 2003). Rogers found that the propensity to adopt an innovation varied between individuals (see figure 2 and table 2), and that for an innovation to diffuse across a social group at least the first 16%, comprised of innovators and early majority (visionaries), needed to adopt before a critical mass was reached and adoption spreads to the Early majority (pragmatists) The latter groups of late majority and laggards will become interested in adoption when it is apparent they are straying from group norms. For technology adoption the gap ('Moore's chasm) between the visionaries and pragmatists can only be crossed when proof of the technology efficacy has been demonstrated and championed by early adopters (Gombault, Allal-Chérif & Décamps 2016; Moore 1991).

Table 2 Diffusion of Innovations - Definition (page 1 of 2)

Innovation	
<i>'Idea, practice or object that is perceived as new by an individual or unit of adoption'</i> (Rogers, 2003: p.12)	
Relative advantage	Innovation offers an improvement over existing practices
Compatibility	Innovation fits with existing practices, values and experiences of potential adopters and their social system
Complexity	The ease of understanding and/or implementation of innovation.
Observability	Potential adopters are able to witness the innovation in use by peers
Trialability	Whether potential adopters have an opportunity to test or experiment with the innovation before a final adoption decision is made
Re-invention	Degree to which the innovation is able to be modified or adapted to suit a potential adopters specific circumstances
Communication Channel	
<i>'Medium through which information is passed between individuals'</i> (Rogers, 2003: p.18)	
Intrapersonal - Person to person contact	An individual's intrapersonal channels are a function of their social network. The number and variability of communication channels are the biggest influence on access to innovation knowledge. These communication channels are the most influential across all stages of innovation-decision and for all types of adopters except innovators.
Mass media	Print or electronic mediums that are able to deliver bulk information to a broad range of individuals. Examples include journals, television and the Internet.
Time	
Type of adopter	An individual's rate will be mediated by: <ul style="list-style-type: none"> • attitude to risk-taking and openness to new ideas • intrapersonal communication channels • centrality in social network • income and education
Individual's innovation-decision process	Five stage process where stages may be visited more than once: <ul style="list-style-type: none"> • knowledge-awareness • persuasion • decision • implementation and reinvention • confirmation
Rate of innovation adoption within a social system	Regardless of the innovation, adoption within a social system follows an 'S' curve where the uptake is initially slow until a critical number of individuals have adopted which leads to faster diffusion and adoption throughout the social group as the innovation is now seen as standard.

Table 1 Diffusion of Innovations – Definitions (page 2 of 2)**Social System**

'Set of interrelated units engaged in joint problem solving to accomplish a common goal'
(Rogers, 2003: p.23)

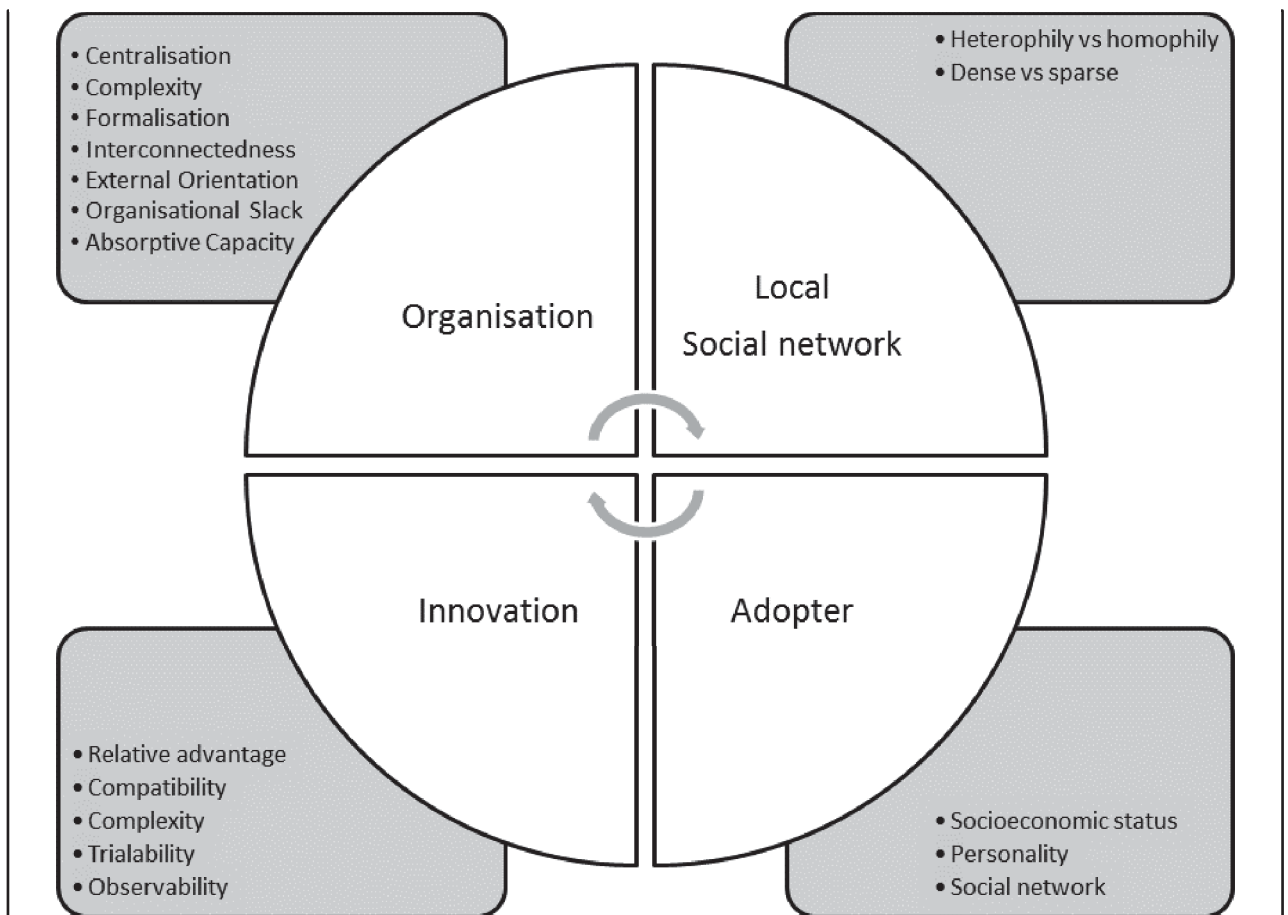
Structure	Patterned arrangements of units within a social system that promote regularity, stability and predictability of behaviour including: social structures; and communication structures that control the flow of information between individuals
Norms	Established patterns of behaviour that are considered acceptable within a social system
Characteristics	Homophily: The degree to which two or more individuals who interact are similar in certain attributes Heterophily: The degree to which two or more individuals who interact are dissimilar in certain attributes

Early research focused on how the interplay between the relative characteristics of the innovation, time, communication channels and structure of a social group affected the diffusion and adoption of that innovation over time. Contemporary understanding however has now demonstrated how organisational or group factors exert a powerful influence on both individuals and the organisation (See Figure 2) (Fleuren, Wiefferink & Paulussen 2004; Greenhalgh et al. 2005a; Grossan & Apaydin 2010). In health adoption and assimilation decisions are a process of formal organisation decisions and a series of informal decisions by individual users which are influenced by colleagues and peers (Robert et al. 2010).

Updates from the original DoI now identifies seven key internal organisational factors that influence an organisation's ability to develop or implement innovations: centralisation, complexity, formalisation, interconnectedness, organisational slack (Rogers 2003) and absorptive capacity (Greenhalgh et al. 2005a; Zahra & George 2002) (see figure 3.). In healthcare, it is uncertain which element is the most important, as

literature findings are inconsistent, perhaps due in part to a lack of quality studies (Greenhalgh et al. 2005a).

Figure 3 Diffusion of Innovations as applied to the Organisation



Interconnectedness (connections between organisational members and units) and external orientation (organisational leaders with external networks) are both mediated by communication channels or networking internally or external to the organisation (Greenhalgh et al. 2005a; Grossan & Apaydin 2010; Rogers 2003).

Individuals with communication channels outside their everyday social and professional networks (weak ties – low frequency) will have greater access to new information (Granovetter 1982; Singh & Cullinane 2010) however unless the source is

considered trustworthy (strong ties – high trust) the veracity of information will be questioned (Nieves & Osorio 2012).

Intra-professional interaction helps HCPs to interpret scientific findings (Dopson et al. 2002) but use of evidence may be limited where these interactions are restricted to local professional colleagues (Mascia & Cicchetti 2011). The optimal network structure that generates and integrates innovation into a healthcare organisation is one of densely linked groups with sparse external ties (Long, Cunningham & Braithwaite 2013). Importantly these external ties are thick (i.e. comprised of multiple individuals) rather than being reliant on key individuals or hubs (Mayrhofer, Goodman & Holman 2015).

The credibility of intrapersonal channels (e.g. peer to peer or opinion leader to professional) makes these channels more influential on adoption decisions (Fleuren, Wiefferink & Paulussen 2004; Granovetter 1982; Locock et al. 2001; Rogers 2003; Valente 1993). In health however there have been mixed results where these channels (e.g. opinion leaders) have been used to promote evidence base practice (Doumit et al. 2007; Thompson, Estabrooks & Degner 2006). Peer-to-peer communication becomes more important as final adoption decisions are made (Locock et al. 2001) with adoption more likely when individuals receive multiple messages (Centola 2015). For nurses intrapersonal channels are most common when information for clinical decision making is sought (Spenceley et al. 2008), particularly in times of clinical uncertainty or stressful situations (Marshall, West & Aitken 2011; O'Leary & Mhaolrunaigh 2011).

Absorptive capacity refers to an organisation's capability to identify and acquire external knowledge and assimilate this new knowledge by transforming it into working

organisational knowledge (Oborn, Barrett & Racko 2013; Zahra & George 2002). Knowledge acquisition is mediated by the external orientation of organisational leaders and boundary spanners who have communication channels external to the organisation, exposing them to novel information (Nystrom, Ramanmurthy & Wilson 2002). Assimilation however will not occur if the local knowledge base and organisational interconnectedness are inadequate (Greenhalgh et al. 2005a). Boundary spanners are organisational members whose roles cross internal and external unit lines and are seen as key personnel when coordinating and integrating external and internal information within the organisation (Meyer et al. 2011). At present, understanding the role of absorptive capacity is a relatively unexplored area in relation to translation of evidence into clinical practice (Oborn, Barrett & Racko 2013).

Barriers to Best Practice and TRIP

When examining TRIP and achieving best practice through a DOI lens, numerous barriers can be identified (see table 3). In particular there is strong evidence that local and professional networks shape clinical behaviour (Dopson et al. 2002; Duncan et al. 2014; Hollingsworth et al. 2015; Mascia & Cicchetti 2011; Shah et al. 2015; Tasselli 2014), and this influences the quality of care delivered and patient outcomes in both directions (Bae et al. 2015; Tasselli 2014); e.g.:

1. Adverse drug errors (ADE) increased in a ward where the lead physician was not central to the advice seeking network in comparison to a similar ward where they were (Creswick & Westbrook 20145)
2. Where surgeons were not central to the care network, patients experienced increased complications following urological surgery (Evan Pollack et al. 2014)

3. In predominantly African American neighbourhoods patients experienced poorer outcomes following cardiac surgery due to the high professional isolation of surgeons who worked within small clustered networks with few external ties (Hollingsworth et al. 2015).

Table 3 DoI and barriers to best practice and TRIP (page 1 of 3)

DOI element	Innovation Research
<i>Not Looking for innovation</i>	New graduates find a strong adherence to ritualistic practices (Mooney 2007)
<i>Innovation availability</i>	Lack of research to underpin practice(Hutchinson & Johnston 2006; Rolls & Elliott 2008)
<i>Finding innovation</i>	Limited awareness of new evidence (Hutchinson & Johnson 2004; Hutchinson & Johnston 2006)
<i>Using innovation</i>	Limitations on ability to identify or time to find useable evidence(Estabrooks et al. 2005; Gerrish et al. 2008; Hutchinson & Johnston 2006; Kajermo et al. 2008; Salinas 2014; Waters et al. 2009) Perceived limited useability of research (Estabrooks et al. 2005; Marshall, West & Aitken 2011) Limited use of local organisational evidence or guidelines (Marshall 2008; Thompson et al. 2001)
<i>Relative advantage</i>	Limitations on how to apply research or guidelines to local setting (Gerrish, Guillaume, et al. 2011; van der Weide & Smits 2001)

Table 3 DoI and Barriers to Best practice and TRIP (page 2 of 3)

DOI element	Communication channels Research
<i>Interpersonal</i>	<p>Information source use is driven by accessibility and perceived credibility by nurses (Curran et al. 2013; Ebenezer 2015; Estabrooks et al. 2005; Marshall, West & Aitken 2011; O'Leary & Mhaolrunaigh 2011; Spenceley et al. 2008), physicians (Curran et al. 2013; Hughes, Wareham & Joshi 2010; Kostagiolas et al. 2014; Tagliaventi & Mattarelli 2006) , social workers (LaMendola, Ballantyne & Daly 2009), pharmacists (Curran et al. 2013), and public health practitioners (Meagher-Stewart et al. 2012).</p> <p>Inability to discuss new evidence and new practices due to limited interpersonal communication channels with professional colleagues (Berwick 2003; Bostrom et al. 2008; Halford & Leon 2003)</p> <p>Limited access to or use of knowledge brokers or boundary spanners (Estabrooks et al. 2005; O'Leary & Mhaolrunaigh 2011)</p> <p>Preference for same discipline as source of information (Farrugia & Borg 2012)</p>
<i>Mass media</i>	<p>Limited journal reading (Brown et al. 2007; Hegney et al. 2007; Olmsted et al. 2006; Spenceley et al. 2008)</p> <p>Limited use of or access to online sources for evidence (Gerrish et al. 2008; Gosling, Westbrook & Spencer 2004; Hegney et al. 2007; Marshall, West & Aitken 2011)</p>

Table 3 DoI and Barriers to Best practice and TRIP (page 3 of 3)

DOI element	Social Group Research
Professional	<p>Opinion leaders influence uptake of innovation in both directions (Doumit et al. 2007; Flodgren et al. 2011; Francke et al. 2008; Pearsall 2014)</p> <p>Professional networks shape clinical behaviour (Dopson et al. 2002; Duncan et al. 2014; Hollingsworth et al. 2015; Mascia & Cicchetti 2011; Shah et al. 2015; Tasselli 2014)</p> <p>Ineffective professional networks may adversely effect patient outcomes (Creswick & Westbrook 2014; Evan Pollack et al. 2014; Hollingsworth et al. 2015; Rangachari et al. 2010; Weller, Boyd & Cumin 2014)</p> <p>Professional boundaries inhibit development of a shared understanding of knowledge (Currie & White 2012; McDonald et al. 2005; Rangachari et al. 2010; Shah et al. 2015; Williams 2011)</p>
Working environment	<p>In the clinical setting professional boundaries and division of labour inhibit inter-professional cooperation and adversely affect patient outcomes (Braithwaite et al. 2016; Mackintosh 2012; Ramsay et al. 2014).</p> <p>In the clinical setting social and cognitive inter-professional boundaries create mono-discipline networks which inhibit innovation diffusion and adoption (Ferlie et al. 2005; Rangachari et al. 2010)</p> <p>Lack of time to find or implement is a major barrier to EBP irrespective of country (Fink, Thompson & Bonnes 2005; Francke et al. 2008; Hutchinson & Johnston 2006; Nagy et al. 2001; Spenceley et al. 2008)</p>
Working environment	<p>New staff have to be socialised to comply with accepted norms of new unit, (Krusen 2011; Maben, Latter & Clark 2006; Mooney 2007; Voldbjerg et al. 2016)</p> <p>Ineffective clinical practices can become normalised and increase adverse events (Ramsay et al. 2014)</p> <p>Failure to develop a shared MDT culture impacts on patient safety (Weller, Boyd & Cumin 2014)</p>
Organisation	<p>Lower research culture [value placed on research evidence in decision making] is a moderating factor when attempting TRIP in public health organisations (Dobbins et al. 2009) whereas a positive nursing culture, leadership & evaluation enhances TRIP at a speciality level (Estabrooks et al. 2007)</p>

These findings are contrasted against evidence demonstrating how effective social networks contribute to improved patient care as well as organisational and staff outcomes including:

1. In an emergency department a dense inter professional network enhanced efficiency and care coordination (Hossain, Guan & Chun 2012)
2. Patient satisfaction, symptom management and safety (e.g. reduction in adverse drug events and falls) increased In wards with dense communication networks and cliques (Effken et al. 2013).

Community of Practice

Communities of practice are groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis (Wenger, McDermott & Snyder 2002, p. 4).

While CoPs are not a 21th century phenomenon, they are increasingly important given the need for astute management, increasing complexity and rapidly reducing half-life of knowledge in the global community (Nicolini, Scarbrough & Gracheva 2016; Wenger, McDermott & Snyder 2002). The business sector began to use CoPs In the 1990's, in an attempt to maintain a competitive edge and to effectively leverage their intellectual assets, especially the transfer of experiential and tacit knowledge, (Hildreth & Kimble 2004; Li et al. 2009).

Contemporary healthcare is immersed in this reality, but the structure of healthcare organisations into time and space isolated environments (Brooks & Scott 2006b;

Curran-Smith & Abidi 2007; Estabrooks et al. 2005), and vertical hierarchical structures do not support the development of a cohesive and cooperative multidisciplinary culture needed to address evolving healthcare challenges (Kothari et al. 2011; Nicolini, Scarbrough & Gracheva 2016). Communities of practice may be an ideal mechanism to address structural and professional silos by overcoming barriers to MDT collaboration and inter-disciplinary learning (Bate & Robert 2002; Kislov, Harvey & Walshe 2011; Oborn & Dawson 2010).

As a social learning theory, CoP is based on the perspective that professional development is fundamentally a social behaviour where individuals learn through their participation in the world (Wenger 1998). The discourse (conversations, discussions and conflict) that occur between members develops the professional knowledge of individuals and the practice knowledge of the community leading to improvements in practice (Gunawardena et al. 2009; Hara & Hew 2007; Wenger 1998; Wenger, McDermott & Snyder 2002). A CoP requires a critical mass of members of varying levels of expertise. Experienced practitioners take responsibility for community coordination and development and experts are generous with time and knowledge (Nicolini, Scarbrough & Gracheva 2016). Novice practitioners linger at the peripheries, observing and absorbing the experiential knowledge of experienced practitioners and learning the essential elements which delineate the identity and competencies of professional practice (legitimate peripheral participation-LPP) (Lave & Wenger 1991; Wenger 1998). As a CoP evolves, so does the social capital embedded within the network of relationships between members, which then underpins organisational knowledge creation, sharing and utilisation (Andreatos 2009).

The core elements of a CoP are a common body of knowledge, practice and identity with members interacting in a dynamic multi-dimensional social space, that includes related CoPs, and facilitates learning and practice development (Wenger, McDermott & Snyder 2002). The three modes of belonging to a CoP (engagement, imagination and alignment) interact with community, boundary and identity dimensions (Wenger 2004). The community dimensions are:

- Enterprise - the level of learning energy within the CoP, reflected by the evolution of knowledge and professional development of members
- Mutuality - a sense of belonging generated by community engagement and includes a sense of trust and reciprocity
- Repertoire reflects members' degree of self-awareness or how community artefacts (concepts, language and tools of practice) reflect the CoP (Wenger 2004).

Community of practice boundaries connect the local community with other CoPs as well as the broader professional context and world; the potential of a CoP to learn and innovate depends on the relationship between strong core practices and active boundary processes (Wenger 1998). A boundary is a separation between social groups that occurs due to hierarchical, physical, geographical, social, cognitive, relational, cultural, temporal/spatial, division, occupational or disciplinary differences (Hsiao, Tsai & Lee 2012). Boundaries may be multiple and ambiguous (Vakkayill 2012) and are barriers to the free movement of innovations between social groups (Rau, Neyer & Möslein 2012). Overcoming these barriers involves CoP members taking on the important boundary roles of 'spanners', 'roamers' and 'outposts' where they actively

undertake to obtain novel knowledge by linking the primary CoP to others (Long, Cunningham & Braithwaite 2013).

There is tension between the assertion that CoPs are best when they are a naturally occurring phenomena, driven by the need to develop practice (Wenger, McDermott & Snyder 2002), and the managerialism of KM, where CoPs are established for the benefit of the organisation (Bolisani & Scarso 2014; Ferlie et al. 2012). The success of a CoP may hinge of its ability to establish a mutuality and enterprise (Wenger 1998) that supports interaction and addresses knowledge deficits (cognitive pressure) of members (Agrawal & Joshi 2011).

Healthcare CoPs

At present, understanding how healthcare CoPs might contribute to professional development, knowledge transfer, evidence uptake and improved outcomes is limited, with variability in how they have been operationalised, reported and evaluated (Hanlis & Abbass 2015; Li et al. 2009; Ranmuthugala, Plumb, et al. 2011). Two systematic reviews found two streams in the literature concerning healthcare CoPs. The first stream focused on learning and LPP where students or novices can develop their professional knowledge, skills and identity (Li et al. 2009; Ranmuthugala, Plumb, et al. 2011); e.g. where students actively participated in local CoPs and engaged with experienced clinicians, they reported increased confidence in being able to transition from student to early practitioner (Burkitt et al. 2001; Cope, Cuthbertson & Stoddart 2000; Plack 2003). In the other stream the CoP was a managerial tool for information sharing or creation, with the goals of professional development and improving the quality of care (Li et al. 2009; Ranmuthugala, Plumb, et al. 2011); e.g. an RCT found

that a CoP resulted in increased content knowledge and use of a mental health assessment tool for adolescents, but no difference in readiness for change or reported practice change (Barwick, Peters & Boydell 2009).

Current research suggests that healthcare CoPs may positively shape professional learning and knowledge transfer across a variety of settings (Greenfield et al. 2007; Ranmuthugala, Plumb, et al. 2011). A recent review found that in 25 of 31 reports the CoPs were multi-disciplinary (Ranmuthugala, Plumb, et al. 2011). A multi-disciplinary CoP facilitates knowledge absorption by developing a shared meaning across disciplines about how external codified knowledge applies within a local context (Kitson 2009). Unfortunately the effectiveness of a multi-disciplinary CoP may be diminished because of social and cognitive boundaries between healthcare disciplines (Ferlie et al. 2005). External validity of these primary studies is limited by the significant variation in how these CoPs were operationalised, especially because only two of 31 studies discussed the effect of the communication method (Ranmuthugala, Plumb, et al. 2011).

In this thesis the term 'local CoP' is used when referring to the immediate working environment of HCPs such as a ward or facility.

Virtual Community of Practice

Virtual community of practices (VCoP) capitalise on the affordances of social media to overcome the need for face to face meetings, enabling members to interact across time and organisational barriers (Burrell, Elliott & Hansen 2009; Kothari et al. 2011; Nicolini, Scarbrough & Gracheva 2016; Wenger, White & Smith 2009). By facilitating knowledge distribution VCoPs are crucial in innovation development in large

companies (Hara, Shachaf & Stoerger 2009; Hildreth & Kimble 2004), and have been identified as a key knowledge management strategy to ensure best practices are delivered to patients (Kothari et al. 2011; Nicolini, Scarbrough & Gracheva 2016). This is achieved by overcoming professional isolation (Barnett et al. 2012; Cassidy 2011; Rolls et al. 2008; Valaitis et al. 2011) to establish social ties between members (Barnett et al. 2012; Russell et al. 2004) as well as supporting ongoing professional development (Booth 2012). The review cited previously (Ranmuthugala, Plumb, et al. 2011) identified two studies where a CoP functioned effectively using predominantly online methods to communicate (Huckson & Davies 2007; Russell et al. 2004). However a significant barrier to establishing and sustaining a VCoP is an inability to achieve sufficient interaction because of limited access to computers, a preference for human to human interaction (Chandler & Fry 2009; Hoffmann, Desha & Verrall 2011), or a mismatch between members and the chosen platform (Francis-Coad et al. 2017; Mayrhofer, Goodman & Holman 2015). At present, a critical factor limiting the evidence base concerning the effectiveness of VCoPs is the use of content analysis techniques which do not take into account the critical role of the social network of the online community, the social capital created and learning that evolves (Li et al. 2014).

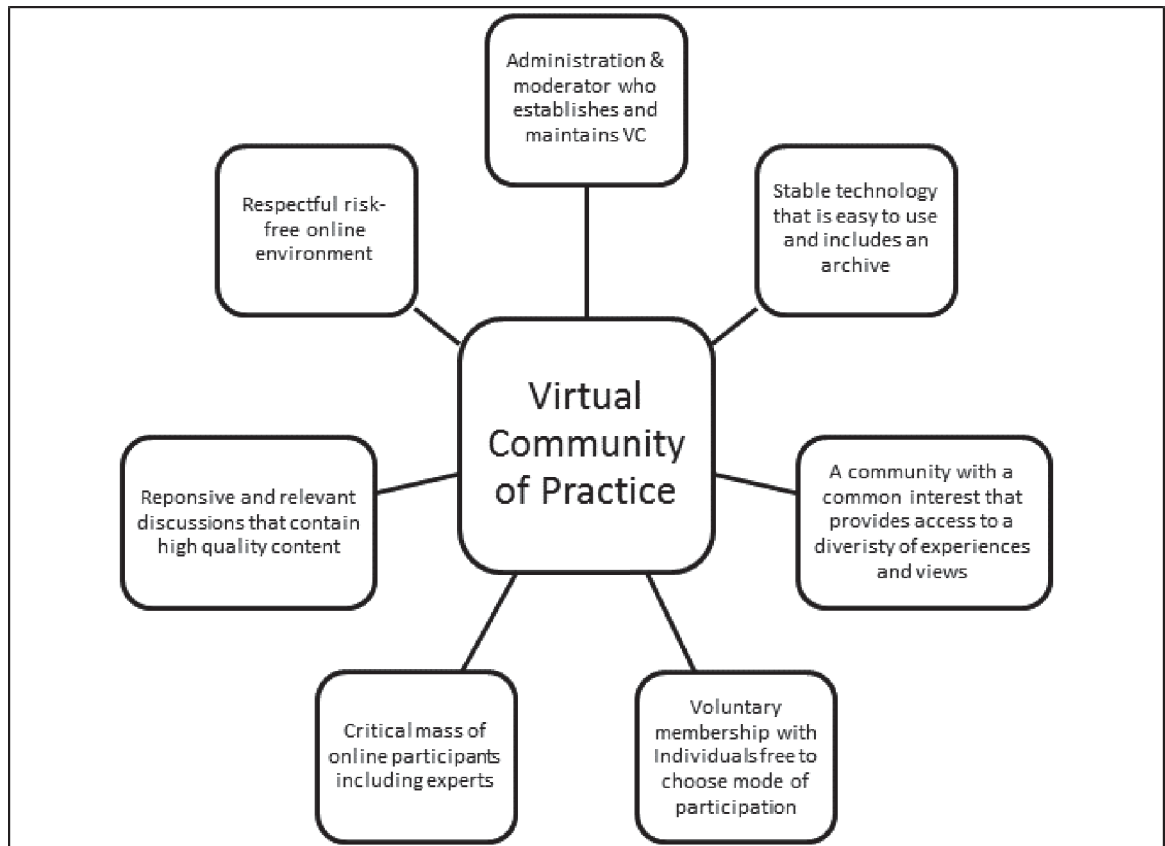
Virtual communities (VC) are formed when a group of people with a common interest meet online using social media (Young 2013, p. 3) and with the exponential rise in available technologies and the Internet it is possible to form worldwide VCs on any topic of interest (Leimeister & Rajagopalan 2014). For a VC to move beyond simple online networking and become a VCoP that facilitates knowledge sharing and professional development, the VC needs to develop and display seven key attributes

(see figure 3) (Barnett et al. 2012; Chang et al. 2014; Hara, Shachaf & Stoerger 2009; Hew 2009).

There needs to be an individual/s who manage and maintain the VC including the technology, community membership and overseeing the online culture of the community so that it supports interaction and knowledge exchange (Barnett et al. 2012; Chang et al. 2014; Hew 2009; Wenger, White & Smith 2009). This moderator role may also involve being a technical steward so that the platform remains responsive to community needs (Wenger, White & Smith 2009). The social media platform should be stable, reliable and easy to use, compatible with member work practices and ideally have an archive so that discussions can be revisited and knowledge is not lost (Barnett et al. 2012; Chang et al. 2014; Hew 2009). Interestingly only the minimal technical requirements need be present for knowledge seeking activities to be satisfied (Chang et al. 2014).

Community members need to share a common interest or practice domain (Wenger, McDermott & Snyder 2002), and also have a shared knowledge base so that new knowledge and discussions are understood (Carlile 2004). A diverse membership base spread across multiple organisations is of significant importance as this will ensure a multiplicity of views and experiences are available (Barnett et al. 2012; Chang et al. 2014; Hew 2009), and so that structural, professional and pragmatic boundaries are crossed (Vakkayill 2012).

Figure 4 VCoP attributes



The online experience of the community should engender participation and knowledge sharing. Members need to be free to participate in whatever way they feel is right for them including posting or not (Chang et al. 2014; Hew 2009), especially inexperienced practitioners engaging in LPP (Wenger, White & Smith 2009). Knowledge self-efficacy is a mediator of knowledge sharing (Hew & Hara 2007a) therefore by allowing voluntary participation there will be no pressure on any individual to share. Experts, or those members with high knowledge self-efficacy tend to share (Bock et al. 2005; Hsu, Chang & Yen 2011) because of sense of altruism (Cho, Chen & Chung 2010; Wasko & Faraj 2000) and collectivism (Hew & Hara 2007a).

Crucially there needs to be a critical mass of online participants who have developed community norms of reciprocity (Bock et al. 2005; Chiu, Hsu & Wange 2006), social

interaction (Chiu, Hsu & Wange 2006), knowledge sharing (Bock et al. 2005) and trust (Hsu et al. 2007; Usoro et al. 2007). For online discussions to be seen as valuable they need to be responsive and relevant and contain high quality content provided by experts (Barnett et al. 2012; Chang et al. 2014; Hew 2009). To be seen as relevant discussion content needs to include knowledge that has a direct practical application to everyday practice (Hew 2009). The last and perhaps most important attribute is a respectful risk-free environment where members trust they are able to speak freely without negative consequences such as flaming or trolling (Chang et al. 2014; Hew 2009; Sharratt & Usoro 2003).

Summary

Inter-professional conversations are integral to professional development, information sharing and uptake or not of new knowledge or practices within a healthcare organisation and local CoP. Ideally these conversations occur within the context of dense local networks balanced against sparse external networks with high social capital to ensure knowledge credibility and transfer. For healthcare organisations it is important that key individuals in KB and management roles are positioned so that they have access to novel knowledge to ensure that local know-what, -how and -why reflect best practice and evidence.

At present however the evidence would suggest that HCP social networks may be ineffective, due in part to structural and professional boundaries that limit access to novel knowledge and professional development. A question that remains then, can social media address the problem of ineffective social networks? In the following chapter an integrative review is presented on the use of social media by HCPs to

establish VCs that facilitate professional networking, knowledge sharing and evidence-informed practice.

Chapter 3 - How healthcare professional use social media to create virtual communities: an integrative review

The purpose of this chapter is to present the literature review that informed development of the research program. As indicated in the Chapter 1, the review was originally developed in 2008 and updated over time to ensure an accurate and contemporary report of the research base. The literature review is presented as published (Rolls et al. 2016a). An integrative review structure (Whittemore & Knaf 2005) was used because of the relative recency of social media, immaturity of the research base and understandings from non-health literature sources on how a virtual community functioned.

The aim of this review was to evaluate whether HCPs have been able to effectively leverage social media platforms to develop virtual professional communities that facilitate knowledge sharing and created learning communities. The chapter is structured as per the published article, with the content duplicated verbatim. Please note there is some repetition of content in the Background below and the previous chapter; e.g. for Diffusion of Innovations, Evidence Based Practice, Knowledge Management and Community of Practice. Tables, figures and boxes have being inserted in the text at appropriate locations for this thesis format. A short additional summary is provided at the end of the chapter.

Abstract

Background

Prevailing healthcare structures and cultures restrict intra-professional communication, inhibiting knowledge dissemination and impacting on the translation of research into practice. Virtual communities (VC) may facilitate professional networking and knowledge sharing in and between health care disciplines.

Objectives

To review the literature on the use of social media by healthcare professionals (HCP) in developing VCs that facilitate professional networking, knowledge sharing and evidence-informed practice.

Methods

An integrative literature review was conducted to identify research published between 1990- 2015. Search strategies sourced electronic databases (Pubmed, CINAHL), snowball references and table of contents of three journals. Papers were included that evaluated social media use by healthcare professionals (unless within an education framework) using any research design (except for research protocols or narrative reviews). Standardised data extraction and quality assessment tools were used.

Results

Seventy-two studies were included: 44 qualitative (including two ethnographies, 26 qualitative descriptive and one q-sort), 20 mixed methods studies and eight literature reviews. The most common methods of data collection were online observation (n=39), surveys (n=23), interviews (=11), focus groups (n=2) and diaries (n=1). In general study quality was mixed.

Social media studied included listservs (n=22), twitter (n=18), general social media (n=17), discussion forums (n=7), Web 2.0 (n=3), virtual community of practice (n=3), wiki (n=1) and Facebook (n=1). A range of healthcare professionals (HCP) were sampled in the studies, including physicians (n=24), nurses (n=15), allied health (n=14), followed by HCPs in general (n=8), a multidisciplinary clinical specialty area (n=9) and midwives (n=2). Of 36 VCs, 31 were mono-discipline for a discrete clinical specialty. Population uptake by the target group ranged from 1.6% to 29% (n=4). Evaluation using related theories of 'Planned behavior' and the 'Technology acceptance model' (n=3) suggest social media use is mediated by an individual's positive attitude towards and accessibility of the media, which is reinforced by credible peers.

The most common reason for a VC was to establish a forum where relevant specialty knowledge could be shared and professional issues discussed (n=17). Most members demonstrated low posting behaviors but more frequent reading or accessing behaviours. The most common online activity was request for and supply of specialty specific clinical information. This knowledge sharing is facilitated by an online culture of collectivism, reciprocity and a respectful non-competitive environment. Findings suggest HCP view VC as valuable knowledge portals for sourcing clinically relevant and quality information that enables them to make more informed practice decisions.

Conclusions

There is emerging evidence that HCP use social media to develop VCs to share domain knowledge. These virtual communities however currently reflect tribal behaviours of clinicians that may continue to limit knowledge sharing. Further research is required to

evaluate the effects of social media on knowledge distribution in clinical practice and importantly whether patient outcomes are significantly improved.

Key Words

Social media; literature review; physicians; nurses; midwives; virtual community, networking; pharmacist; social worker; occupational therapist

Introduction

Although modern healthcare organizations are purported to be knowledge intensive (Drucker 1992), current management structures and work practices do not always facilitate development of intellectual and structural capital (Moody 2004) or innovation uptake, leading to challenges for translating research into practice (TRIP) (Oborn, Barrett & Racko 2010). Contemporary organizational (Drucker 1992) and learning theories (Wenger 2004) highlight learning and behavior as being socially constructed and therefore influenced by social networks (Borgatti & Halgin 2011). However, despite implementation of clinical network structures aimed at improving patient care and facilitating knowledge sharing between healthcare professionals (HCP) and across organizational boundaries, bureaucratic, hierarchical and intra-professional barriers persist (Braithwaite 2010).

Information technology and the Internet have revolutionised communication to such an extent that humans can now communicate with colleagues anywhere at any time using social media (SM) platforms. Within the healthcare literature there are however polarized views regarding the benefits and negative aspects of professional social media use (Decamp & Cunningham 2013; Ferguson 2013). Given this evolving technological environment and related continuing professional debate, the purpose of this paper is to review the literature on the use of SM by HCPs for facilitating professional networking, knowledge sharing and evidence-informed practice. Theoretical frameworks used to embed the use of SM in enabling collegial networking, knowledge sharing and supporting evidence-informed practice are explored in the following section for context, prior to the focused literature search and review.

Background

Professional networking is a process of establishing a mutually beneficial relationship with other like-minded professionals (The Australian Concise Oxford Dictionary 2004). For an organization, professionals networking between separate operational units promote knowledge flow and diffusion of innovations, potentially leading to improved professional performance (Oborn, Barrett & Racko 2010). Evolving views of learning, including community of practice (Wenger 2004) and connectivism (Siemens 2008) highlight that professional development can be achieved through collective learning within social groups or networks. With the creation of online communities, social media applications may facilitate this networking and professional development, enabling interactions between individuals regardless of time, space or geography (Barnett et al. 2012; Deng & Poole 2008). The following inter-related concepts and frameworks are described below as background for exploring this topic area: diffusion of innovations, learning theories, evidence based practice, knowledge management and work in healthcare practice and social media.

Diffusion of innovations

This theory describes how a novel idea, practice or object is adopted by a particular social group or network (Rogers 2003). In health, these innovations include new equipment, research findings or practices. Rogers (Rogers 2003) demonstrated while heterophilous communication (when individuals do not share common attributes such as values or socioeconomic status) increases access to novel ideas, for the vast majority of individuals, adoption of an innovation is dependent on homophilous communication (when individuals share common attributes). Five distinct types of

individuals in a social group were identified. 'Innovators' and 'early adopters' are the first to adopt innovations with use mediated by a higher income and having greater access to novel information because of their broader, heterophilous social networks. The 'early majority' are in turn influenced to adopt practices by observing use of and / or recommendation by early adopters. Finally, the 'late majority' and 'laggards' are the last to adopt because their communication channels are limited to those that share their views and experiences (homophilous) and are unlikely to be exposed to non-redundant knowledge or differing opinions (Borgatti & Halgin 2011; Tasselli 2014).

Contemporary understanding of Diffusion of Innovations acknowledges that organizational or group factors also exert a powerful influence on individuals as well as the organisation (Fleuren, Wiefferink & Paulussen 2004; Greenhalgh et al. 2005a; Grossan & Apaydin 2010)). In particular, interconnectedness (connections between organisational members and units) and external orientation (organizational leaders with external networks) are both mediated by communication channels (networking internally or external to the organisation) (Greenhalgh et al. 2005a; Grossan & Apaydin 2010; Rogers 2003). Individual innovators and early adopters with communication channels outside their everyday social and professional networks will learn more new information (Granovetter 1982; Nieves & Osorio 2012; Singh & Cullinane 2010), although unless these individuals hold a central position within their local social network it is unlikely this new knowledge will become embedded locally (Tasselli 2014). Credibility of intrapersonal channels (for example peer to peer or opinion leader to professional) makes these channels more influential on adoption decisions (Fleuren, Wiefferink & Paulussen 2004; Granovetter 1982; Locock et al. 2001; Rogers 2003;

Valente 1993). Current social networks in healthcare organisations are generally homophilous with strong professional boundaries (Creswick & Westbrook 2007; Creswick, Westbrook & Braithwaite 2009) which tend to control clinical practice (Duncan et al. 2014).

Learning theories

Current views of learning also highlight the importance of interaction or networking between individuals for learning and professional development. As a social learning theory, Community of Practice (CoP) positions learning as a fundamentally social behaviour where individuals learn through their interactions and participation in the world (Wenger 2004). Within a CoP members acknowledge a shared knowledge domain (craft knowledge), practice and identity (Wenger 2004). Professional development therefore occurs during everyday workplace interactions, where important 'how to' knowledge can only be gained from other colleagues (Brown & Duguid 1991). For healthcare professionals, CoP is particularly relevant as the theory provides a framework for understanding the professional development of individuals within the workplace through different forms of participation (Hara & Hew 2007; Wenger 2004; Widemark 2008). At present however the effectiveness of healthcare CoPs to facilitate professional development and improve clinical practice needs further investigation as projects to date have operationalized and measured the effectiveness of the CoP in different ways (Li et al. 2009; Ranmuthugala, Plumb, et al. 2011).

Evidence based practice

Recent literature on adoption of evidence-based practice (Oborn, Barrett & Racko 2010) suggests traditional healthcare structures do not create learning organizations that support: 1) development of intellectual capital (Moody 2004); 2) knowledge work (Brooks & Scott 2006b); or 3) assimilation of research findings into practice (Crow 2006). Further, as knowledge does not flow freely between the silos of academia, clinical practice, publishing and healthcare organizations, variations in the types and quality of care are common (McGowan 2012). In healthcare there have been mixed results where these channels (for example opinion leaders) have been used to promote evidence base practice (Doumit et al. 2007; Thompson, Estabrooks & Degner 2006) and peer-to-peer communication becomes more important as final adoption decisions are made (Locock et al. 2001). In practice however clinicians continue to rely on personal knowledge (gained through education and experience) before seeking advice from close credible colleagues (LaMendola, Ballantyne & Daly 2009; Marshall, West & Aitken 2011; Spenceley et al. 2008; Tagliaventi & Mattarelli 2006), despite the veracity of this advice not being critiqued or evaluated (Marshall, West & Aitken 2011).

Knowledge management, knowledge work and healthcare practice

Currently organizational productivity (Weston, Estrada & Carrington 2007), improved health outcomes and cost-effectiveness are linked to the presence of a definitive knowledge management (KM) strategy that supports activities of 'knowledge workers' (KW)(Orzano et al. 2008). Contemporary KM strategies focus on human and contextual elements of knowledge, such as how knowledge is created and diffused through an organization (Newell et al. 2003; Wickramasinghe 2007). Inter- and intra-

organizational networks are central to knowledge creation and diffusion, given that much knowledge is experiential, implicit or tacit (Newell & Swan 2000), particularly in healthcare organizations.

Knowledge work involves evaluating data from novel situations and applying specialized and expertise transfer, to discover or create knowledge in a given context (Ayers LaFave 2008). Healthcare professionals (nurses, physicians and allied health disciplines) are a subgroup of knowledge workers identified as 'technologists,' where a personal knowledge store, initially based on formal academic education, evolves through experience and professional development (Moody 2004). Knowledge work can therefore be viewed as a form of evidence-based practice as it is the active thoughtful mode of work where clinicians decide how best to apply current knowledge, both personal and evidence, to individual patient care and other practice situations.

Social media

Computers, the Internet and social media have revolutionised human communication (Ryan 2010) . Web 1.0, existing between 1980-2000, was an online environment characterised by static webpages with centralized creation, control and distribution of content (Chu et al. 2010) and user interactivity facilitated by early social media (discussion forums, bulletin boards and listservs) (Crier & Campbell 2000). The range of social media platforms exploded with arrival of Web 2.0, enabling new technologies including social and professional networking sites (e.g. Facebook and LinkedIn), thematic networks, microblogs, wikis, social photo and video sharing tools,

collaborative filtering tools and multi-user virtual environments (Grajales 2012; Paton & Luquel ; van Zyl 2009).

Aided by diffusion of smartphone and tablet technology, Internet access and improved mobile connectivity, use of social media has increased exponentially over the past few years. Between 2015 and 2016 both Internet and social media users increased by 10% to 46% (3.419 billion) and 31% (2.307 billion) respectively there are however significant regional and national differences (Kemp 2016). With respect to Internet use Iceland has the highest penetration (98%) followed by Bermuda (97%) and Norway, Denmark, Andorra and United Arab Emirates next (96%). North Korea has the lowest population usage (0.03%) followed by a number of central African countries with less than 5%. Active population use of a social media account is greatest in North America (59%), South America (50%) and East Asia and Western Europe (48% each) and lowest in Central Asia (6%) and South Asia (11%). Social media use is similar across Western nations (for example 58% Australia, 59% US, 59% United Kingdom) but less in China at 47%. While Facebook continues to dominate the social sphere, with 1 590 million active accounts, users appear to be gravitating towards apps for networking including WhatsApp (900 million), QQ (860 million) and Facebook messenger (800 million) . Among other platforms Tumblr, Instagram and Twitter continue to experience growth while Skype and LinkedIn are stable (Kemp 2016). For this paper we adopted the International Medical Informatics Association's (Paton & Luquel) classification which identifies thirteen types of social media platforms (see box 1).

Box 1 Social media types

1. Social networks	8. Social photo and video sharing tools
2. Professional networks	9. Collaborative filtering tools
3. Thematic networks	10. Multi-user virtual environments
4. Microblogs	11. Social applications and games
5. Blogs	12. Integration of social media with health information technologies
6. Wikis	
7. Forums/Listserv	13. Other (eg FriendFeed)

Importantly, not all social media applications have the functionality to promote development of an online or virtual professional community. The success of interactive conversational technologies (including discussion forums, listservs, wikis, blogs, microblogs and social networking sites (SNS), is contingent upon members joining and participating in ongoing interaction; these are therefore the main types of social media platforms capable of creating virtual communities (VC). While VC have been examined by a number of researchers from different disciplines, at this time there is no universally accepted definition (Young 2013). For this paper we define an online (virtual) community as ‘... a group of people who share a strong common interest, form relationships and interact online’ (Young 2013, p. 3). A community’s existence depends on the structural capital produced from relationships established by member interaction and sharing of resources through the network (Kane et al. 2014). Increasing numbers of organizations, professionals and patients are now using social media to communicate and interact both internally and externally (Oliver Young 2008). These real-life VC or networks created by social media establish intra-personal communication channels, overcoming barriers of time and geography, empowering

users to communicate and interact (network) with a broad range of colleagues (Deng & Poole 2008).

The purpose of this review is therefore to examine the research literature to identify how healthcare professionals use social media to develop virtual communities that facilitate professional networking, knowledge sharing and evidence-informed practice. This review will add to the current literature by developing an understanding of how HCP use social media on a purely voluntary basis including integration of new media and behaviours such as conference tweeting.

Methods

Within the context of learning theories, diffusion of innovations and social media in healthcare, an integrative literature review (Whittemore & Knaf1 2005) was conducted to evaluate whether HCPs have been able to effectively leverage social media platforms to develop virtual professional communities that facilitate knowledge sharing and created learning communities.

Literature search

Two major electronic health databases, CINAHL and Pubmed were searched for research articles published between January 1990-December 2015. Keywords were used as they applied to the main concepts of social media, networking and professional development including virtual communities, social media, computer mediated communication, listserv, discussion forum, networking, Twitter and Facebook. Additional search strategies included a review of reference lists of the

articles and hand-searching the table of contents of key journals (see appendix A for detailed search).

Articles that fulfilled the following criteria were selected for review: involved HCP participation exclusively as a voluntary activity; English language; peer-reviewed; and all research designs which highlighted HCP interaction using social media to develop a virtual community as the core component. Social media included were listservs, discussion forums, social networking sites and microblogs. Articles were excluded if they: 1) described a project within an education context including under- or post-graduate learning or organizational education or training; 2) study protocol; 3) narrative review. The first author extracted data from studies using a standard data extraction tool (Elliott 2007).

Study Methods Evaluation

Following data extraction the quality of each study was evaluated by two authors using standardized criteria. The CASP appraisal tool was used for qualitative studies (not including studies using content analysis) (CASP International 2013). For studies using content analysis techniques (Graneheim & Lundman 2004; Krippendorff 2004; Zhang & Wildemuth 2009) this included:

- Data: appropriateness to research question, data corpus, sampling unit, unit of analysis and sampling plan (described and justified)
- Coding schema: appropriateness of approach, development, coders, training, theoretical underpinning of categories and reliability of coding schema
- Analysis: appropriateness of approach

Quality criteria for surveys included: 1) research question and design; 2) sampling framework and participant understanding; 3) instrument metrics; 4) response rate; 5) coding and analysis; and 6) result presentation (Greenhalgh et al. 2005a). The Scottish intercollegiate guidelines network (SIGN) (SIGN Scottish Intercollegiate Guidelines Network) appraisal tool was used for literature reviews. Studies were categorized as strong (most elements described with satisfactory quality), moderate, fair and limited (poor reporting or description of research method).

Data analysis

Following data extraction and evaluation of study quality, summary tables were constructed to reduce data into manageable frameworks (Whittemore & Knafel 2005) and to facilitate identification of patterns. These tables included data pertaining to:

1. Research overview including context, social media type, research design, sample and/or data corpus, data analysis and quality;
2. Online behaviour including manifest and latent characteristics of emails or tweets and posting habits of members;
3. Reasons for belonging to a virtual community including meaning or value of community to members and motivators and barriers to online participation;
4. Descriptions of online communities including context, membership and reasons or objectives for establishing online community; and
5. Research examining general social media use.

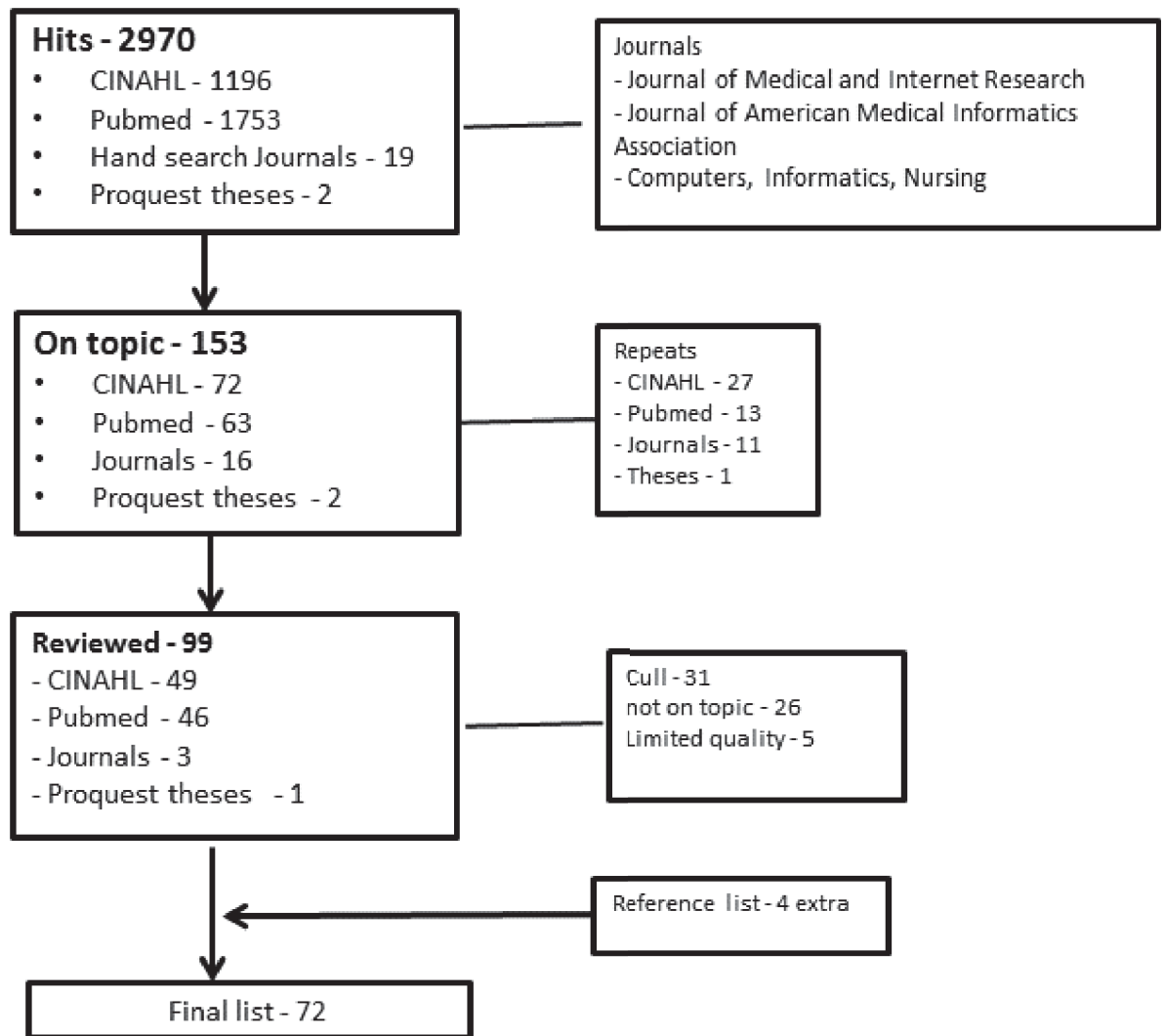
Only a limited amount of quantitative data could be aggregated for comparison across studies because of different data collection methods and outcomes. Qualitative data were synthesized to identify consistent patterns and themes.

Findings

Seventy-two studies were included in the final review (see figure 5 and appendix B). An overview of studies including context, design, instruments and data collection, sample and data corpus, data analysis and study quality is listed in appendix 2). Findings are presented in the following sections

1. Overview of research methods and critique of study quality
2. Social media use by healthcare professionals
3. Online posting behaviours including the manifest and latent content of communication (emails, posts or tweets) and posting habits
4. Mediating factors of online posting

Figure 5 Literature search using PRISMA



Overview of research methods and critique of study quality

Of the 72 studies selected, there were 44 qualitative, 20 mixed methods and eight literature reviews. The most common methods of data collection were online observation (n=30 studies), surveys (n=18), interviews (n=12) and focus groups (n=2).

Qualitative methods included: 1) qualitative (n=14; survey 11; discourse analysis 1; interviews 2); 2) qualitative descriptive (n=26; content analysis 19, descriptive 5; thematic 1; social network analysis 1); 3) ethnography (n=2), Q-sort (n=1) and social network analysis (n=1). Q-sort is a multi-level study method where qualitative (subjective) responses are refined to develop a quantitative understanding or hierarchy of the phenomenon of interest (Valaitis et al. 2011). Of the 20 mixed method studies combinations of methods included: content analysis and interviews (n=5); content analysis and survey (n=3); content analysis, survey and social network analysis (n=1); online observation and thematic analysis (n=1); online observation and social network analysis (n=2); survey and diaries (n=1); survey and interviews (n=2); survey, interviews and online observation (n=1) and survey and online observation (n=2).

Overall, the quality of these qualitative studies was satisfactory, with most fulfilling the CASP criteria (CASP International 2013) (see appendix C quality assessment table for qualitative studies). The quality of studies using content analysis (see appendix D), survey methods (see appendix E) or literature review (appendix F) was mixed.

Content Analysis

Content analysis was commonly used in studies to reveal the content and meaning of textual data which remains embedded in its origin or context (Krippendorff 2004). In relation to online communication, this approach can reveal the acquisition of new

knowledge and skills and the social construction of knowledge (De Wever et al. 2006). Thirty studies used online observation to collect emails, discussion threads or tweets and applied either inductive (n=10) or deductive (n=20) content analysis techniques to identify: manifest content (topic, type of post, type of knowledge, frequency, discussion thread length and/or participation rate); and latent content (accuracy of information, presence of knowledge work or sophistication of discussion). Listservs or mailing lists (n=15) were the most common social media type examined followed Twitter (10), discussion forums (n= 3), online journal clubs (n=1) and Facebook (n=1).

The quality of studies were evaluated as high quality (n=12) or moderate quality (n=8), with the remaining ten only fulfilling a limited number of required criteria (See appendix 3.4). Common study limitations affecting the validity of results included failure to report or justify the following elements: 1) data corpus and/or sampling unit (Abrahamson, Fox & Anderson 2013; Berman 1996; Morken, Bull & Moen 2009; Rodriguez-Recio & Sendra-Portero 2007; Whitaker, Cox & Alexander 2003); 2) unit of analysis (Berman 1996; Bowers 1997; Long et al. 2009; Macdonald, MacPherson & Gushulak 2009; Morken, Bull & Moen 2009; Murty et al. 2012; Rodriguez-Recio & Sendra-Portero 2007; Smith 2004; Whitaker, Cox & Alexander 2003); 3) coding schema development and categories with a limited theoretical basis for categories (Abrahamson, Fox & Anderson 2013; Brynolf et al. 2013; Cervantez Thompson 2002; Mishori, Levy & Donovan 2014; Rodriguez-Recio & Sendra-Portero 2007; Smith 2004; Whitaker, Cox & Alexander 2003); and 4) evaluate inter-rater reliability (Abrahamson, Fox & Anderson 2013; Chaudhry et al. 2012; Foong & McGrouther 2010; Macdonald, MacPherson & Gushulak 2009; Matta, Doiron & Leveridge 2014; Rodriguez-Recio &

Sendra-Portero 2007; Smith 2004; Whitaker, Cox & Alexander 2003). Only two studies kept the unit of analysis (that is post or email) within its contextual unit (that is discussion thread) (Mishori, Levy & Donovan 2014; Murray 2001). Sampling methods to gather the data corpus for analysis varied considerably. Most reports describe using a census sample (Anderson et al. 2014; Brooks & Scott 2006a, 2006b; Burg, Adorno & Hidalgo 2012; Cervantez Thompson 2002; Ferguson et al. 2014; Foong & McGrouther 2010; Long et al. 2009; Macdonald, MacPherson & Gushulak 2009; Mishori, Levy & Donovan 2014; Moorley & Chinn 2014; Morken, Bull & Moen 2009; Rodriguez-Recio & Sendra-Portero 2007) with stratified (Chaudhry et al. 2012; Desai et al. 2012; Hara & Hew 2007; Hew & Hara 2007b; McKendrick, Cumming & Lee 2012; Neill et al. 2014; Reutzler & Patel 2001) or convenience samples (Abrahamson, Fox & Anderson 2013; Berman 1996; Brynolf et al. 2013; Hajar, Clauson & Jacobs 2014; Murray 1996; Murray 2001; Whitaker, Cox & Alexander 2003) used less often. A random sample was used only (Murty et al. 2012) however this was not well described .

Surveys

A survey design was used by 23 studies to examine member experiences with or intentions to use social media; only two demonstrated strong quality, nine were moderate quality and 12 were fair quality (see appendix .55). Methodological limitations impacting on the validity and generalizability of these findings included: 1) limited information regarding survey tool development (Cook-Craig & Sabah 2009; Deen, Withers & Hellerstein 2013; Frisch et al. 2014; Fuoco & Leveridge 2015; Hughes et al. 2009; Kim et al. 2014; Klee, Covey & Zhong 2015; Loeb et al. 2014; Rodriguez-Recio & Sendra-Portero 2007; Schoch & Shooshan 1997; Tunnecliff et al. 2015; Watson 2003); and 2) sampling bias including recruitment methods, low response rate and/or

failure to identify whether respondents were representative of community membership or study population (Apostolakis et al. 2012; Burg, Adorno & Hidalgo 2012; Cook-Craig & Sabah 2009; Deen, Withers & Hellerstein 2013; Fuoco & Leveridge 2015; Hoffmann, Desha & Verrall 2011; Klee, Covey & Zhong 2015; Kukreja, Heck Sheehan & Riggins 2011; Loeb et al. 2014; Rodriguez-Recio & Sendra-Portero 2007; Stewart, Sidebotham & Davis 2012; Tunnecliff et al. 2015; Usher 2012).

Literature reviews

Eight literature reviews were identified (four systematic; two scoping; two with no specific descriptor) with variable quality demonstrated (see appendix G) (SIGN Scottish Intercollegiate Guidelines Network). The main deficits were: limited description of method (Lawson & Cowling 2015; von Muhlen & Ohno-Machado 2012); a search strategy that was limited by years and/or databases (Benetoli, Chen & Aslani 2015; Lawson & Cowling 2015; von Muhlen & Ohno-Machado 2012); and failure to evaluate the quality of studies covered (Benetoli, Chen & Aslani 2015; Grindrod et al. 2014; Hamm et al. 2013; Lawson & Cowling 2015; Roberts et al. 2015). Though each review had different questions there were overlapping content areas: 1) social media adoption by clinicians (von Muhlen & Ohno-Machado 2012), pharmacists (Benetoli, Chen & Aslani 2015; Grindrod et al. 2014), radiographers (Lawson & Cowling 2015); 2) social media use for communication between patients, patient-clinician or clinicians (Moorhead et al. 2013); 3) type of social media use by clinicians (Hamm et al. 2013); 4) virtual communities for general practitioner professional development (Barnett et al. 2012); and 5) twitter journal clubs (Roberts et al. 2015). Two studies (Hamm et al. 2013; Moorhead et al. 2013) used the same definition of social media (Kaplan & Haenlein 2010). Overall, the quality of studies was mixed with 41 of moderate or

higher methodological quality (strong 17; satisfactory 10; moderate 18) with 21 being of fair (17) or limited (4) quality and there were six where we were unable to apply a quality framework. Despite a lack of methodological quality for a significant proportion of studies, all were retained in the review because of the limited contemporary evidence base and to therefore provide a comprehensive synthesis of this topic area.

Social media used by healthcare professionals

Healthcare professionals (HCP) currently use a broad range of social media platforms in practice, although understanding the extent is limited by study methods used and a lack of population data. Previous literature reviews (Barnett et al. 2012; Benetoli, Chen & Aslani 2015; Grindrod et al. 2014; Hamm et al. 2013; Lawson & Cowling 2015; Moorhead et al. 2013; von Muhlen & Ohno-Machado 2012) described use of most social mediums by most HCP groups to communicate inter- and intra-professionally and with healthcare consumers. The common types of SM platforms identified in this current review were listservs (n=22), twitter (n=18), general social media (n=17), discussion forums (n=7), Web 2.0 (n=3), topic-specific discussion forums plus document repositories (n=3), a wiki (n=1) and Facebook (n=1). Physicians (n=24) in general and from 14 clinical specialties were the most common professional group studied, followed by nurses (n=15) in general and from nine specialty areas, four groups of allied health professionals (n=14), HCPs in general (n=8), a multidisciplinary clinical specialty area (n=9), and midwives (n=2).

Four papers described the uptake and use based on a population of potential users.

Twenty percent or more had joined listservs for occupational health practitioners

(Morken, Bull & Moen 2009), nurse practitioners (Widemark 2008) and intensive care (nurse data only) (Rolls et al. 2014). While 13% (209/1559) of Korean emergency physicians had participated on a Facebook page (Kim et al. 2014) , only 1.6% of United States and 1.7% of Australian emergency physicians had joined Twitter by 2011 (Lulic & Kovic 2013).

A number of studies of variable quality evaluated the general use of social media and found that HCPs reported or demonstrated limited use of social media for professional purposes, and when they did they preferred specialty specific closed communities. Only two studies however were of a high to moderate quality (Hughes et al. 2009; McGowan et al. 2012). A study examining US physicians' professional use of SM for connecting with colleagues reported limited use; only 52% currently used closed online communities, 25% used wikis, while less than 20% used Facebook, podcasts, blogs or Twitter. More than half also indicated they were unlikely to use these latter four platforms in the future (McGowan et al. 2012). A mixed method study (Hughes et al. 2009) used diaries to directly track the use of Web 2.0 by 35 junior physicians; 2.6 medical sites were accessed per day and 53% of these visits were to user-generated platforms, but there was limited professional use of social networking sites. A study of a broad range of Australian HCP found limited use and knowledge of Web 2.0 technologies, although the response rate was less than 10% (89/965), there were limited responses by physicians and the researcher was unable to distribute to nurses (Usher 2012). The remaining surveys, of Greek HCPs (Apostolakis et al. 2012), pharmacy preceptors (Kukreja, Heck Sheehan & Riggins 2011) mental health (Deen, Withers & Hellerstein 2013), family physicians (Klee, Covey & Zhong 2015) and

urologists (Fuoco & Leveridge 2015; Loeb et al. 2014) found limited SM use, including social networks, for professional purposes. A single study of limited quality (Tunnecliff et al. 2015) found that 80% of respondents were using social media for professional purposes, however the specific purpose was highly variable with only 44% using it for professional networking and 25% for obtaining or disseminating research evidence and professional development.

Two theories were applied across three studies to understand actual or future use of social media by HCPs. Two high quality studies applied the Theory of Planned Behaviour (TPB); a survey on the future use of Web 2.0 by Hong Kong nurses (Lau 2011) and a qualitative study on the use of a wiki to transfer best practice care for patients with head injuries, where nurses were considered credible or influential peers by physicians (Archambault et al. 2012). Another survey of US physicians (McGowan et al. 2012) applied the Technology Acceptance Model (TAM; explains human behavior in relation to computer use) to explore user adoption. To use social media, clinicians required a positive attitude that the media was easy to use (usability), they were able to have a practice run to see how it worked (trialability), the platform worked better than current solutions (relative advantage), and the technology was accessible in the workplace and fitted in with current work practices. The final mediating factor was that their peers also shared these attitudes; a reflection of the influence of homophily.

Social media and virtual communities

Overall, 36 reports described 31 discrete virtual communities (Abrahamson, Fox & Anderson 2013; Berman 1996; Brooks & Scott 2006a, 2006b; Burg, Adorno & Hidalgo 2012; Cervantez Thompson 2002; Cervantez Thompson & Penprase 2004; Cook-Craig

& Sabah 2009; Foong & McGrouther 2010; Frisch et al. 2014; Hara & Hew 2007; Hew & Hara 2007b, 2008; Hoffmann, Desha & Verrall 2011; Kim et al. 2014; Macdonald, MacPherson & Gushulak 2009; Moorley & Chinn 2014; Morken, Bull & Moen 2009; Murray 1996; Murray 2001; Murty et al. 2012; Rodriguez-Recio & Sendra-Portero 2007; Rolls et al. 2014; Rolls et al. 2008; Schoch & Shooshan 1997; Stewart & Abidi 2012; Watson 2003; Whitaker, Cox & Alexander 2003) that were established in three main ways. The most common were discussion forums or listservs created by a professional society (Berman 1996; Burg, Adorno & Hidalgo 2012; Cervantez Thompson 2002; Cervantez Thompson & Penprase 2004; Foong & McGrouther 2010; Hoffmann, Desha & Verrall 2011; Kim et al. 2014; Long et al. 2009; Macdonald, MacPherson & Gushulak 2009; Morken, Bull & Moen 2009; Murty et al. 2012; Reutzel & Patel 2001; Rodriguez-Recio & Sendra-Portero 2007; Schoch & Shooshan 1997; Whitaker, Cox & Alexander 2003; Widemark 2008). Nine communities appear to have been established by an individual or group of HCP using inexpensive or open access platforms such as YAHOO groups, mailing list software or Twitter (Abrahamson, Fox & Anderson 2013; Dieleman & Duncan 2013; Hara & Hew 2007; Hew & Hara 2007b, 2008; Moorley & Chinn 2014; Murray 1996; Murray 2001; Watson 2003). Eight communities were established by a government health department with the purpose of improving communication and knowledge distribution between HCPs to enhance care (Brooks & Scott 2006a, 2006b; Cook-Craig & Sabah 2009; Frisch et al. 2014; Roberts & Fox 1998; Rolls et al. 2014; Rolls et al. 2008; Stewart & Abidi 2012; Valaitis et al. 2011).

The most common reasons for establishing a discrete virtual community were to:

1. Create a professional forum where relevant professional and academic issues could be discussed and information and knowledge shared (Berman 1996; Cervantez Thompson 2002; Dieleman & Duncan 2013; Foong & McGrouther 2010; Frisch et al. 2014; Hoffmann, Desha & Verrall 2011; Kim et al. 2014; Long et al. 2009; Reutzel & Patel 2001; Roberts & Fox 1998; Smith 2004; Stewart & Abidi 2012; Thomas & James 1999; Valaitis et al. 2011; Watson 2003; Whitaker, Cox & Alexander 2003; Widemark 2008)
2. Address professional isolation (Dieleman & Duncan 2013; Hoffmann, Desha & Verrall 2011; Long et al. 2009; Reutzel & Patel 2001; Rolls et al. 2008; Smith 2004; Valaitis et al. 2011)
3. Facilitate networking (Burg, Adorno & Hidalgo 2012; Cervantez Thompson 2002; Dieleman & Duncan 2013; Frisch et al. 2014; Hara & Hew 2007; Hew & Hara 2008; Hoffmann, Desha & Verrall 2011; Reutzel & Patel 2001; Valaitis et al. 2011)
4. Foster peer collaboration and mentoring (Burg, Adorno & Hidalgo 2012; Frisch et al. 2014; Hoffmann, Desha & Verrall 2011; Valaitis et al. 2011)
5. Facilitate professional development (Burg, Adorno & Hidalgo 2012; Murty et al. 2012; Reutzel & Patel 2001)
6. Improve clinical practice through research and evidence translation (Dieleman & Duncan 2013; Frisch et al. 2014) and
7. Obtain clinical advice or opinion (Kim et al. 2014)

Where a distinct professional community was evaluated, 31 of 36 were a VC in a single HCP discipline such as physician, nurse, occupational therapist, social worker,

pharmacist or medical librarian. Note that these VCs were for a specific clinical specialty, except for two nursing communities (Nursenet (Murray 1996; Murray 2001) and Allnurses (Abrahamson, Fox & Anderson 2013)) and the medical librarian VC (Schoch & Shooshan 1997; Smith 2004). Five multidisciplinary VCs were all listservs for a clinical specialty established by: 1) an international professional society for travel medicine clinicians (Macdonald, MacPherson & Gushulak 2009); 2) a Norwegian professional society for occupational health clinicians (Morken, Bull & Moen 2009); 3) Spanish speaking radiation medicine clinicians (Rodriguez-Recio & Sendra-Portero 2007); 4) an Australian jurisdiction-based health unit for intensive care clinicians (Rolls et al. 2014; Rolls et al. 2008) and a twitter network connecting physicians from three specialty areas (Mishori et al. 2014) .

Social network analysis of three VCoPs demonstrated early evidence supporting the flow of knowledge across VCs. A study examining the growth and social network of an intensive care listserv demonstrated an evolution from a single state nurse-specific network to an Australian-wide, multi-disciplinary and multi-organisational network over six years (Rolls et al. 2014). A distinct Twitter VC, created via following patterns of emergency physicians (board certified in United states or Australia) showed a small core (2.8%) with a larger interconnected group, although 34% were not connected to any others (Lulic & Kovic 2013). Another study examined Twitter VC connections across four physician groups from the United states and reported four distinct communities with a small overlap where there was some information flow between groups (Mishori et al. 2014).

The question of whether a CoP might be possible using social media was examined in several studies. Three high quality qualitative studies exploring a critical care nursing listserv found that motivators of online knowledge sharing mapped to key aspects of CoP theory, including reciprocity, collectivism, respectful environment and altruism (Hara & Hew 2007; Hew & Hara 2007b, 2008). A survey of a nurse practitioner listserv reported that a sense of community correlated with learning (pearson coefficient = + 0.94) and connectedness ($r=0.95$), although the response rate was only 22% and there was no indication whether respondents were active posters or non-posters (Widemark 2008). A literature review (Barnett et al. 2012) adapted a seven-item framework for a healthcare VCoP from a business model (Probst & Borzillo 2008), exploring: 1) facilitation; 2) champion and support; 3) objectives and goals; 4) a broad church; 5) supportive environment; 6) measurement, benchmarking and feedback; and 7) technology and community.

How members use social media virtual communities

Most research on how healthcare virtual communities were used by members focused on posting behaviours. Online roles of members can be broadly described as participants (on-line posters) and non-posters. Direct measurement of posting behaviours across a number of platforms demonstrated a pattern of a minority of members being responsible for the majority of posts (Berman 1996; Brooks & Scott 2006a, 2006b; Morken, Bull & Moen 2009; Rodriguez-Recio & Sendra-Portero 2007; Schoch & Shooshan 1997; Thomas & James 1999; Whitaker, Cox & Alexander 2003) or conference tweeting (Anderson et al. 2014; Desai et al. 2012; McKendrick, Cumming & Lee 2012; Mishori, Levy & Donovan 2014; Neill et al. 2014) (see table 3; appendix G).

The same pattern was revealed across four surveys asking HCPs about their online behaviour (Cook-Craig & Sabah 2009; Rolls et al. 2008; Schoch & Shooshan 1997; Whitaker, Cox & Alexander 2003).

Table 4 Summary of studies examining online posting behaviours by VC members

Reference	Social media; time span	Non-posting	Low posting	Medium posting	High posting
(Cervantez Thompson 2002).	Listserv; 18 months	33%	27.8% at least once in 18 months		10 members > 30
(Long et al. 2009).	Discussion forum; 12 months	28% (n=170)	48% (n=239) < 4 times	30% (n=179) 4-20 times	0.2% (n=12) 19-59 times (17% of total data corpus)
(Stewart & Abidi 2012).	Discussion forum; 27 months	33% (n=14)	46% (n=21) < 14 times	13% (n=6) 15-28 times	9% (n=5) 29-56 times
(Rodriguez-Recio & Sendra-Portero 2007).	Listserv; 5 years	46.3% (n=175)	43.4% (n=161) 1-10 times	8% (n=30) 11-3 0 times	3.2% (n=12) 31 to < 200
(Macdonald, MacPherson & Gushulak 2009).	Listserv; 6 months				Top 20 users - 43% of posts
(Morken, Bull & Moen 2009).	Listserv; 1997-2004		average number of posts = 2.1; this reduced to 0.6 in 2004		
(Brooks & Scott 2006a, 2006b).	Discussion forum;		11 aged care nurses posted over 7 months	26 cardiac nurses posted over 7 months	29 midwives posted over 1.5 months

Conversely, 'Non-posting' or 'lurking' behaviour (Lai & Chen 2014) was generally high, ranging from 28-46% (see table 5) . These findings however do not indicate whether non-posters were active in reading posts. Where being active non-posters was directly measured, it ranged from 1-33% while survey respondents self-reported reading levels of post as 64-96% (see table 4).

Table 5 Summary of studies examining reading (access) behaviours

Reading	Social media	0	low	medium	high
(Stewart & Abidi 2012)	Discussion forum; online observation; access	33%	54%	4%	9%
(Cook-Craig & Sabah 2009)	Discussion forum; online observation; access	1%	11%	38%	50%
(Rolls et al. 2008)	Listserv; survey		4%	13%	83%
(Schoch & Shooshan 1997)	Listserv; survey; access		36%	24%	40%
(Kim et al. 2014)	Facebook; survey; access	once or less each week - 22.3	2-4 times per week – 23.7%	5-6 times per week – 16.6%	> 1 per day – 37.4%
(Whitaker, Cox & Alexander 2003)	Listserv; survey	Seldom or never 10%	1 per week to month	Several times per week 40%	Daily 40%

Current evidence describing barriers and motivators to posting online is difficult to quantify; only four studies examined these elements, two of which reviewed the same listserv and included frequent poster activity (Hara & Hew 2007; Hew & Hara 2007b) (see table 5). This limited data suggests a symbiotic relationship between members and the online community, with behaviours of posters are influenced by both access to new knowledge and contributing for other members of the community. These elements of altruism, reciprocity and collectivism are essential components of CoP building (Hara & Hew 2007; Hew & Hara 2007b; Widemark 2008). Reported barriers suggest that knowledge self-efficacy and time are key mediators of online participation or knowledge sharing in healthcare virtual communities (Hew & Hara 2007b; Rolls et al. 2008).

Table 6 Mediators of online posting by HCP on social media and VC (page 1 of 2)

Motivators	
<i>Individual-level</i>	<i>Community-level</i>
Personal gain: 1. more knowledge (Hew & Hara 2007b; Mishori, Levy & Donvan 2014; Widemark 2008); 2. better reputation (Hew & Hara 2007b); 3. emotional support (Hew & Hara 2007b)	Collectivism (Hew & Hara 2007b, 2008; Mishori, Levy & Donvan 2014; Widemark 2008)
Seeker interest (Hew & Hara 2007b)	Reciprocity (Hew & Hara 2007b, 2008; Widemark 2008)
Altruism (Hew & Hara 2007b, 2008; Mishori, Levy & Donvan 2014; Widemark 2008)	Respectful environment (Hew & Hara 2007b, 2008)
Self-selection (Hara & Hew 2007)	Technology (Hew & Hara 2007b, 2008)
Validation of one's practice (Hara & Hew 2007)	Asynchronous nature (Hara & Hew 2007)
Advocacy (Mishori, Levy & Donvan 2014)	Facilitate networking (Mishori, Levy & Donvan 2014)
Better understanding of current knowledge and best practice in the field (Hara & Hew 2007; Mishori, Levy & Donvan 2014; Tunnecliff et al. 2015)	Non-competitive environment (Hara & Hew 2007)

Table 6 Mediators of online posting by HCPs in social media and VC (page 2 of 2)

Barriers	
<i>Individual-level</i>	<i>Community-level</i>
Nothing to add (Hew & Hara 2007b)	Information not trustworthy (Tunnecliff et al. 2015)
Nothing to say (Rolls et al. 2008)	Lack of privacy (Tunnecliff et al. 2015; Widemark 2008)
Lack of time (Hew & Hara 2007b; Rolls et al. 2008; Tunnecliff et al. 2015)	Technology (Hew & Hara 2007b; Tunnecliff et al. 2015)
Unfamiliarity with subject (Hew & Hara 2007b)	Confidentiality of sharing organisation documents (Hew & Hara 2007b)
Lack of confidence (Rolls et al. 2008)	Tone of discussion (Rolls et al. 2008; Widemark 2008)
Local unit constraints (Rolls et al. 2008)	Alienation(Widemark 2008)
Attitude of seeker (Hew & Hara 2007b) or poster agenda(Tunnecliff et al. 2015)	Unprofessional behaviour (Tunnecliff et al. 2015; Widemark 2008)

Overall, these findings supported the use of social media by healthcare professionals, specifically discussion forums and mailing lists platforms, to develop virtual professional CoPs. These communities valued the online forums as information/knowledge portals, enabling members to 'keep up to date' (Hew & Hara 2008; Schoch & Shooshan 1997; Smith 2004) with clinically relevant and quality information (Rodriguez-Recio & Sendra-Portero 2007), develop workplace resources (Cervantez Thompson & Penprase 2004) and benchmark practice (Cervantez Thompson & Penprase 2004; Hara & Hew 2007; Hew & Hara 2008). Importantly, access to a broader range of professional colleagues beyond their local organization

enabled members to make more informed practice decisions and with greater confidence that these decisions reflected current best practice (Hew & Hara 2008).

Manifest content of posts

Manifest content is the text immediately visible and easy to identify and count (Graneheim & Lundman 2004). The quality of evidence describing the manifest content of posts, including posting behaviours, number of posts, length of discussion thread and ratio of initial post to responses, was limited by both the quality of studies (see appendix D) and variability in the sampling and measurement methods used. Making sense of the types of posts in social media was also challenging as researchers used variable descriptors when categorizing post types (see appendix .G).

The proportion of clinical versus non-clinical posts varied greatly across studies. Clinical posts were in the majority across five listservs: travel medicine professionals (88%) (Macdonald, MacPherson & Gushulak 2009); radiology professionals (71.8%) (Rodriguez-Recio & Sendra-Portero 2007); rehabilitation nurses (60%) (Cervantez Thompson 2002); forensic occupational therapists (59.9 %) (Dieleman & Duncan 2013); and occupational health (54%) (Morken, Bull & Moen 2009). Posts on professional issues were more common on a plastic surgery discussion forum (60% concerned education and introduction of new members) (Foong & McGrouther 2010) and an international nursing discussion forum (83% focused on career and education advice, work issues and handling job related emotions) (Abrahamson, Fox & Anderson 2013).

Analysing categories of conference tweets revealed similar results to listserv and discussion forum data, however understanding how it related to clinical knowledge or new research was difficult because of variable taxonomies and mixed quality. Five

studies, evaluating eight conferences, used the same taxonomy (Dann 2010) and found that tweets concerning conference content (termed informative) ranged between 20-30% (Desai et al. 2012; Matta, Doiron & Leveridge 2014), 30-40% (Awad & Cocchio 2015; Matta, Doiron & Leveridge 2014), 40-50% (Hawkins, Duszak & Rawson 2014; Matta, Doiron & Leveridge 2014) and 50-60% (Matta, Doiron & Leveridge 2014)).

Similar data was found across two conference years where the majority of tweets from an oncology conference were clinical topics (54.5% and 60.4 %), such as clinical management discussions and clinical news or trial outcome (Chaudhry et al. 2012).

Contrasted against this was a study of an emergency conference which found that 75% of tweets related to conference content (Neill et al. 2014). Note however that the most commonly used taxonomy (Dann 2010) has limited validity within or generalisability to healthcare conference data, as it was developed from a single twitter feed specific to the author, was not reviewed by a second coder or tested against another data set. A systematic review of twitter journal clubs which cross referenced hashtag use with online data (Roberts et al. 2015) found sustained and increasing use of five specific tags (#ADC_JC; #ebnjc; #IGSJC; #Nephjc; and #urojc).

Four studies of mixed quality found that topics of clinical posts in VCs mapped to the knowledge domain of a professional speciality. Within a travel medicine listserv there were 27 topics across five major categories (vaccine preventable diseases, vector-borne diseases, pre-travel, general and miscellaneous) (Macdonald, MacPherson & Gushulak 2009). Paediatric occupational therapists posted on four categories (practice, performance component, performance area and health conditions) (Long et al. 2009). Members of an occupational health forum posted on four clinical categories (chemical

hazards, methods in health and safety environment, ergonomics and noise and radiation) (Morken, Bull & Moen 2009). Pharmacists discussed a broad range of topics including patient and clinical problems, pharmacy politics, legal issues, drug tariffs, government policy, business and finance, risk management and pharmacy information technology (Whitaker, Cox & Alexander 2003).

Latent content of posts

Latent content reflects the hidden meaning of textual content by a researcher (Hsieh & Shannon 2005). Latent content examined included types of knowledge exchanged, and presence of discussion and existence of knowledge work. Understanding the types of posts was limited by variability in study methods and challenging because of widely varying definitions and lack of robustly developed content analysis tools. Only three studies examined the types of knowledge within virtual community posts (appendix G). Two high quality studies that examined a nursing listserv found that more than 90% of knowledge exchanged was practical knowledge (related to institutional practices, person opinion or suggestion) rather than book knowledge (facts, general regulations, statutes or published works) (Hara & Hew 2007; Hew & Hara 2007b). On a Spanish radiological listserv 43% of emails were classified as scientific information (Rodriguez-Recio & Sendra-Portero 2007) .

As described earlier, knowledge work involves elements of interaction, critical reflection and learning as a dialogical process (Brooks & Scott 2006b). Only limited data were identified supporting the presence of knowledge work within virtual professional communities. Three studies (Rodriguez-Recio & Sendra-Portero 2007; Smith 2004; Thomas & James 1999) described the presence of discussion or meta-

discussion within emails exchanged, however no content analysis tool or definitions were provided to justify these conclusions. One single high quality study (Murray 2001) effectively described the presence of reflection in discussion, where participants reported changes in practice through an iterative process that included off-line and online discussions. One organisational project demonstrated mixed results, with high levels of knowledge work on a midwifery forum but lower levels in both aged care and cardiology forums (Brooks, Rospopa & Scott 2004; Brooks & Scott 2006a, 2006b; Scott et al. 2004).

Discussion

The focus of this review was to identify whether healthcare professionals have effectively created virtual communities that facilitated knowledge sharing and created learning communities. The current evidence is mixed in terms of quality and type of studies undertaken. Apart from a couple of exceptions, studies published before 2004 were limited by common methodological limitations including sample and measurement bias, especially when content analysis techniques or surveys were used. The quality of more recent studies, including those using focus groups, surveys, interviews and q-sort, has improved and reveals important insights into how healthcare professionals use social media to develop virtual communities and interact with professional colleagues. Importantly these insights indicate that virtual communities may provide significant opportunities to overcome current barriers to knowledge flow and professional networking in healthcare.

This beginning evidence supports the view that healthcare professionals have adopted social media to create viable virtual professional communities, and that healthcare

virtual communities share similar characteristics to other professional communities. A consistent pattern in online communities was that the majority of contributions were attributed to a limited number of individuals (Berman 1996; Brooks & Scott 2006a, 2006b; Cervantez Thompson 2002; Macdonald, MacPherson & Gushulak 2009; Morken, Bull & Moen 2009; Rodriguez-Recio & Sendra-Portero 2007; Thomas & James 1999). The voluntary nature of participation within social networks and virtual communities means that members participate at different levels and may adopt specific online roles (Dahlander & Frederiksen 2012). A virtual community is likely to have a mixture of lurkers, observers, passive and active contributors (Ikioda et al. 2013). Importantly, non-posting virtual community members continue to belong because of potential access to important information (reflective of Burnett's information neighbourhood) (Irvine-Smith 2009), but this requires further investigation.

There is a modest level of evidence that the most common activity in healthcare virtual communities is the exchange of experiential domain-specific knowledge. Importantly, the rise of conference tweeting and journal clubs suggest Twitter may have a role in reducing the evidence practice gap. There is however only limited contemporary data supporting the transfer of empirical knowledge or how this new knowledge is used in practice (Cervantez Thompson & Penprase 2004; Chaudhry et al. 2012; Desai et al. 2012; Hara & Hew 2007; Hew & Hara 2008). In addition while there are generally positive attitudes towards and intention to use social media (Lau 2011; McGowan et al. 2012) a scepticism persists regarding the veracity of information (Archambault et al. 2012; Hughes et al. 2009; Tunnecliff et al. 2015). Understanding the exchange of

knowledge remains limited as all but one study (Mishori, Levy & Donvan 2014) failed to appreciate that SM interactions reflects a conversation with each post likely influenced by an antecedent (Chen & Chiu 2008).

Gaining access to previously unknown information or knowledge is an essential benefit of networking (Nieves & Osorio 2012) and sharing this information is a major driver of social networks and virtual communities (Wasko & Faraj 2005). Effective knowledge transfer and innovation development occurs in social networks where there is a shared understanding of knowledge but also a density of ties providing access to novel information (Nieves & Osorio 2012). The symbiotic relationship between the culture of a VC and its members creates an ethos of knowledge sharing in an online context. Similar to non-health VC (Chiu, Hsu & Wange 2006; Lin, Hung & Chen 2009), online knowledge sharing is facilitated by a culture of altruism, trust, collectivism and reciprocity, as well as a respectful non-competitive environment (Hew & Hara 2007b, 2008; Rolls et al. 2008; Widemark 2008). Knowledge self-efficacy, a belief the answer supplied is correct and worthwhile, influences knowledge sharing by individuals (Bock et al. 2005; Cho, Chen & Chung 2010; Hew & Hara 2007a; Hsu et al. 2007). Moreover group behaviors perceived as negative (e.g. tone of discussion or contentious issues) have an undesirable effect on both willingness to share knowledge and retention of community members (Irvine-Smith 2009; Rolls et al. 2008; Widemark 2008).

The dominance of listservs and discussion forums in this search period is not surprising, given these platforms have been available since the early 1990s (Crier & Campbell 2000). While these social media platforms provide HCP with the ability to interact, they are limited in functionality, particularly with their capacity to create and

/ or store permanent community artefacts (such as guidelines or learning packages) required by a CoP for knowledge and practice development (Wenger 2004). The relatively recent arrival of Web 2.0 platforms, enabling users to create and/or upload content, overcomes these problems (Chu et al. 2010); however there were only two reports (Hoffmann, Desha & Verrall 2011; Valaitis et al. 2011) of VCs using this modality evident in this review. Conference tweeting, tweet chats and journal clubs have emerged in recent years, however the current variability in methods used limits our understanding how this might contribute to distribution of scientific knowledge.

At this time, the evidence suggests that clinicians prefer to use social media that allows them to communicate within their own profession and within a clinical speciality, as the majority of VC identified were for a clinical speciality within a single HCP discipline. While this may reflect continuing tribal behaviour of clinicians in practice (Creswick & Westbrook 2007; Creswick, Westbrook & Braithwaite 2009; Rangachari et al. 2010), mono-discipline social networks can create strong boundaries that inhibit inter-professional learning and knowledge sharing (Dopson et al. 2002), and promoting practice initiatives to improve patient outcomes (Rangachari et al. 2010). Sharing knowledge and adoption of innovation is enhanced where there is homophily (shared within a multi-disciplinary clinical specialty domain such as emergency or intensive care) and credibility (Dopson et al. 2002). Since patients are commonly cared for by a multi-disciplinary team and these clinicians generally share a common specialty knowledge domain, multidisciplinary networks are more likely to be effective in knowledge transfer and creation (Newell et al. 2003; Nieves & Osorio 2012). In this review this potential was demonstrated in two multi-disciplinary VCs (Rolls et al. 2014;

Stewart & Abidi 2012). A social medium that creates an open VC through user-generated follow patterns (such as Twitter) have this potential, but this is yet to be demonstrated in health care.

Strengths and limitations of the review

The key strengths of this review were the timeline, promoting the inclusion of the broad range of current social media applications, and the specific focus on voluntary professional participation. Previous reviews were unable to provide clear information on our focused question because of inclusion of education and undergraduates (Hamm et al. 2013; von Muhlen & Ohno-Machado 2012) or patients (Moorhead et al. 2013) . Nonetheless exclusion of research within a training framework remains a limitation as does the exclusion of wikis and other collaborative writing technologies and blogs. Another limitation was for the keyword search, where we were dependent on how keywords were applied when papers were published. Of note, the term social media was only added to the MeSH list in Pubmed In 2012. We attempted to address this by undertaking a series of searches (see appendix A) using a range of keywords, however, we may not have captured all relevant publications. Additionally, we only used English language publications, so we may have missed other important studies.

Recommendations for further research

As the current evidence is limited in quality and with the majority of studies examining older technological platforms, there are a number of recommendations for future research. Recent studies (Long et al. 2009; Macdonald, MacPherson & Gushulak 2009; Morken, Bull & Moen 2009) show solicitation and supply of knowledge of craft specific knowledge are the most common posts exchanged on professional healthcare VC.

There are limited data however to describe: 1) the specific types of knowledge exchanged (for example scientific versus experiential, or tacit versus explicit); 2) accuracy of this knowledge; 3) whether the knowledge supplied addressed what the poster requested; and 4) what the receivers of the emails, including the original poster, did with this knowledge. Further content analysis of posts using a more systematic approach may reveal not only the knowledge needs of members but the knowledge embodied within the network.

At present there is limited understanding of why individuals join or participate in an online community; previous studies have generally examined activity from the perspective of online posters. Some data suggests professionals will join a virtual community where they find local resources inadequate (Hara 2007). Importantly, while non- or limited posters constitute a large portion of VC membership, it is not clear why they belong to the community or why they chose to limit posting. As movement of knowledge or innovation into and around an organisation is the role of boundary spanners and knowledge brokers (e.g. educators or researchers), do these individuals see membership as a valuable tool for their substantive position, as preliminary data suggests (Cervantez Thompson & Penprase 2004)? If so, could healthcare organizations improve knowledge flow by facilitating communication between key personnel using online communities? Understanding these phenomena is important if leaders or moderators of virtual communities, researchers or health system change agents are to create optimal online experiences and ensure the viability of the social medium within professional healthcare environments.

Early research suggested online forums may facilitate the development of higher-order cognitive skills, such as tertiary students' critical thinking (Bullen 1998). These important findings may be linked to educational design, implementation and evaluation for effective adult learning by today's HCP. This contrasts with the self-selective and voluntary nature of professional forum membership. Only two studies verified the presence of a CoP within an online healthcare community (Hew & Hara 2008; Widemark 2008). There is however now a worldwide education movement based around the use of social media for the professional development of clinicians. Free online medical education (#FOAMed) (Cadogan & Nickson 2014) is an egalitarian movement promoting open online publication of a wide range of resources for the education of any clinician. Further research is required however to identify the viability of social media platforms for voluntary professional development of healthcare professionals. This may require a mixed methods approach to comprehensively understand the learning interaction (via a social network analysis), process (via content analysis) and outcome (via a survey) (Li et al. 2014).

Conclusion

The current evidence on the use of social media by healthcare professionals suggests VCs are viewed as valuable knowledge portals where craft knowledge is exchanged. This review, apart from the recent emergence of conference tweeting and twitter journal clubs, found only a limited number of publications concerning newer social media platforms. Arguably, the current range of SM platforms and electronic devices facilitating exchange of information make professional networking possible wherever the Internet is available. Given that a number of the current challenges of TRIP are

related to a lack of inter- and intra-professional communication channels, there is significant potential within multi-disciplinary virtual communities to facilitate the transfer of experiential and research knowledge by breaking down professional and organisational boundaries. Further research is required to evaluate whether virtual communities may improve patient outcomes by facilitating professional development, evidence-based practice and elimination of clinical practice silos.

Summary

This chapter presented a previously published integrative literature review that evaluated whether HCPs have been able to effectively leverage social media platforms to develop virtual professional communities that facilitate knowledge sharing and created learning communities. The main finding was that while HCPs are using social media to establish VCs, significant gaps remain, including a clear understanding of the structure of these VCs, the types of knowledge exchanged, the context in which these exchanges occur, and why clinicians are members of these communities. Of note, these gaps in the literature have persisted over the course of the candidature. The next chapter presents an overview of the research program.

Chapter 4 -Overview of Methods

"The practical value of true ideas is thus primarily derived from the practical importance of their objects to us" William James 1906-7 (James 2013, p 1422)

Introduction

In the Frames of Reference Chapter the importance of individual and organisational social networks was described in relation to access to best practice knowledge and professional development; and in particular the centrality of conversations that cross organisation and professional boundaries. It was posited that healthcare professional (HCP) virtual communities (VC) might address these needs by leveraging social media to establish VCs that facilitate communication across a broader professional network. The Literature Review, presented in the previous chapter, found that while HCPs were using social media to establish VCs there was insufficient evidence to understand the contribution of HCP VCs to knowledge distribution and professional development. A consistent theme however was that these VCs are complex social phenomena, with symbiotic and multi-directional relationships between members, the community and online culture, available knowledge, and the social media platform being used.

To understand the phenomena of HCP VCs and their resulting contributions to individual HCPs and healthcare organisations a research program using a qualitative multi-method concurrent design, underpinned by pragmatism, was conducted. Within a pragmatic multi-methods study program the question drives the research design (Hunter & Brewer 2015); this chapter is therefore presented four sections: 1) overview of research program; 2) ethical considerations; 3) strengths and limitations; and 4) rigour of research.

Research program

The complex symbiotic nature of the relationship between HCP and the VC requires an examination beyond a unidirectional or positivistic approach (Hunter & Brewer 2015).

A pragmatic multi-method design was employed to uncover the nature and value of HCP VCs using an exemplar VC, ICUConnect (a listserv for intensive care clinicians). In this section the following are presented: 1) research aim and question; 2) study setting; 3) methodology and 4) methods.

Research Aim and Question

As noted earlier, the literature review found there was insufficient evidence to understand the contribution of HCP VCs to knowledge distribution, translation of research into practice and professional development when members have a broader professional network. This was in part due to previous studies focussing on specific aspects of HCP VC interaction and/or experiences of a limited number of members. Also identified was the complex symbiotic relationships that exist in HCP VCs suggesting a need to understand how the inherent characteristics of a VC work together to create the nature of this social context. The nature of a thing refers to 'its innate or essential qualities' (p936) and its value is 'the worth, desirability or utility' (The Australian Concise Oxford Dictionary 2004, p. 1585).

The aim of the thesis research program was therefore to evaluate whether HCP VCs facilitate knowledge and clinical expertise exchange within a broader professional social network. The related research question was, 'What is the nature and value of HCP VCs using an exemplar VC?' Three study sub-aims were to:

1. Describe what type of network the listserv had developed into since inception

2. Explore the nature of knowledge exchanged and knowledge work undertaken online between 2004 and 2013 and
3. Explore why HCPs belong to an intensive care practice based VC.

Given the increasing use of social media across populations and within professional groups, developing an understanding of the essential nature of HCP VCs will enable HCPs, clinical specialities, healthcare professions and organisation to recognise how these specific types of VCs may contribute to knowledge distribution, translation of research into practice, and professional development.

Study setting – exemplar VC

The exemplar VC, *ICUConnect*, was introduced previously in the introductory chapter. ICUConnect was established by a jurisdictional health department to connect the state's adult intensive care units for the purposes of reducing professional isolation and to promote knowledge exchange. It operates as a closed private VC, with prospective members approved for membership by the moderator, and non-members cannot post on-list. Members are able to post directly to group list without prior approval by the moderator. The VC is a large open VC because it is multi-organisational, with a high geographic dispersion (Hara, Shachaf & Stoerger 2009) and a stable heterogeneous membership (Hara, Shachaf & Stoerger 2009; Rolls et al. 2014). As each original study in this thesis were undertaken over a five year period (2009-2014), the specific context of how ICUConnect was positioned at the time are described within each study chapter (Chapters 5-7).

Methodology

A 'methodology' is the epistemological framework that guides a research design and subsequent research method, while 'methods' describe the specific research procedures and techniques utilised within the selected research design to address the stated study aim (Giacomini 2010). At the core of multiple and mixed methods research (MMMR) is a view that many research problems are complex and multi-dimensional, reflecting questions that can be optimally answered by combining the best fit in terms of quantitative and qualitative research approaches (Creswell 2013; Johnson & Onwuegbuzie 2004; Morse & Niehaus 2009).

Pragmatism

This program of research used a pragmatic methodology, as the aim was to investigate the consequences of an existing practice-based HCP VC. Pragmatism emerged in the late 19th century where American scholars, including Pierce, James and Dewey, rejected positivism for a worldview where the significance of knowledge is embedded in its application and practical value in the real world (James 2013; Ormerod 2006).

Ontologically the philosophy is positioned between the realist and idealist paradigms (Cresswell 2014; Giacomini 2010). The value of knowledge is therefore inherently dependent on the social context and values of both the research participant and scientist (Biddle & Schafft 2015). This worldview has been applied across a number of social science disciplines including health (DeForge & Shaw 2012; Shaw, Connelly & Zecevic 2010), evidence-based practice (Hannes & Lockwood 2011) and education and operational research (Ormerod 2006).

In relation to this topic, different modes of online participation and the symbiotic nature of the relationship between members and the VC suggest that there is no universal VC experience. At the core of pragmatism is the acceptance of pluralism; therefore ontologically, pragmatism is concerned with the inherent pluralistic and practical nature of reality (Biddle & Schafft 2015; DeForge & Shaw 2012). Moreover this pluralism extends epistemologically to examining these realities using both objective and subjective evidence (Cresswell 2014). This philosophy frequently underpins MMMR where researchers answer questions using a design that pragmatically incorporates a method/s because they best fit the question and context as well as the practical outcomes in the world (Feilzer 2010; Giacomini 2010) (Biddle & Schafft 2015; Feilzer 2010; Giacomini 2010; Johnson & Onwuegbuzie 2004; Onwuegbuzie, Johnson & Collins 2009).

Multiple Methods

Researchers undertake MMMR because they are interested in everyday problems with multidimensional questions (Hunter & Brewer 2015; Morse 2015). Multiple methods research programs differ from mixed methods in that rather than being a single study these programs are '*a series of inter-related studies conducted to address a single program aim*' (Morse & Niehaus 2009, p. 147). Research methods and data collected should be 'mutually informative' (p. 21) so as to build a cohesive story about the phenomenon under investigation (Bryman 2007). It is therefore necessary to gather data on multiple levels when aiming to understand the consequences of a given social context including individual (micro), interactive (meso) and collective (macro) levels (Hunter & Brewer 2015; Irwin 2010; Maxwell, Chmiel & Rogers 2015). A multiple methods concurrent design was therefore chosen to investigate these core

characteristics of a HCP VCs, all of which have been shown to be important to the whole.

Three principles of MMMR assist a researcher in designing a study: theoretical drive, dominance of the paradigm and methodological staging.

The theoretical drive, or conceptual direction, of MMMR refers to whether the overall nature of the research is deductive or inductive (Morse & Niehaus 2009). The research aim and question dictate theoretical drive; that is whether the research is about confirmation or discovery. The resulting direction of the theoretical drive provides the researcher with a beginning framework when designing the study. The aim of this doctoral program was exploratory and therefore the theoretical drive was inductive (Morse & Niehaus 2009).

Given the context of a pragmatic, inductive, multiple methods approach to the overall research program, it was next important to consider the research aim and question of each project and decide upon the research method/s to be used; including whether qualitative, quantitative or a mix of both was appropriate to address the stated aim and questions (Morse & Niehaus 2009). The importance of this was to ensure that the candidate remained faithful to each paradigm for the related study and the theoretical drive of the overall research program, and to avoid contamination of study methods (Morse 2003). Table 7 provides an overview of the paradigm for each section of the study program.

Table 7 Dominance of each project

Theoretical Drive	Component	Methods/s
QUAL	Research program	Qualitative multiple-methods concurrent design
QUAN	Social network study	Qualitative descriptive
QUAL-quan	Knowledge exchange study	Summative content analysis
QUAL	Why we belong study	Focus groups Interviews

Methodological staging ensures that individual methods for each study remain intact; in particular the sampling framework is suitable for the research question and study design developed (Morse 2003). This principle is described in relation to each study in the next section.

Methods

This multiple methods research program comprised three concurrent studies and was similar to a conceptual approach proposed to examine professional development in a virtual community of practice (Li et al. 2014). The three aspects of ICUConnect examined were; macro level -the 'social network' study, meso level – 'knowledge exchange' study and micro level – 'why we belong' study. Table 8 provides an overview of the research program. Two mid-range theories, Diffusion of Innovations (Greenhalgh et al. 2005a; Rogers 2003) and CoP (Wenger 1998) provided the theoretical underpinnings for the thesis and were described in Chapter 2. The influence of social networks on innovation access and adoption, and professional development are central to these theories.

Table 8 Overview of research program

Thesis title: The nature and value of healthcare professional virtual communities: an exploration of the ICUConnect listserv	
Major research purpose	To evaluate whether HCP VCs facilitate knowledge and clinical expertise exchange within a broader professional social network.
Major research question	What is the nature and value of a healthcare professional virtual community?
Design	Pragmatic inductive multiple methods design
Setting	Australasian intensive care professional listserv managed by a jurisdictional health service
Theory	Diffusion of innovations (Rogers 2003) Community of practice' (Wenger & Snyder 2000)
Study 1 Analysis of the social network development of a virtual community for Australian intensive care professionals (short name: Social network study)	
Aim	Describe what type of network the listserv had become since inception
Question	How had the membership of the listserv evolved over the first six years?
Method	A retrospective qualitative descriptive study (Sandelowski 2000, 2010)
Sample	All healthcare professionals who had joined the VC between December 2003- 2009
Data Analysis	Descriptive quantitative
Study 2: An exploration of knowledge exchange on an intensive care virtual community (short name: Knowledge exchange study)	
Aim	The nature of knowledge exchanged and knowledge work undertaken online between 2004 and 2013;
Question	Describe the nature of knowledge exchanged Identify functionality of listserv as an environment for knowledge work
Method	A retrospective qualitative descriptive study (Sandelowski 2000, 2010)
Sample	Cluster and stratified sampling to obtain 40 discussion threads with a focus on airway or ventilation (2004-2013)
Data Analysis	Summative content analysis (Krippendorff 2004; Zhang & Wildemuth 2009)
Study 3: Why we belong: exploring membership of an intensive care virtual community via online focus groups (short name: Why we belong study)	
Aim	Explore why HCPs belong to an intensive care practice based VC.
Method	A qualitative study using three asynchronous three online focus groups and key informant interviews
Sample	23 participants were allocated to a focus group based on their online behaviour (frequent posters - more than five posts; low posters – between one and five; and non-posters). Four structured interviews were added due to limited participants in frequent posters group.
Data Analysis	Thematic analysis (Braun & Clarke 2006):

The purpose of the thesis was not seeking to prove or disprove the existence of the theories or different aspects, rather the theories provide a theoretical lens through which the data was viewed after inductive data analysis and when considering all findings. Findings from all studies were integrated using a parallel-results convergent synthesis design (Bt Maznin & Creedy 2012; Hong et al. 2015; Thomson et al. 2014) and are presented in the Discussion chapter.

Study1 - Social network study

The first study was a qualitative descriptive study which examined how the social network [who] of ICUConnect had evolved over its first six years of existence. To ensure adherence to methodological staging the sampling framework for the 'Social network' study included all members who had joined ICUConnect during an explicit study period. Most commonly social network analysis involves an analysis of communication patterns by inputting interaction data into computer program (Alaşan, Sayin & Aydin 2013; Munoz, Alonso & Nembhard 2014). The strength of this evaluation is that it has demonstrated HCP VC engagement patterns and shows that readers significantly outnumber posters on a VC (Stewart & Abidi 2012).

This type of evaluation was not possible because the existing technology supporting ICUConnect (an email-based listserv) did not allow for extraction of data pertaining to which members opened and/or replied to emails. While there were a number of studies describing successful long term VCs (Cervantez Thompson & Penprase 2004; Hara & Hew 2007; Macdonald, MacPherson & Gushulak 2009; Rodriguez-Recio & Sendra-Portero 2007; Smith 2004), most reports did not include a detailed description of the social network or membership profile of the VC. Therefore it was difficult to

ascertain how a HCP VC might contribute to moving knowledge across organisational, geographic or professional boundaries (Vakkayill 2012) or whether the membership profile might provide a diversity of views on topics to support professional development (Barnett et al. 2012; Chang et al. 2014; Hew 2009). The 'social network' study is described fully in the following chapter.

Study 2 - Knowledge exchange study

The second study used a retrospective qualitative descriptive design (Sandelowski 2000, 2010) employing summative content analysis techniques (Krippendorff 2004; Zhang & Wildemuth 2009) to explore the content of discussions on ICUConnect. The aim of this 'knowledge exchange' study was to identify both knowledge exchanged and the context of this interaction, including the level of knowledge work present. The literature review revealed that there was a preference for domain specific experiential knowledge exchange in VCs, and the recent emergence of research exchange via conference tweeting and Twitter journal clubs. The validity and generalisability of these findings were limited however as a number of reports lacked a valid coding schema (including theoretical foundations of knowledge categories) or calculations for any inter-rater reliability. In addition, most reports did not view discussion threads as conversations and treated individual contributions as isolated posts.

In this study, each email was considered within its context unit, the discussion thread. The use of a summative content analysis technique permitted examination of both manifest and latent content of exchanges to reveal the types of knowledge exchange, the motivations of members, and the environment in which these exchanges took place. A two stage sampling method was used to ensure adherence to methodological

staging; cluster sampling was used to gather discussions on a key component of the intensive care knowledge domain and stratified sampling was used to gather data over a ten year timeline between 2004-2013.. The 'Knowledge exchange' study is reported in full in Chapter 6.

Study 3 - Why we belong' study

The final study, 'why we belong', aimed to understand why ICUConnect members joined and stayed with the listserv, and used online focus groups and interviews to gather data. The literature review demonstrated that most VC members did not post; consequently little was known about the views of a broad range of HCP VC members as most studies gathered only online activity data.

The 'why we belong' study considered HCP VC membership from the micro or individual member level, using a stratified sampling method to ensure participants reflected a broad range of ICUConnect members. This was achieved by convening separate focus group based on the posting behaviours of participants; high posters had posted more than five times in the preceding two years, low posters between one and five, and non-posters had not posted. To further comply with methodological staging, key informant interviews were added when recruitment for the high-posting focus group was inadequate. The 'Why we belong' study is reported in full in Chapter 7.

Integration and synthesis of findings

Findings from all studies were then integrated and synthesised within the Discussion chapter, using a parallel-results convergent synthesis design (Bt Maznin & Creedy 2012; Hong et al. 2015; Thomson et al. 2014). Integration of findings is essential if a study is to be correctly classified as MMMR, although this step has been typically

challenging for researchers and difficult for the reader to understand as many reports limit discussion of this integral component of study design (Bryman 2006; Maxwell, Chmiel & Rogers 2015).

This research program therefore comprised three studies that examined inter-related components of a HCP VC, ICUConnect; the social structure (social network study), interaction (knowledge exchange study) and individual level (why we belong study). The function of integration was explanatory with findings from the different studies being compared and contrasted to elaborate or clarify (complementarity) findings and to increase the breadth and range (expansion) (Bryman 2006) of understanding. A matrix of findings was created: that is essential components of a virtual community of practice (VCoP) (see figure 4) and diffusion of innovations (DoI) (see table 2 and figure 2) were listed in the rows. with each study findings as they related to each study and components of VCoP and DoI. This table facilitated triangulation of findings across the three studies (see table 9).

Table 9 Triangulation and integration of findings

Virtual community of practice					
- Attributes	Findings Study 1	Findings Study 2	Findings Study 2	Meaning	Synthesis
1-7 (see figure 4) New					
Diffusion of innovation					
Innovation – knowledge					
Innovation – ICUConnect as social media					
Communication channels Interpersonal Mass media					
Time Type of adopter					
Social system Structure Norms Characteristics					
Organisation Interconnectedness Social capital External orientation Absorptive capacity					

In the following section the ethical considerations are discussed..

Ethical considerations

As social media research continues to evolve, direct application of traditional research ethics is challenging (Eynon, Fry & Schroeder 2008; Jang & Callingham 2013; Sixsmith & Murray 2001). For example participant autonomy is at risk because of ambiguity in how social media participants and researchers view online participation and ownership of online posts (Eynon, Schroeder & Fry 2009). The Social network study and Knowledge exchange studies were granted low- negligible risk ethics clearance by the UTS HREC committee (see appendices H and I) while a full ethics clearance was granted for the Why we belong study (see appendices J and K) .

In this section the principles of ethical research and how they were addressed in the thesis are discussed. The National Health and Medical Research Council (NHMRC) National statement on Ethical Conduct of Human research (Council 2007/2015) guided development of the ethical practices for this thesis program, and are discussed below in relation to merit and integrity, beneficence and maleficence, justice, participant autonomy and management of data integrity. The main risk for participants in the research program was in relation to autonomy. Specific ethical considerations for each study are detailed within the relevant chapter.

Research merit and Integrity

According to national guidelines all research must have merit; that it: 1) is appropriately designed to achieve the stated aim/s; 2) is based on a sound literature review; 3) ensures respect for participants is central to the design; and 4) is undertaken or supervised by a suitably qualified team of researchers (Council 2007/2015). This research program was informed by a comprehensive and concurrent review of the literature review. The review identified that HCP VCs may have a role in improving knowledge access for and professional development of HCPs, however there were methodological issues limiting a clear understanding of the benefits to members, their professions and healthcare organisations. The research context was that a healthcare organisation had introduced a VC for intensive care clinicians to address perceived professional isolation. Therefore by identifying the nature and value of HCP VCs the potential benefits would be understood.

This doctoral research was conducted under the supervision of a highly qualified supervisory team and in accordance with UTS HREC requirements. This included

submitting ethics applications specific to each study and submitting annual research reports. The 'social network' and 'knowledge exchange' studies were approved as no risk/negligible risks studies as de-identified retrospective data were accessed (Kozinets 2010). The 'Why we belong' study involved recruitment of participants with subsequent interaction; therefore a full ethics application was submitted and granted. In addition a revision of the protocol was submitted and approved for the key informant interviews. The candidate completed online modules pertaining to Research Integrity. Finally, some research findings have been disseminated through three conference presentations and three peer-reviewed publications, as outlined in Chapter 1.

Beneficence and Maleficence

Balancing the benefits with any potential harm arising from research was clear in this research program; as participants were HCPs, members were not from a vulnerable group, nor were they being asked to divulge potentially psychologically harmful or stressful experiences. The greatest potential risk across all studies was loss of member autonomy, which is discussed below.

There were however several risks to be balanced in the 'Why we belong' study where online focus groups and key informant interviews were used to collect data. There was a minor risk of unprofessional online behaviour in the focus groups (e.g. flaming or trolling) however this was considered minor as the 'knowledge exchange' study had shown only positive professional behaviours. Nonetheless, a 'netiquette' was developed for this study and participants agreed to this when enrolling in the focus groups and providing consent (See appendix N.). There was some participant burden

associated with being a focus group participant and a key informant. The burden of participation in a focus group, which were scheduled to run over three weeks was reduced by: 1) convening asynchronous groups so participants could provide their input at their convenience; 2) using an internet platform that was accessible across multiple device types; 3) sign posting when new information was required through direct emails; and 4) reducing the number of questions after the first focus group because of the way the index group had answered questions. The burden for the key informants was reduced by allowing them to control the date and time, and modality of recording their interviews.

Justice

The principle of justice ensures all potential and actual research participants are treated equally in terms of recruitment, participation, burden and access to benefits and outcomes of the research (Council 2007/2015). All members of ICUConnect had an equal opportunity to participate in the research for two reasons: 1) Individual members made their own decision to post or not within a discussion thread; and 2) An invitation email was posted to ICUConnect asking for participants the focus groups and all registrants were included.

There are a variety of views regarding whether social media posts are freely available data because they are published in a (semi) public space (Eynon, Fry & Schroeder 2008; Sixsmith & Murray 2001). In 2009, emails were not considered to be the intellectual property of an individual poster, however this changed with 2014 copyright legislation indicating that social media posts remain the copyright of the original poster (Australian Copyright Council 2014b). The use of copyright materials for research is

considered a legitimate exception covered by the concept of 'fair dealing'. To comply, the research must be a '*diligent and systematic enquiry into a subject in order to discover facts or principles*' (Australian Copyright Council 2014a, p. 1). Fair dealing of material was adhered to when using exemplars for the 'knowledge exchange' and 'why we belong' studies.

Participant autonomy

There are four dimensions to participant autonomy: 1) confidentiality; 2) anonymity; 3) disclosure; and 4) informed consent) (Eynon, Fry & Schroeder 2008; Sixsmith & Murray 2001).

Privacy

Ensuring confidentiality of participant involvement and their contributions, and de-identification of individuals (maintaining anonymity) when reporting findings reflect participant privacy (Eynon, Fry & Schroeder 2008). Perceptions of privacy however differ between individuals and age groups, and across cultures (Jang & Callingham 2013). In terms of potential privacy breaches, there were three occasions that needed to be addressed within the research program. To create the research database for the 'social network' study, member names were deleted from the ICUConnect database. To prevent re-linking the data, de-identified data was kept within a password protected folder on a separate server to the full membership workbook; with access limited to the candidate. During the 'social network' study a taxonomy describing the professional role of members and type of ICU was developed, and then used across subsequent studies as part of the descriptors for individual members, and to provide

contextual and source information for exemplars. This taxonomy also enabled maintenance of privacy and confidentiality for members.

In the 'knowledge exchange' study it was possible another member might be able to identify the origin of a discussion thread exemplar, however these individuals were already privy to the information on the listserv. This was different in the case of the 'why we belong' study, because the privacy of high posting participants was at risk due to their high visibility on ICUConnect and it was possible that their demographic information might identify them. Therefore no location information (for example level of ICU or geographic location) was included.

Disclosure

As described in the Introduction, the candidate was the long-term moderator of ICUConnect. Members were formally informed of the research program through two online posts. In 2009 they were made aware of the research program (see appendix M) with one response received. Although these suggestions were not about the research program they were incorporated into how exemplars have been reported, that is removal of facility name from exemplar. In 2014 members were further informed through the recruitment email for the 'Why we belong' study.

Informed Consent

Informed consent ensures that potential research participants are fully aware of the research purpose and processes, including what is required of them, so that they are able to make a knowledgeable decision regarding participation and consent (Council 2007/2015). In practice this means providing research information which is clear, concise and easily understood (Mann & Stewart 2000). For the 'why we belong' study

participants were recruited via an ICUConnect email that included a brief description of the study and a link to an online registration page with a copy of the HREC approved participant information sheet attached. Google Forms (Google, Mountainview, California, USA) were used for the online registration and consisted of several sections including: 1) the participant information sheet; 2) a consent form with a widget to indicate consent; 3) a demographic form; and 4) a survey of netiquette to be completed (see appendix N). Potential key informants were sent a similar email with an amended online form. All documents and online forms were approved by the relevant HREC. Voluntary participation was made clear during all focus groups and reiterated at the beginning of all interactions with participants.

Integrity of data management

The research program consisted of three datasets, two of which were retrospective and the third via online focus groups / interviews. The specific data collection procedures are discussed within each relevant study chapter. Several practices were common across two or more studies, and are described here. Protection of data integrity is an important aspect of research practice and ethics, as mishandling could potentially undermine the privacy of research participants and loss of data may add to participant burden (Council 2007/2015). To prevent non-researchers accessing data, all study files were kept on the candidate's computer protected by a password and high-level online data security (Trend Micro, Tokyo Japan). Backups of study data for the discussion threads (knowledge exchange and why we belong studies) were kept in the UTS approved Cloud server (Oxygen cloud). Lastly regular backups of thesis were completed.

Candidate's relationship with ICUConnect

The candidate had a complex relationship with ICUConnect, acting simultaneously as an expert intensive care clinician, the moderator of ICUConnect and researcher. The candidate was a senior intensive care nurse in a major intensive care unit, was enrolled in the index membership cohort in 2003 and became an active poster in 2004.

Moderator responsibilities included membership management; enrolling or removing HCPs from the list, and monitoring discussions and responding to breaches of netiquette. Additionally, the principal supervisor is also a long term member but rarely posts, while other members of the supervisory panel were not members. In 2006 the candidate became interested in completing research training and decided that she wanted to understand why ICUConnect was popular with NSW clinicians and how the discussions and knowledge gained contributed to knowledge distribution and professional development.

Minimising the effects of the moderator and participant role on data collection and analysis has been thoughtfully considered and was addressed throughout the candidature. This has been accomplished by using pre-existing data for the 'social network' and 'knowledge exchange' studies, and sharing the moderator role since 2014. Additionally, while the 'why we belong' study was developed and implemented the candidate was not the moderator and on leave from her substantive position (April 2014-January 2015).

Strengths and limitations of the method

A number of strengths were identified during development of the research program.

One key strength is that the program adopts a holistic view of HCP VCs by using

multiple methods to examine how key aspects of the ICUConnect listserv come together to address the overall study aim. This research was embedded within the context of an important contemporary clinical problem, namely clinical practice variation and translation of research into practice. Although an exploratory program of research, the use of two mid-range theories ensures that findings are underpinned by a strong theoretical foundation. Another strength is the use of naturalistic data that was provided by members whether by their participation in ICUConnect discussions or as participants in a focus group or as key informant interviews. Pragmatic research programs allow the researcher to remain embedded within the research context and use methods that are practical to explore both quantitative and qualitative aspects of reality (Cresswell 2014).

There were three main limitations. Firstly, the use of purposive rather than random sampling to obtain discussion threads for 'Knowledge exchange' study. Gathering a representative sample of discussion may have increased the validity and generalisability of findings from the 'knowledge exchange' study, however it was not possible because the archival arrangements for ICUConnect discussions did not permit random sampling. The effects of this are discussed further in Chapter 6. This sampling limitation was addressed by focussing on a specific intensive care knowledge area and obtaining a sample from a long period of time (ten years between 2004-2013). Second, to answer the 'why' question a qualitative study ('why we belong') with purposive sampling was again used. A survey to a random or census sample of members may have answered this question from a whole of ICUConnect perspective. A survey was not however undertaken because no survey instrument was available, and as discussed in the literature review, surveys have generally been unsuccessful in

achieving an adequate return rate that was also reflective of members, especially the low posting majority. Finally, data was obtained from a single speciality specific HCP VC, thus potentially limiting transferability to other settings. However the literature review also demonstrated a number of exemplar VCs that enabled comparison and contrasting with ICUConnect.

Rigour of the research program

Rigour in qualitative research is a contentious space (Borbasi & Jackson 2012; Porter 2007; Shenton 2004). The preferred terms of 'trustworthiness' or 'confirmability' reflect the accuracy and comprehensiveness in how data were collected, analysed and reported. For this research program a number of strategies were used. Auditability was established by providing a thorough description of the research process, enabling the reader to develop a clear understanding of how findings were arrived at (Cresswell 2014; Noble & Smith 2015). Clear audit trails were developed using Excel (2007/2010, Microsoft, Redmond, US) work books to plan and record research actions for all studies. Additionally NVIVO (QRS International, Melbourne Australia) software was used to create a master study file for the 'knowledge exchange' and 'why we belong' studies. This repository included the research diary, field notes and data. Field notes record what the researcher experiences during data collection and includes: 1) both a description of and reflection on what occurred; 2) a reflective journal that includes personal thoughts and feelings; and 3) any insights, judgments, and interpretations made in the field (Borbasi & Jackson 2012; Noble & Smith 2015). These field notes enabled refinements during data collection (for example aided in development of elaboration and clarification questions in the 'why we belong' study) and analysis (for

example through the development of preliminary themes). Included in field notes were preliminary reports of study outcomes which were discussed at research team meetings.

Credibility refers to whether the data and findings are an accurate interpretation of participant meanings (Cresswell 2014). Data accuracy was addressed by allowing research participants to have direct control of their online posts within discussion threads and their focus group contributions. To minimise bias and enhance credibility all members of the research team were responsible for data analysis across all studies. In the discussion thread study, content analysis was used and an inter-rater reliability evaluation of knowledge categories was conducted. To enhance the credibility of study findings researchers may complete member checking by asking participants for their opinions regarding preliminary themes (Cresswell 2014), although this may not be straightforward and easily accomplished (Carlson 2010). Early member checking was accomplished during focus groups by summarising responses where consistency was emerging and asking participants whether these summaries were accurate. This was not however aimed at demonstrating group consensus, as this is not considered a necessary component of focus group method (Liamputtong 2011).

A rich thick description allows the reader to evaluate the transferability of research findings to similar settings and / or participants (Cresswell 2014; Shenton 2004). This has been addressed by describing: 1) the setting (ICUConnect) and context of the research; 2) participants in terms of their professional roles and where they work; and 3) the recruitment process.

Reflexivity

Within the qualitative research paradigm, it is accepted that the researcher and their values, beliefs and experiences are part of the research process (Cresswell 2014).

Reflexivity refers to how the researcher/s understand and disclose how their personal biases, values and experiences influence the study (Cresswell 2014; Noble & Smith 2015). The potential for bias may be significant if this is not understood or managed (Ahern 1999; Hanson 2011). The dual role of moderator and researcher created a conflict of interest and power imbalance. No changes were made to how the VC was managed over the course of the candidature to ensure that data collected reflected the natural evolution of VC interactions and experiences. For example, making changes to the VC such as the introduction of journal clubs may have artificially increased the level of research knowledge and biased the data collected for the 'knowledge exchange' study.

The candidate's role as moderator may have made VC members feel pressured or obligated to take part (Davies 2005). This was considered a potential problem particularly in the 'why we belong' study. To address the influence of this power imbalance a number of steps were implemented:

- The candidate withdrew from moderator role during development and data collection for the 'why we belong' study
- To minimise coercion a general email to all members was sent out and there was direct communications with individual members until they agreed to participate

- A bracketing process was completed prior to the first focus group, outlining the researcher position by documenting any assumptions and therefore identifying potential sources of bias (Ahern 1999; Hanson 2011), and forming part of the research diary. Additionally these assumptions were revisited during data analyses
- During focus group moderation, the roles of candidate and non-participant observer (chief supervisor) were explicitly described. Additionally during the focus groups the candidate and supervisor communicated regularly to discuss the development of discussions, facilitation effectiveness and to review the need for changes in the question schedule
- The chief supervisor also reviewed interviews to evaluate performance of candidate.

Conclusion

The purpose of this chapter was to provide an overview of the research program; a qualitatively driven multi-method concurrent design underpinned by pragmatism.

With the research question of 'what is the nature and value of a HCP VC?' three studies were completed on a practice based VC, ICUConnect. The three studies were a 'Social network study', which uncovered the demographic characteristics of the VC, the 'Knowledge exchange' study, which examined the interaction between members on the VC and the 'Why we belong' study, which revealed member motivations for joining the VC. These studies are presented in their entirety in the following three chapters, beginning with the 'Social network' study.

Chapter 5 - Analysis of the social network development of a virtual community for Australian intensive care professionals

This chapter presents the Social network study as previously published in a peer-reviewed journal (Rolls et al. 2014). The social network study used a retrospective descriptive design to evaluate how membership of ICUConnect had evolved over the first six years. Please note that when the manuscript was published the term 'IC-VC' was used instead of 'ICUConnect'. The chapter structure follows the format as per the journal article, using the following section headings: abstract, introduction, background (literature review), methods, results, discussion and conclusion. As for Chapter 3, there is some repetition of content in the Background and Literature Review, for Diffusion of Innovations and Community of Practice; this content provided relevant context for readers of the journal article. Tables and Figures have been re-numbered to reflect their location in this Chapter of the thesis.

Abstract

Social media platforms can create virtual communities, enabling healthcare professionals to network with a broad range of colleagues facilitating the exchange of knowledge. In 2003 an Australian state health department established an intensive care mailing list to address the professional isolation felt by senior intensive care nurses. This paper describes the social network created within this virtual community (VC) by examining how the membership profile evolved from 2003 to 2009. A retrospective descriptive design was used. The data source was a de-identified member database. Since 2003, 1340 healthcare professionals subscribed to the VC with 78% of these (n=1042) were still members at the end of 2009. The membership profile has evolved from a single state nurse-specific network to an Australian-wide multi-disciplinary and multi-organisational intensive care network. The uptake and retention of membership by intensive care clinicians indicates this VC is valued by its members. Healthcare organisations should consider VC as a means of breaking down professional and organisational barriers to promote knowledge flow. Further research is required to demonstrate a link between these broader social networks enabling the exchange of knowledge and improved patient outcomes.

Keywords: nurses; intensive care; mailing list; social networks; social media

Introduction

Despite 30 years of evidence based practice (EBP) and the emergence of implementation science, significant evidence- and best-practice gaps and clinical practice variation persist (Hewson-Conroy et al. 2011; Melnyk et al. 2012; Oborn, Barrett & Racko 2010). A contributing factor is restriction of knowledge flow between practitioners because the social networks within current healthcare organization structures and cultures have created clinical silos, limiting networking and knowledge sharing opportunities between healthcare professionals (McGowan 2012). Through the formation of virtual communities (VC) social media platforms can mitigate against this isolation and facilitate the spread of knowledge through professional social networks (McGowan 2012).

Background

The structure and practices of a social network and subsequent effects on knowledge sharing sits across several theoretical concepts including the 'diffusion of innovations', (Rogers 2003), 'community of practice' (CoP) (Wenger & Snyder 2000) and social networks (Borgatti & Halgin 2011). Common to these theories is that for a social network to have access to new and/or contemporary knowledge there must be:

1. Effective communication channels to distribute knowledge;
2. A shared bond and understanding between members so that knowledge is understood;
3. Effective boundary practices to bring in new knowledge; and

4. Network members who take on roles to facilitate knowledge identification and distribution (Borgatti & Halgin 2011; Rogers 2003; Wenger & Snyder 2000).

For healthcare organisations diffusion of innovation (involving research, medical technologies and best practice) is complex and influenced by several key factors (Greenhalgh et al. 2005a). The ability of an organisation to acquire, understand, process and assimilate an innovation into everyday practice is termed 'absorptive capacity' (Aarons, Hurlburt & Horwitz 2011). Where organisational managers and leaders have professional networks outside their workplace, called an external orientation, the organisation has greater access to novel information (Soo, Devinney & Midgley 2007). Formal and informal connections or ties among organisational members and units that create the internal social networks reflect 'interconnectedness' of the ecosystem (Aarons, Hurlburt & Horwitz 2011). Importantly, these ties need to cross both departmental and professional boundaries if healthcare clinicians are to understand and respect the perspectives, knowledge, and skills of fellow clinicians (Braithwaite 2010; Nieves & Osorio 2012). Effective identification and integration of knowledge requires organizations to balance a dense homogenous internal social network with low density diverse external social networks (Borgatti & Halgin 2011; Greenhalgh et al. 2005a; Nieves & Osorio 2012). The density of a social network is dependent on the number of ties and interactions between network members (Borgatti & Halgin 2011). Where there are holes in this network and / or a member has a tie with individuals in other social networks there is an opportunity to access novel information or knowledge (Braithwaite 2010). For nurses the role of ensuring patients receive care based on the best available evidence falls within the purview of nurses in boundary spanning roles such as management and advanced

practice, and knowledge brokering roles, such as educators or nurse researchers (Currey, Considine & Khaw 2011; Gerrish, McDonnell, et al. 2011).

Current healthcare structures and professional cultures, however, limit both internal and external communication channels, creating clinical practice silos (McGowan 2012) making patient care contingent on what might be an imperfect local knowledge pool. These hospital social networks also tend to be mono-disciplinary (Creswick, Westbrook & Braithwaite 2009), which restrict development of a homogenous culture between disciplines (Nieves & Osorio 2012) and may adversely affect quality improvement and implementation programs. This is a particular problem for the working environment and culture of nurses, where limited access to new knowledge is evident because of limited mass media engagement, evidenced by ambivalent journal reading habits (Spenceley et al. 2008) and ineffective professional social networks due to limited interpersonal communication channels (Bostrom et al. 2008).

Conversely the rapid development and increasing use of computer mediated communication technologies, or as they are now referred to social media platforms, within society have broadened the scope of social networks for professional groups (de Vries, Bloemen & Roossink 2000). Conversational technologies, including discussion forums, mailing lists, weblogs and wikis, empower users to network with a broad range of colleagues (Deng & Poole 2008; Grajales 2012). These VCs can overcome barriers of time, geography and organisational structure to facilitate the exchange of experiential and local practice knowledge (De Lusignan, Pritchard & Chan 2002; Hamm et al. 2013) between network members. Gaining access to previously unknown knowledge is an essential benefit of networking (Nieves & Osorio 2012).

Literature review

Healthcare professionals have been using social media since the 1990s, with long standing online communities for: 1) medical librarians [MEDLIB 1991] (Schoch & Shooshan 1997); 2) nurses [NRSING-L -1991 and NurseNET -1993] (Murray 1996); and 3) doctors [critical care medicine mailing list -1994] (De Witt et al. 2004). The current literature describes a number of successful VCs (Cervantez Thompson & Penprase 2004; Hara & Hew 2007; Macdonald, MacPherson & Gushulak 2009; Rodriguez-Recio & Sendra-Portero 2007; Smith 2004) however most reports do not include a detailed description of the social network or membership profile of the VC. Many studies have instead focused on evaluation of discussion threads and emails or used member surveys, which tend to capture a minority of members (Irvine-Smith 2009). Most of these reports describe a VC with members from a single healthcare profession (mono-disciplinary), usually in a clinical specialty area (Brooks & Scott 2006b; Cervantez Thompson & Penprase 2004; Hara & Hew 2007; Hoffmann, Desha & Verrall 2011; Schoch & Shooshan 1997; Smith 2004). Only one study (Morken, Bull & Moen 2009), regarding a Norwegian occupational health mailing list, provided any longitudinal data, describing rapid growth in membership over four years until a steady state was reached and then maintained for six years, with approximately 20% of potential members involved in the VC.

The most common reason for establishing a VC was to facilitate networking and knowledge sharing between healthcare professionals (Cervantez Thompson & Penprase 2004; Hara & Hew 2007; Hew & Hara 2007a; Hoffmann, Desha & Verrall 2011). The most frequent online activity in healthcare VCs is the exchange of

experiential domain specific knowledge (Cervantez Thompson & Penprase 2004; Macdonald, MacPherson & Gushulak 2009; Morken, Bull & Moen 2009; Rolls et al. 2008). Some data suggests that nurses may be motivated by their job role to belong to a VC (Cervantez Thompson & Penprase 2004) and that participation may be further influenced by involvement from their nurse managers (Brooks & Scott 2006b). One survey found members with knowledge brokering aspects in their employment, such as educators or researchers, tended to translate this role to a VC (Cervantez Thompson & Penprase 2004). Another project to facilitate clinician engagement in policy development found participation in a midwifery discussion forum was egalitarian and included affirming contributions from midwife managers. Conversely, participation in both the cardiology and aged care forums was oriented towards senior nurses (Brooks & Scott 2006b).

Understanding the social network created by a VC is important as increasing numbers of organisations, professionals and patients are considering social media platforms to facilitate communication, interaction (Oliver Young 2008) and uptake of best practice (Archambault et al. 2010; David, Poissant & Rochette 2012). Missing, however, from the current evidence base are descriptions of how the membership profile or social network of an online community evolves over time. This includes the types of members and their roles in a healthcare organisation, healthcare professional type or specialty, the distribution of members across an organisation or locations, and the uptake and maintenance of membership by the potential population of members.

Establishing IC-VC (ICUConnect)

An intensive care monitoring unit was established in 2003 to provide the health department in one Australian state with accurate data regarding the provision and outcomes of care delivered to adult intensive care patients. During introductory meetings, senior clinicians described professional isolation and were concerned about the potential impact on patient care. To address this problem the mailing list, IC-VC (ICUConnect), was launched in December of the same year to facilitate communication and knowledge sharing between clinicians of 43 intensive care units (ICU).

Methods

Aims

The study aim was to describe the IC-VC (ICUConnect) social network by examining how the membership evolved over the first six years of existence without direct intervention to increase membership. Specifically, we sought to describe how the demographic characteristics of membership, including healthcare profession, type of nursing role, and level of ICU, had changed over time. We also wanted to identify whether there were any relationships between demographic variables and length of membership or retention of membership. Finally, we wanted to identify the uptake of VC membership by potential members. The study findings would therefore provide valuable preliminary data about the use of the VC by clinicians, and support the idea social media platforms are able to create lasting communication channels between healthcare professionals, between ICUs and across organisational boundaries.

Design

A retrospective descriptive design was used to examine how the membership profile of IC-VC (ICUConnect) had evolved from foundation in 2003 to 2009. The study was approved as a 'Low Risk/Negligible Risk' project by the relevant Human Research Ethics Committee as the dataset was retrospective and included only de-identified demographic information (see appendix L).

Setting

In Australia healthcare the majority of healthcare is provided by the public sector, centrally funded by the Federal government but delivered by state based services, and a small private sector. Most states organize this care using geographically based networks of healthcare facilities of various sizes and complexity. In 2009 there were approximately 158 ICUs in Australia and 29 in New Zealand (Drennan, Hicks & Hart 2010). There are national and state standards covering the structure and staffing of ICUs (Australian College of Critical Care Nurses 2003; College of Intensive Care Medicine 2010a, 2010b). The level of ICU reflects the complexity of care provided:

- CICM 3 are large tertiary referral ICUs with a minimum of six beds and that are capable of providing the highest levels of critical care services for an indefinite period including respiratory, cardiovascular and renal monitoring and support. Additionally a small number of these ICUs are resourced to provide extremely complex therapies such as extra-corporeal membrane oxygenation or organ transplants

- CICM 2 ICUs are metropolitan or major rural or regional ICUs with a minimum of four beds and are capable of providing high quality critical care services for at least a few days
- CICM 1 ICUs provide short term non-complex critical care services as well as immediate resuscitation for critically ill patients
- A HDU provides intermediate care between an intensive care unit and a general ward (College of Intensive Care Medicine 2010a, 2010b).

The majority of public ICUs use a closed model where patient care is overseen by an attending intensive care specialist and bulk of direct patient care provided by registered nurses (called clinical nurse-internal)(College of Intensive Care Medicine 2010a) . This attending will manage a small team of junior physicians who may be training. The availability and clinical input of allied health professionals, including physiotherapists, speech pathologists, dieticians, pharmacists and social workers, varies according the level of ICU.

The nurse-patient ratio depends on a patient's severity of illness and attendant treatment and monitoring requirements. Intensive care patients are critically ill and unstable, and require invasive monitoring and treatment for one or more organ failure. As their condition stabilizes to where these treatments and monitoring are being removed, patients are reclassified as high dependency and may remain in the same bed or moved to a specific high dependency ward. The nurse-patient ratio is one to one for intensive care patients and one to two high dependency. Most patients with a cardiology diagnosis are cared for in separate coronary care units (included within non-ICU units).

In Australian ICUs there is a team of nurses in management, education and advanced practice roles who is responsible for ensuring patients received high quality care. The availability of these roles generally depends on the level of ICU. The nurse who has overall responsibility for management of the unit may be a nursing unit manager or nurse manager (termed clinical unit manager in this study). Education programs are delivered by clinical nurse educators and nurse educators. In CICM 2 and 3 ICUs there is usually a nurse responsible for developing practice. These last two roles have been termed as knowledge brokers (Gerrish, McDonnell, et al. 2011) because they are charged with integration of external knowledge into internal practices. Depending on the function of the ICU within its facility there also may be one or more nurses who provide clinical services to patients outside their designated ICU (termed clinical nurse-external). This may include post-ICU follow up services (nurse liaison), vascular access services and rapid response teams.

Sample/Participants

The entire membership of the VC was included in the study. Members were assigned both a healthcare professional group and a nurse group according to how best their job designation on enrolment fitted the descriptors. Place of work and level of ICU was assigned according to Australian national guidelines (College of Intensive Care Medicine 2010a, 2010b) .

Data collection and analysis

The IC-VC (ICUConnect) member database was established using Excel (2007, Microsoft, Redmond, US). Members were informed that their details would be recorded on this database when they applied to join the VC. Following data cleaning, a

de-identified dataset was exported into SPSS (Version 18, SPSS Inc. 2009, Chicago Illinois, USA) for analysis. Data included each member's unique identifier and demographic information from inception of the VC in December 2003 to 31 December 2009. This end date was chosen because in 2010 staff from the State unit conducted site visits with the specific intent of raising the profile of unit and IC-VC (ICUConnect) with clinical staff. The dates selected therefore enabled exploration of how membership of IC-VC (ICUConnect) evolved prior to specific promotion.

To evaluate changes over time we used each calendar year. Individual member's length of membership was calculated based on subscription data. The variable 'retention of membership' was calculated comparing the total number of individuals who had subscribed with how many were still members at the end of 2009. The participation rate (uptake of VC membership by the potential population of members) could only be evaluated for registered nurses (RN), where population data were available using a national intensive care resources report (Drennan, Hicks & Hart 2010).

Continuous variables were initially examined using descriptive statistics, revealing an abnormal distribution; therefore a non-parametric test (independent k-samples) was used to compare groups. Categorical variables are described using frequencies and proportions with Chi²-test used to identify relationships. A p-value of 0.05 was considered significant.

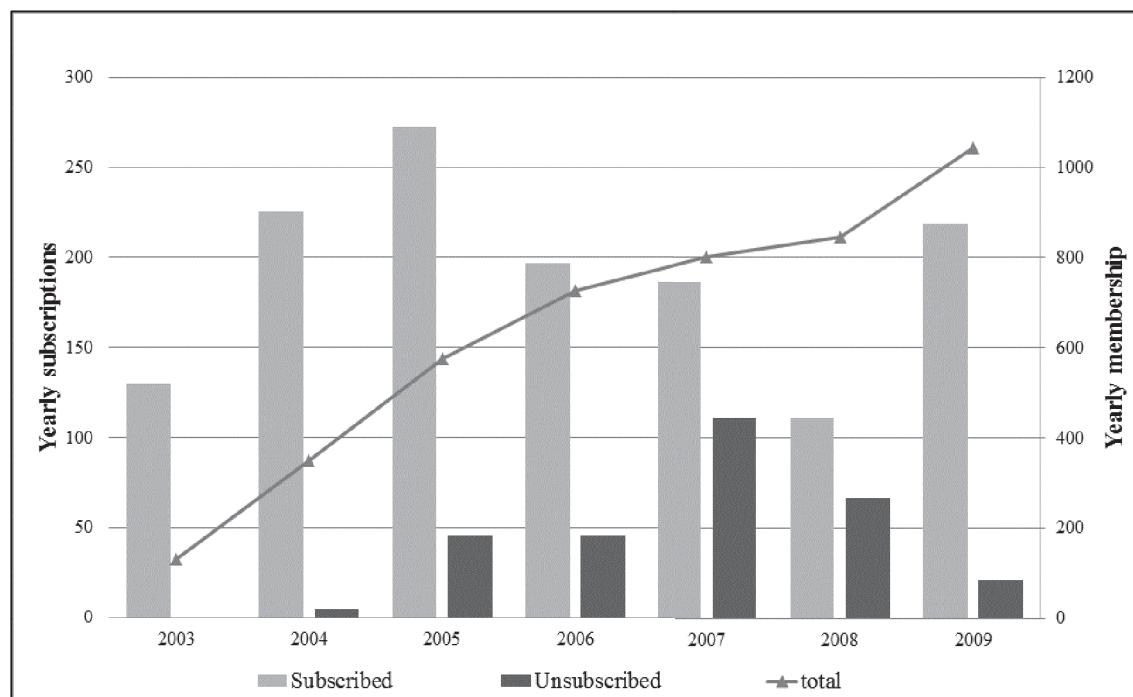
Results

The findings are presented in the following order: (1) The core characteristics of the IC-VC (ICUConnect) members, (2) Healthcare professional and nurses' group profiles, (3)

Length and retention of the VC membership by healthcare professional and nurse group, (4) Distribution of members by level of ICU, (5) Uptake of membership by the potential population of members.

Core characteristics of IC-VC (ICUConnect)

A total of 1,340 healthcare professionals subscribed to IC-VC (ICUConnect) since 2003; 296 of subscribers had unsubscribed by the end of 2009, leaving 1,042 members (retention rate =78%). Of the original 130 members, 83% remained members. The median length of membership was 2.65 years (IQR 1.1-4.47). Annual VC subscriptions were generally stable with a median of 208 (IQR 189-224) new members joining each year (see figure 6). Over the six years members were located in 225 departments from 155 hospitals distributed across 29 healthcare organisations worldwide, 11 international facilities, 16 healthcare companies, and 14 universities. Originally confined to one state, the geographic distribution of members progressively changed over time. At the end of 2009, 83% of the VC members were from the original state, 12% elsewhere in Australia, and 4% in nine other countries, with 2% unknown. No statistical comparison could be undertaken because of the distribution of members across geographical locations overtime.

Figure 6 Changes to IC-VC (ICUConnect) membership

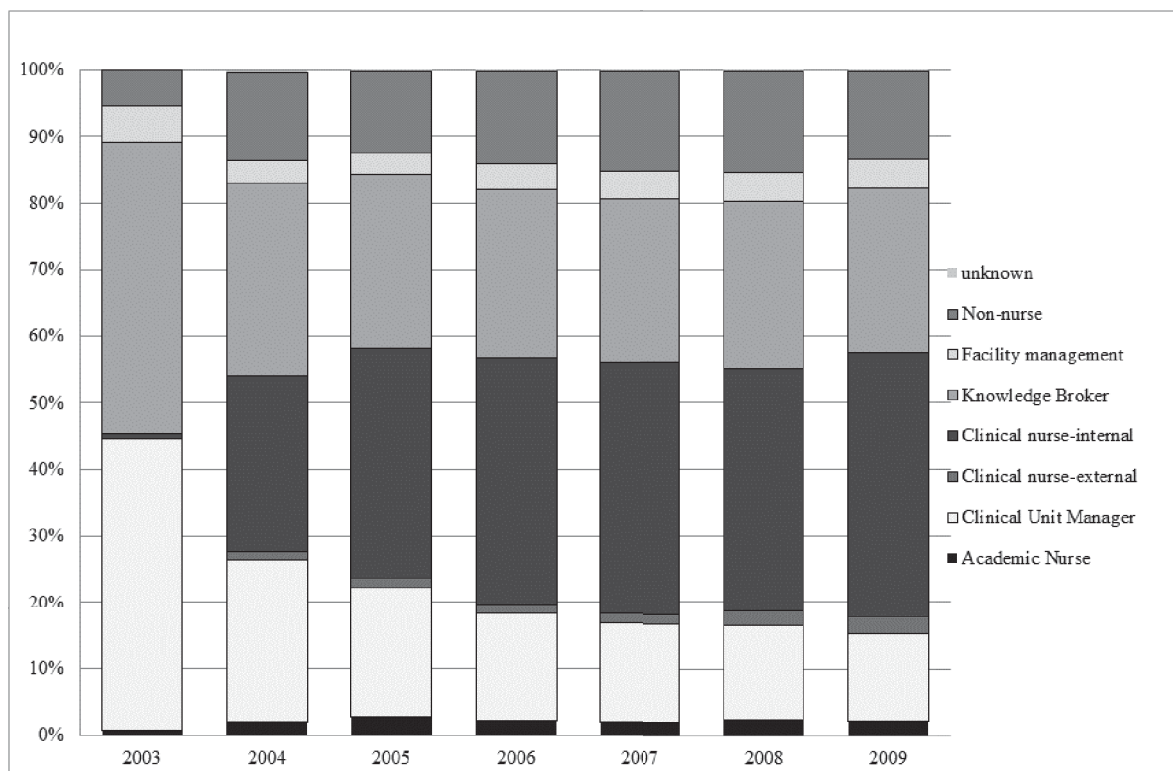
Healthcare professional and nurse group profile

When IC-VC (ICUConnect) was launched, 94% (122/130) of the members were nurses; within twelve months the proportion of nurses declined to 85% with 10% physician and 5% allied health or bureaucrats. Over the following five years these proportions remained relatively unchanged (see table 10). The Nurse Group profile changed significantly over time ($\chi^2=169$; $df=30$; $p=0.000$) (see figure 6) with the most marked changes occurring in proportions of nurses providing direct clinical care (clinical nurse-internal) and clinical managers. When the VC was established VC membership originally was dominated by clinical nurse managers (87.6%) and knowledge broker nurses (92.6%). Within the first year, nurses with a direct clinical care role became the largest proportion of all members and this was maintained to the end of 2009, accounting for 40% of all members (46% of nurse members). Conversely, clinical nurse managers accounted for only 13.1% of all members (15.2% of nurse members) and knowledge broker nurses 28.7% of all members (24.8% of nurse members) by 2009.

Table 10 Length of membership by HCP group

Professional Group	All subscriptions % (n=)	Subscribed end 2009 % (n=)	Retention of membership rate	Length of membership Median (IQR) years
Nurse	83.8% (1123)	84.8% (884)	79-100	2.68 (1.06-4.55)
Medical	6.6% (88)	6.5% (68)	77-100	3.70 (2.38-5.13)
Industry	2.1% (28)	2.3% (24)	86-100	1.33 (0.45-3.34)
Academic	2.3% (31)	2.1% (22)	71-100	2.13 (0.91-4.12)
Health Bureaucrat	2.6% (35)	2.4% (25)	70-100	2.31 (1.14-3.56)
Allied health	2.5% (34)	1.7% (18)	53-100	2.28 (1.131-3.11)
Total	100% (1340)	78% (1042)	78-100	2.65 (1.1-4.47)
			$\chi^2_{27} = 17.841;$ df 7; p=0.015	p= 0.037

Note: 1 member removed as professional status unknown

Figure 7 Nurse group membership 2003-2009

Length of membership and retention of membership by Healthcare professional group

Over the study period there were significant differences in length of VC membership and retention of membership according to healthcare professional type (see table 5.1).

Physicians had the longest length of membership followed by nurses, with industry professionals having the shortest (independent k-samples; $p=0.037$). As a group industry professionals have chosen to retain their membership more than other groups, followed by nurses and physicians. By contrast retention of membership by academics, healthcare bureaucrats and allied health professionals was less than overall VC retention ($\chi^2= 17.841$; $df 7$; $p=0.015$).

Length of membership and retention of membership by nurse group

Over the study period there were significant differences in length of VC membership and retention of membership depending on the type of nurse. (see table 11). Clinical unit managers had the longest length of membership followed by knowledge broker nurses with academic nurses having the shortest. Facility management retained their membership more than any other nurse group followed by nurses in the clinical unit manager, knowledge broker and clinical nurse-external groups. All other groups had retention of membership rates less than the overall study sample.

Table 11 Nurse group profile

Nurse Group	All subscriptions	Subscribed end 2009	Retention of membership rate [RoM]	Length of membership
	% (n=)	% (n=)		Median (IQR)
Clinical nurse-internal	41.4% (555)	39.5% (412)	74-100	2.31 (0.66-3.86)
Clinical nurse-external	2.4% (32)	2.6% (27)	84-100	1.61 (0.58-3.1)
Knowledge Broker	23.2% (311)	25% (261)	84-100	3.34 (1.6-5.02)
Clinical unit manager	12.8% (171)	13.2% (138)	81-100	4.41 (2.26-6.09)
Facility management	4% (53)	4.3% (45)	85-100	2.9 (1.61-4.29)
Academic Nurse	2.1% (31)	2.1% (22)	71-100	2.13 (0.94-4.25)
Non-nurse	13.9% (186)	13.1 (131)	73-100	2.58 (1.41-4.29)
Total	1340	1042	78-100	2.65 (1.1-4.47)
		Unknown 1	($\chi^2=2$ 17.841; df 7; p=0.015	(p= 0.000)

Notes

1 member removed because of unknown status

Clinical nurse-internal: provides clinical services within a clinical unit; Clinical nurse-external: Provides clinical services across multiple clinical unit; Knowledge Broker: Job role could include advanced practice, education, research or practice development; clinical unit manager – manages a defined ward or clinical area; Facility management - Manages at a facility level academic nurses - employed by a tertiary education institution.

Distribution of members by level of ICU

Over time the type or level of ICU also influenced the demographic profile of IC-VC (ICUConnect) members, with differences in length and retention of membership, as well as distribution across the aforementioned ICU descriptions. Length of membership was significantly different depending on the type or level of ICU (independent K-samples $p < .000$). Members from CICM 3 had the longest membership (6.62 years ; IQR 1.64-5.02), followed by HDU (3.50 years ; IQR 1.07-4.81), CICM 2 (2.84 years; 1.02-4.35), CICM 1 (2.35 years; IQR 1.02-4.35), Non-ICU (2.20 years; IQR 0.74-3.34) and Private ICU (2.15 years; IQR 0.54-3.24). Retention of membership was also higher in the larger, more complex units; for CICM 2 (82%) and CICM 3(80%), compared to individuals from HDU (71%), CICM 1(72%) or those who were not working in an ICU / HDU (73%) ($\chi^2 = 14.854$; df 6; $p = 0.021$).

The distribution of members according to type of ICU also changed significantly over time (Yates $\chi = 83.963$; df 36; $p = 0.0000$). The most marked changes occurred for CICM 3 where the proportion of members fell from 52% to 39%, and non-ICU/HDU workplaces, where the proportion increased from 6% to 20%. Minor proportional changes were also noted in the private ICUs (increased from 2% to 6%) and HDUs (fallen from 4% to 1%); while the proportion of VC members in small (CICM 1) and metropolitan or major rural/regional (CICM 2) units remained largely unchanged.

Uptake of IC-VC (ICUConnect) membership

In 2009, 8,975 RNs were rostered to Australian ICUs and 8.28% ($n = 743$) were VC members. The NSW had the highest participation rate (21.88%; $n = 653/2,985$) followed by Australian Capital Territory (17.6% $n = 25/142$) and Tasmania (3.6%; $n = 8/225$), with

participation across other jurisdictions less than 2%. Across the home state there were differences between membership rates across the levels of ICUs with CICM 1 ICUs having the highest level (57%; n=62/108) followed by CICM 2 (34%; n=232/689), CICM 3 (18%; n=319/1778) and private (10%; n= 40/410) [HDU data is not available].

Discussion

The main aim of this study was to describe how the social network of IC-VC (ICUConnect) had evolved over the first six years of its existence. The key finding was the VC evolved from a single state nurse-specific network in 2003 to an Australian-wide multi-disciplinary intensive care network in 2009. This network developed significant boundary crossing as evidenced by the range of represented organizations and jurisdictions. Of note, intensive care professionals valued the IC-VC (ICUConnect), as they chose to remain members and recommended it to colleagues, leading to sustained membership growth. Within the modified virtual community typology (Hara, Shachaf & Stoerger 2009) IC-VC (ICUConnect), would be classified as a large online community with an interdisciplinary culture and stable membership, a medium geographic distribution, and an open and voluntary enrolment.

An online community for nurses caring for intensive care patients

By 2009 the professional profile of IC-VC (ICUConnect) was multi-disciplinary, but continued to be dominated by nurses, with significant differences in length and retention of membership across healthcare disciplines. A multi-disciplinary CoP facilitates knowledge absorption by developing a shared meaning across disciplines about how external codified knowledge applies within a local context (Kitson 2009). Maintaining membership in a VC is influenced by the value found and a sense of

community (Hew & Hara 2007a). Knowledge sharing in online communities is mediated by a sense of belonging to a group of like-minded individuals with access to a multiplicity of views and the chance to interact with peers (Cho, Chen & Chung 2010). The multi-disciplinary profile of this VC suggests a sense of shared values and culture among the nursing and medical disciplines, but not yet allied health professionals. The reasons for this are unclear. These findings, given the majority of the VC members are nurses, indicate discussion threads are likely to be oriented towards nursing knowledge needs. As a consequence allied health clinicians may not feel able to contribute and leave because they are not getting anything of value from the VC. Therefore, at this time the IC-VC (ICUConnect) also reflects the existing trend for VCs to be limited to or dominated by a single discipline.

A multi-organisational geographically dispersed communication network

In 2003, membership of the VC was limited to the 43 ICUs of NSW, the state health department, and one university. Six years later, members worked in 225 individual units distributed across hospitals, wider healthcare structures, healthcare industry, and tertiary institutions. Because of this high level of organizational and geographic boundary crossing significant opportunities are created for collaboration, learning and information sharing (Dahlander & Frederiksen 2012; Dube, Bourhis & Jacob 2006; Wenger & Snyder 2000) within the Australasian IC community.

An online community valued by members

IC-VC (ICUConnect) members appeared to value this virtual network, as they chose to remain members and promote the VC to colleagues. Over the life of IC-VC

(ICUConnect), four-fifths of healthcare professionals who joined, remained members, with a stable membership growth, and meaningful uptake of membership by ICU nurses – approximately one-tenth nationally and almost one-quarter in the home state (Drennan, Hicks & Hart 2010). For an online community to be viable, membership numbers need to be both stable and refreshed by new members so the knowledge base is revised by new content (Hara, Shachaf & Stoerger 2009). These findings also suggest Australian ICU nurses in boundary spanning or knowledge broker roles have an orientation towards networking, and the VC may serve a vital function in fulfilling this need. To be effective in their roles of achieving best practice within their ICU, it is important these nurses position themselves where they have access to new knowledge and external networks provide valuable fertile grounds for new ideas (Dahlander & Frederiksen 2012). Unfortunately, there are no available data describing the relative proportions of different types of nurse roles in place within the Australian ICU environment. We do not therefore know whether knowledge broker and management roles are proportionally represented on the VC. It is however likely that these roles are over-represented as they comprise only a small proportion of the nursing staff establishment (Australian College of Critical Care Nurses 2003) .

The value members found in the VC is also demonstrated by the grass-roots growth of membership. Since it was established IC-VC (ICUConnect) has not been systematically promoted except through passive mass media communication channels such as newsletters. It is likely members have spoken about the VC and recommended it to colleagues. This is in keeping with the idea that the adoption of information and communication technologies is highly influenced in both directions by peers (Gagnon et al. 2012). This grass-roots growth is also supported by the strong uptake of

membership in CICM 1 in NSW where individual staff members are more likely to interact with a greater percentage of colleagues than those in larger ICUs (Hara 2007).

Study strengths and limitations

This study used a retrospective descriptive design to examine the membership profile of a VC, and related limitations are noted. The key strength of the study is that all members were included whereas methods used in previous research have limited their samples to a minority of members. Another strength is the evaluation of uptake of membership by potential members which is largely missing from previous research. The first limitation is the use of retrospective data which means that the data may not be accurate, especially for long standing members. Additionally, we did not examine whether the email addresses were still active however literature indicating how long individuals maintain a particular email address is non-existent. This implies that conclusions based on demographic data should be considered cautiously. Despite these issues, member numbers were accurate because non-functional email addresses are routinely removed from the member database. Importantly because we did not triangulate our data with online posting data or a member survey we cannot definitively confirm that members are actively engaged in the VC. While it is common for the minority of members to post in a VC (Irvine-Smith 2009) a social network will not have been created unless members are actually reading posts. Unfortunately the technology used for IC-VC (ICUConnect) does not provide data on reading behaviours. A survey may provide more data on member behaviours as well as the value they find in belonging to IC-VC (ICUConnect).

Relevance to clinical practice

IC-VC (ICUConnect) evolved from a single state nurse-specific network in 2003 to an Australian multi-disciplinary and multi-organisational virtual intensive care network in 2009. IC-VC (ICUConnect) provides nurses in leadership and practice and professional development roles with valuable external communication channels, enhancing access to new information. High levels of professional, organisational and geographic boundary crossing strongly suggest that healthcare organisations could further leverage virtual communities to facilitate knowledge flow between professions and across organizational units. These online communities could aid to break down the walls of clinical practice silos and facilitate the flow of knowledge to create new opportunities for collaboration, learning and information sharing (Dube, Bourhis & Jacob 2006; Wenger & Snyder 2000).

Future research

This study adds to the current social media evidence base, demonstrating the viability of these technologies to create a broad ranging social network across a healthcare discipline. Most previous studies were limited to surveys or online observation of VC posters who may only be a small proportion of members (Irvine-Smith 2009). A number of questions remain unanswered: Why do the majority of healthcare professionals join a VC? What benefits do these members gain from belonging to the VC? If gaining access to novel information is a key benefit of networking then higher quality research examining the content of discussion threads is required, especially if the purpose of the VC is to facilitate the distribution and uptake of best practice

knowledge . What do VC members do with this new knowledge? Do they use this knowledge to change practice leading to improved patient outcomes?

Conclusion

We described how a VC specifically designed for ICU clinicians evolved over the first six years of its existence. To our knowledge, it is the first study to examine in-depth the members of a social network associated with a long-standing VC. The outcomes of this study demonstrated how a mailing list technology enabled and maintained a diverse professional network of VC members to facilitate knowledge flow for healthcare professionals with an intention to directly affect healthcare. Finally the relative longevity of IC-VC (ICUConnect) demonstrates that nurses caring for critically ill patients were willing to use mailing list technology to network and share information with colleagues.

Summary

This first study in the multiple methods research program examined how the membership profile of ICUConnect had evolved. The VC could be described primarily as for nurses in clinical leadership roles, within a broad social network that increased the potential for novel knowledge acquisition because of the high professional and organisational boundary crossing. Further membership growth and retention of new members suggested that intensive care professionals value ICUConnect. In the next chapter the Knowledge exchange study evaluates how ICUConnect makes use of the broader social network.

Chapter 6 - An exploration of knowledge exchange on an intensive care virtual community

'Hi everyone,

This is a topic that "works the room" within our environment (particularly the tearoom when they are due), but can people give me an idea when they change the ventilator circuits and what current evidence you use to justify this procedure. The same can be applied to closed suction systems I suppose, which we also use.'

Retrieval nurse and equipment manager, Tertiary referral ICU

Introduction

While multi-disciplinary virtual communities (VC) may facilitate knowledge and clinical expertise exchange within professional networks and across organisations (Burrell, Elliott & Hansen 2009; Currie & White 2012; Hew 2009; McGowan 2012), their effectiveness has not been established. This chapter describes a retrospective qualitative descriptive study that explored the nature of knowledge exchanged and knowledge work within ICUConnect. Here the 'what' members talk about is explored using a sample of discussion threads focusing on a key component of the domain knowledge of intensive care practice - ventilation and airway practices.

A short review of the current evidence base, highlighting gaps and limitations in the literature is initially presented, prior to describing the study methods. Findings are presented, within the context of the relevant literature. Finally a short discussion that includes study strengths and limitations is provided. Implications for policy and practice and suggestions for further research will be presented in Chapter 8, along with synthesis and discussion of all three studies.

Background

Development of computer mediated conversational technologies, now referred to as social media, have the potential to revolutionise professional networking. Importantly, discussions between HCP on VCs are commonly characterised by exchange of experiential speciality-specific knowledge (Brooks & Scott 2006b; Macdonald, MacPherson & Gushulak 2009; Morken, Bull & Moen 2009; Rodriguez-Recio & Sendra-Portero 2007), rather than evidence based knowledge (Abrahamson, Fox & Anderson 2013; Hara & Hew 2007; Reutzler & Patel 2001).

Similar to non-HCP forums, exchanges commonly occur between a minority of members (Berman 1996; Brooks & Scott 2006a, 2006b; Morken, Bull & Moen 2009; Rodriguez-Recio & Sendra-Portero 2007; Schoch & Shooshan 1997; Stewart & Abidi 2012; Thomas & James 1999). Also reflecting non-health VCs (Booth 2012; Chiu, Hsu & Wange 2006; Lin, Hung & Chen 2009), a symbiotic relationship develops between the culture of a virtual community and its members, where knowledge sharing is facilitated by a collectivist, altruistic, respectful non-competitive online environment (Hew & Hara 2007b, 2008; Rolls et al. 2008; Widemark 2008), while perceived anti-social behaviours have a negative effect on member engagement (Irvine-Smith 2009; Rolls et al. 2008; Widemark 2008).

Previous research has been conducted using online observation, content analysis techniques and interviews, enabling exploration of the process of acquisition of new knowledge and skills, how the social construction of knowledge evolves through a discussion thread, and the online culture of a VC (De Wever et al. 2006; Zhang & Wildemuth 2009). Developing a comprehensive understanding of knowledge exchange

in this context was limited however because of common study limitations, including: 1) data corpus and/or sampling unit (Abrahamson, Fox & Anderson 2013; Berman 1996; Morken, Bull & Moen 2009; Rodriguez-Recio & Sendra-Portero 2007; Whitaker, Cox & Alexander 2003); 2) unit of analysis (Berman 1996; Bowers 1997; Long et al. 2009; Macdonald, MacPherson & Gushulak 2009; Morken, Bull & Moen 2009; Murty et al. 2012; Rodriguez-Recio & Sendra-Portero 2007; Smith 2004; Whitaker, Cox & Alexander 2003); 3) coding schema development and categories with a limited theoretical basis for categories (Abrahamson, Fox & Anderson 2013; Brynolf et al. 2013; Cervantez Thompson 2002; Mishori, Levy & Donovan 2014; Rodriguez-Recio & Sendra-Portero 2007; Smith 2004; Whitaker, Cox & Alexander 2003); and 4) evaluate inter-rater reliability (Abrahamson, Fox & Anderson 2013; Chaudhry et al. 2012; Foong & McGrouther 2010; Macdonald, MacPherson & Gushulak 2009; Matta, Doiron & Leveridge 2014; Rodriguez-Recio & Sendra-Portero 2007; Smith 2004; Whitaker, Cox & Alexander 2003). (see appendix D – content analysis study quality).

Of note, the current evidence base leaves several important questions with limited answers; for example, What knowledge do HCPs seek on VCs? What knowledge is provided and is this knowledge evidence or best practice based? What intensive care issues, such as clinical practices, advice on equipment or safety issues, do clinicians seek help for online? How does the culture of the online community contribute to knowledge exchange?

A study designed to consider these gaps in knowledge, and informed by the theories of Community of Practice (CoP) (Barnett et al. 2012; Wenger 2004) and Diffusion of innovations (Rogers 2003), is reported below.

Aim

The overall study aim was to explore 'what' content was exchanged between members of an exemplar VC - ICUConnect. The related research questions were: 1) what was the nature of knowledge exchanged on an intensive care listserv?; 2) what type/s of knowledge work were evident?; and 3) how was the online culture of ICUConnect embodied within discussion threads to facilitate knowledge exchange?

Methods

Design

A retrospective qualitative descriptive (Sandelowski 2000, 2010) design with summative content analysis techniques (Krippendorff 2004; Zhang & Wildemuth 2009) was conducted to address the study aim and questions. Summative content analysis combines inductive and deductive approaches that allows the researcher to explore both manifest and latent content of textual data (Zhang & Wildemuth 2009). The manifest content of textual data can be easily identified whereas latent content requires coders to interpret what a writer meant by interpreting the text to identify patterns (Krippendorff 2004; Rourke et al. 2000).

Ethics

The study was approved as a 'Low / Negligible Risk' project by the Human Research Ethics Committee at the University of Technology Sydney, given the dataset was retrospective and identifying data were removed from each email (see appendix M). Members were informed of the research through an online post asking for discussion, noting that issues of privacy and confidentiality were consistently maintained. Data

were stored securely within a university specific cloud server with access limited to the research team.

Setting

The study setting was ICUConnect, focusing specifically on discussion threads that occurred between 2004 and 2013.

Sample

The literature review identified that the most common sampling methods used in studies of online activities were census, followed by stratified or convenience methods. The structure of the online ICUConnect archive held by NSW Health was not suitable as a data source because the output were monthly digests and limited the choice of sampling methods. Decisions regarding the sample for summative content analysis are driven by the research question/s and type of text that will provide these answers (Krippendorff 2004; Zhang & Wildemuth 2009). Purposive sampling methods are considered appropriate for qualitative content analysis because the researcher is concerned with uncovering the themes associated with the phenomena rather than quantifying concepts or words (Zhang & Wildemuth 2009).

For this study the phenomena of interest was both the content and context of knowledge exchange on a HCP VC; therefore the sample (data corpus) was obtained using a two-stage (cluster and stratified) sampling approach to identify 40 discussion threads exchanged online between 2004-2013. A key finding from the literature review was that HCP use VCs to exchange domain specific experiential knowledge. Cluster sampling enabled identification of discussions on ventilation and airway management; these topics represent a key component of the intensive care knowledge domain.

Additionally, an earlier evaluation of ICUConnect discussions found that this topic was the largest clinical subject group discussed (26%; 103/401) (Rolls et al. 2008). Forty threads over a ten-year time period were selected to ensure that the data corpus represented online discussions over time. Procedures related to obtaining the sample are explained below.

Procedure

The study was conducted over six stages: 1) sampling and preparation of data corpus; 2) defining the unit of analysis; 3) inductive development of categories and coding schema; 4) testing of coding schema on sample of text with refinement based on findings; 5) coding of all data; 6) assessment of coding consistency and refinement of latent categories or themes; and 7) drawing conclusions (Krippendorff 2004; Zhang & Wildemuth 2009) .

The audit trail consisted of an Excel workbook, for planning and recording research steps and managing manifest data (Microsoft Excel, Microsoft Corporation, 2010, Redmond, WA, USA), and an NVIVO file (QRS International, Melbourne Australia) for inductive content analysis. Across all steps a research diary was maintained within NVIVO using the memo function, to facilitate data interpretation and reflection.

Stage 1 - Sampling and preparation of data corpus

The data corpus was obtained using a two-stage (cluster and stratified) sampling approach to identify 40 discussion threads for analysis. Cluster sampling was initially used to identify threads related to a core component of intensive care practice - ventilation or airway management - with three or more emails between January 2004

and December 2013, using keywords developed within the research team that reflected discussions on ventilation and airway management (see table 12).

Table 12 Keyword search

Ventilation	Airway
- Ventilation	- intubation
- Invasive	- extubation
- CPAP	- endotracheal tube
- BiPAP	- tracheostomy / tube
- Mask	- trache
- Mode	- humidification
- Non-invasive	

For each relevant discussion thread identified, each post was pasted into a MS Word document (Microsoft Corporation, 2010, Redmond, WA, USA), given a unique code and de-identified. Demographic information based on nomenclature from the social network study (e.g. member number, job title, job role, unit type, workplace code, level of ICU, state, country, and generational depth) was entered into a MS Excel workbook. Generational depth refers to the location of a post within a discussion; the first email or post was the 'parent' email, with subsequent emails called 'child' emails and numbered from two onwards. As 61 threads were identified, the second stage stratified sampling was then completed using a random number generator (using Microsoft Excel) to develop two data corpora, with 20 threads each that included: 1) four threads from each year (where possible); 2) a diversity of subjects and topics related to ventilation or airway management; and 3) threads of a variable length.

Stage 2 - defining the unit of analysis

The unit of analysis, '*the basic unit of text to be analysed*' (Zhang & Wildemuth 2009, p. 3), is determined by identification of whether latent or manifest content was being

analysed (Rourke et al. 2000). Individual emails were treated as the unit of analysis, and the complete discussion thread was the contextual unit. This approach negated the need for unitising and prevented unit boundary overlap (Strijbos et al. 2006). In keeping with the pragmatic approach this decision ensured that the units of analysis remained embedded or linked to their real world origins (the VC) and provided context to the discussion thread (Elo & Kyngas 2007; Krippendorff 2004). It was anticipated that actions and contributions of different posters would directly contribute to a thread's evolution (Chen & Chiu 2008; Johnsen, Steinsvik & Gammon 2004), with inclusion of context adding credibility to data interpretation (Noble & Smith 2015).

Stage 3 - inductive development of categories and coding schema

All discussion threads were then imported into NVIVO. Initially four threads from the first data corpora were read to develop an understanding of the texts, analysed inductively for themes and knowledge type and deductively for knowledge work. The knowledge work taxonomy (Brooks & Scott 2006a, 2006b) was previously used in midwifery, cardiology and geriatric nursing forums. Initial readings revealed significant latent content, indicating a complex landscape of data across three major categories related to ICUConnect member motivations in posting: their purpose, concerns, and virtual community work. The remaining 16 threads (of data corpora 1) were coded for the six main elements using the following schedule:

1. Read email
2. Code elements
 - I. What knowledge was requested or supplied?
 - II. What subject (major-minor) and topic/s were described or discussed?
 - III. What knowledge work was done?
 - IV. What was the purpose of the email: if original, what was the poster looking or asking for? If a reply, what was the poster doing / providing?

- V. What were the critical concerns of the poster?
- VI. What VC work was undertaken?

Following preliminary coding, reports were exported from NVIVO into MS Word to evaluate coding consistency and categories were refined until consensus was reached within the research team. A data dictionary (see appendix K) was developed iteratively to reflect categories and process. Categories for knowledge type and knowledge work data were added to the worksheet.

Stage 4 - testing of coding schema on text samples with refinement based on findings

Reliability of the initial coding schema was evaluated for knowledge type and knowledge work. An independent coder (not part of the research team), with extensive intensive care experience and understanding of knowledge management, was provided with four hours of training and coded 25% of data corpus 1 (seven threads; 43 emails).

No specific guidelines regarding the size of a reliability sample were identified from the literature (De Wever et al. 2006), although when reported ranged from 10% (Hara & Hew 2007) to all data (McKendrick, Cumming & Lee 2012). Twenty-five percent was therefore chosen as a manageable size. Data were entered into SPSS (Statistical Package for Social Sciences; PASW Statistics for Windows, Version 18.0, 2009. SPSS Inc., Chicago). The final coding schema was revised based on outcomes from this process.

Stage 5 - coding of data corpora 2

Coding of the second dataset was undertaken to evaluate the reliability of the knowledge type categories, using the same schedule described in Stage 3 above; identification of knowledge type, knowledge work and subject and topic/s were coded directly into the worksheet while coding of critical concerns, purpose and virtual community work continued using NVIVO.

Stage 6 - assessment of coding consistency and refinement of latent categories or themes

Reports were exported from NVIVO into Word and evaluated for coding consistency. In practice this consisted of reviewing all text coded to a particular node (latent content) to evaluate whether the text reflected the essential essence of the content (Bazeley & Jackson 2013) . Following this a constant-comparative approach (Borbasi & Jackson 2012) was used to refine nodes within NVIVO to develop tree nodes or master categories (Bazeley & Jackson 2013). The second round of inter-coder agreement was completed on 22% of data corpus two (five threads; 33 emails. Two classification sheets were developed and imported into NVivo to facilitate data analysis.

An email classification sheet identified the manifest content or attributes of each email including title, poster (member number), thread title, data corpus, year, generational depth, email date, subject-major, subject minor, primary topic and up to four minor topics, knowledge work and knowledge type. The second classification sheet identified the attributes or demographic details of specific posters including their ICUConnect member number, professional role (job title and job role), location details (workplace code, unit type and level of ICU) and geographic details (state and country.

Data analysis

Summative content (Krippendorff 2004; Zhang & Wildemuth 2009) and thematic analysis (Braun & Clarke 2006) approaches were used to evaluate the data. The manifest content (categorical variables) of emails and demographic or attributes from the above worksheets were used to describe frequencies and proportions. Inter-rater reliability of knowledge type can be evaluated using three coefficients to control for chance agreement between coders: Krippendorff's α , Scott's pi and Cohen's kappa [κ] (De Wever et al. 2006; McHugh 2012). Cohen's kappa [κ] was most appropriate as there were two coders and data were nominal (De Wever et al. 2006). Three other assumptions for calculating κ the same two coders are independent and cross tabulation is symmetrical. An agreement of greater than 0.75 indicates excellent agreement, between 0.74 and 0.4 is considered good agreement and anything less than 0.40 is considered poor (De Wever et al. 2006; McHugh 2012)

Tree nodes and themes identified during summative content analysis were further refined through discussions within the research team. In NVivo, matrix queries enabled identification of patterns between nodes and to reveal potential differences across member types. Tables were created to compare responses from different member types or cross node comparison.

Findings

This section initially reports the description and analysis of the manifest content of the data corpus, including types of knowledge exchanged, the subjects and topics discussed and member posting behaviour. Analysis of the latent content is then reported, including the knowledge work and the central construct of 'virtual

community work' composed of six elements: 1) the discussion thread; 2) sharing of artefacts; 3) community; 4) cordiality; 5) maven work; and 6) promotion of the VC. Two important overarching themes, the 'complexity of clinical practice' and 'loss of corporate memory', also emerged and are discussed last. Where appropriate, quotes from discussion threads are used to elaborate the findings, and related references are cited to provide context.

Analysis of manifest content

Description of discussion threads

The sample consisted of 326 emails across the 40 discussion threads (per thread median 6; IQR 5-10), with contributions from 133 members (posts: mode 1, median 1, maximum 55) across 80 organisations - 67 hospitals (posts: 86%; n=280), five health departments (posts: 10%; n=33), six universities (posts: 3%; n=6) and two healthcare companies (posts: 1%; n=2). For each thread the most frequent number of members interacting was five (median 6 [IQR 4.75-7]). The majority of contributions came from a minority of members; 72% (n=235) were from 40 members who posted more than once, while 50% (n=164) were from the ten members who posted more than five times (range 5-55) (see table 13).

Table 13 Data corpus distribution

Posts frequency (grouped)	Number of members	Posts % (n=)
1	92	27.91 (91)
2-4	30	21.78 (71))
5-9	4	7.67 (25)
10-19	4	18.40 (60)
>20	2	24.23 (79)
	133	100 (326)

Intensive care nurses initiated 82.5% of the discussion threads (n=33) and contributed 64.7% of the replies, whereas physicians initiated 12.5% (n=5) of the discussions and contributed 29% of replies. A healthcare manager and an un-identifiable member commenced the two remaining posts. Table 14 illustrates the differences in how the various professional groups and member types contributed to discussion threads.

The finding that a majority of online posts were from a minority of members is consistent with previous research examining online participation, either directly via online observation (Brooks & Scott 2006a, 2006b; Morken, Bull & Moen 2009; Rodriguez-Recio & Sendra-Portero 2007; Stewart & Abidi 2012)] or indirectly via surveys (Cook-Craig & Sabah 2009; Rolls et al. 2008). A novel result was that there was participation by most members of the MDT from many locations, representing significant structural and professional boundary spanning across the Australasian intensive care community.

Table 14 Contributions to discussion threads by member types

Contributions to discussion threads				
Type of member	% (n=)	Total emails - % (n=)	Parent¹ % (n=)	Child¹ - % (n=)
Nurse	75.9 (101)	66.9 (218)	82.5 (33)	64.7 (185)
Knowledge broker ²	34.6 (46)	39.6 (129)	32.5 (13)	40.6 (116)
Nursing unit manager (NUM) ³	14.3 (19)	13.2 (43)	20.0 (8)	12.2 (35)
Bedside nurse	15.8 (21)	7.7 (25)	27.5 (11)	4.9 (14)
Cross unit clinical nurse ⁴	6.0 (8)	3.4 (11)	2.5 (1)	3.5 (10)
Academic nurse	3.8 (5)	2.5 (8)	0	2.8 (8)
Nurse manager	1.5 (2)	0.6 (2)	0	0.7 (2)
Physician	14.3 (19)	27 (88)	12.5 (5)	29 (83)
ICU specialist ⁵	6.0 (8)	19.6 (64)	10.0 (4)	21.0 (60)
ICU director ⁶	8.3	7.4	2.5	8.0
Allied health	4.5 (6)	3.1 (10)		3.5 (10)
Speech pathologist	4.5 (6)	3.1 (10)		3.5 (10)
Healthcare management	(3 (4)	1.8 (6)	2.5 (1)	1.7 (5)
Facility management	2.3 (3)	0.9 (3)	2.5 (1)	0.7 (1)
Healthcare manager	0.8 (3)	0.9 (3)		1.0 (3)
Industry	1.5 (2)	0.9 (3)		1.0 (3)
Unknown member	0.8 (1)	0.3 (1)	2.5 (1)	
	(133)	(326)	(40)	(286)

1. Parent refers to email which starts discussion thread whereas Child refers to subsequent replies in discussion thread

2. Knowledge broker nurses are in research and education roles; 2 members responsible for 34.5% of all posts; 7 posted > 2; 10 members posted twice; 30 members posted once only

3. One NUM responsible for 38.7% of emails from this member type

4. Cross unit clinical nurses provide cross unit clinical services including ICU liaison, outreach or organ donation

5. One specialist posted 55 times; equals 16.8% of all emails; equals 85.9% for this member type ; 2 members posted twice; 5 posted once only

6. One ICU director posted 11 times; equals 45.8% for this member type; 2 posted ≥ 2; 8 posted once only

A high rate of ICU leader participation also demonstrated a strong willingness to communicate with professional colleagues for obtaining new knowledge, sharing their knowledge, and comparing local practices with colleagues. This embodies an external orientation required of organisational leaders if novel knowledge is to be integrated into organisational practices (Greenhalgh et al. 2005a; Soo, Devinney & Midgley 2007). Based on these findings, ICUConnect has established the crucial weak ties and social network interconnectedness critical for exchange of best practice across a healthcare system (Aarons, Hurlburt & Horwitz 2011; Braithwaite 2010; Rogers 2003).

Thread subjects / topics

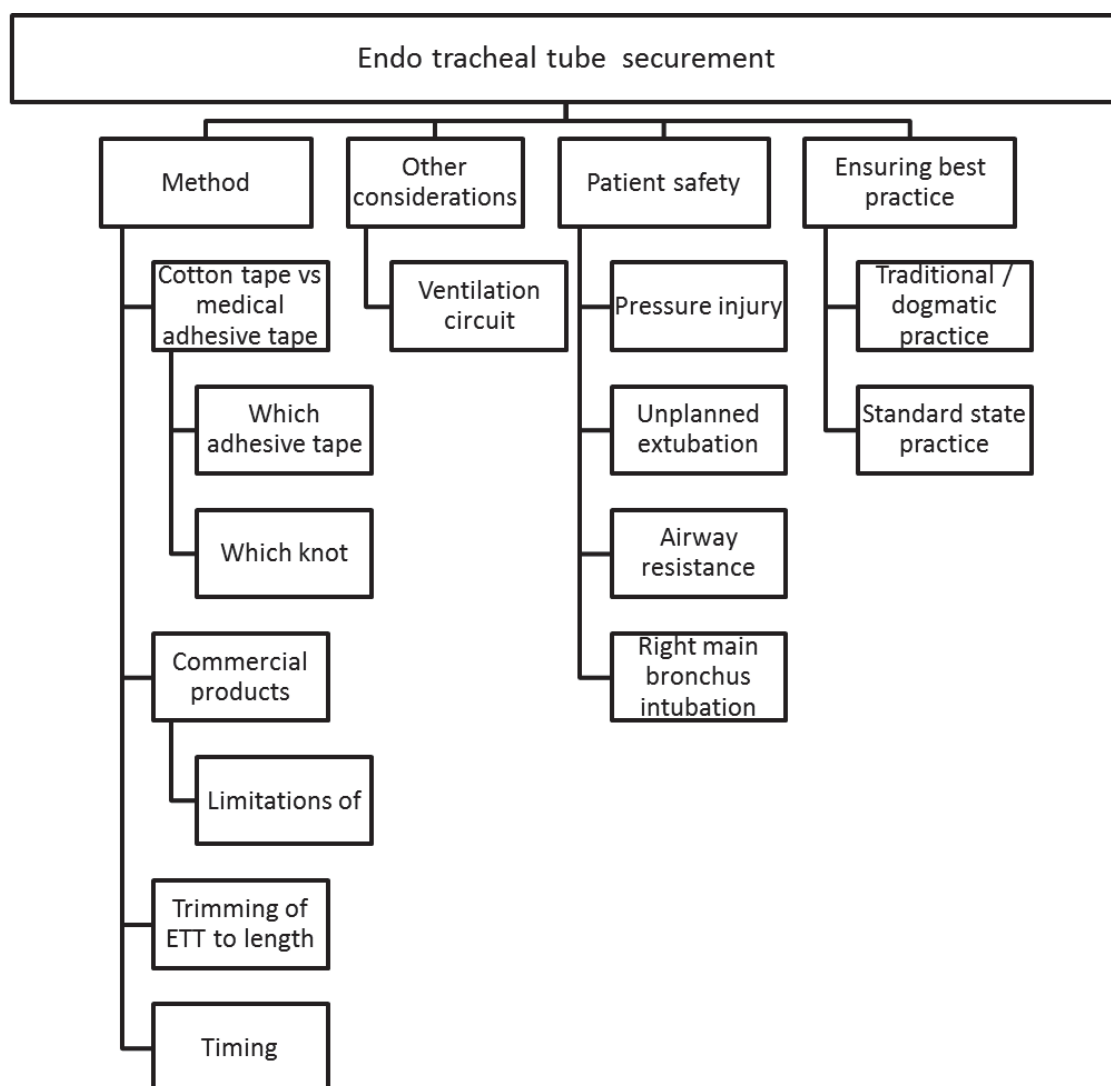
A major and minor subject labels were assigned to each discussion threads followed by primary and secondary topics. Up to four subtopics were also found within discussion threads. Three major subject areas were: 1) clinical practices (70.55%; 230 posts); hospital equipment (23.01; 75 posts); and 3) clinical governance (6.44%; 21 posts). Eleven minor subject areas covering 28 primary topic areas were also identified from the data (see table 15).

Table 15 Major and minor subject areas

Major subject	Threads n=	% (n= posts)
Minor subject		
Clinical practices	25	70.55 (230)
Procedures	14	49 (159)
Ventilation management	5	9 (30)
Infection Prevention	2	6 (21)
Assessment and Monitoring	2	3.37 (11)
Respiratory support	1	2 (5)
Drug protocol	1	1 (4)
Equipment	12	23.01 (75)
Airway - artificial	4	8.0 (26)
Ventilation circuit	5	9.5 (31)
Ventilator	3	5.5 (18)
Clinical governance	3	6.44 (21)
Risk management	2	5.52 (18)
Staffing	1	0.92 (3)
	40	100 (326)

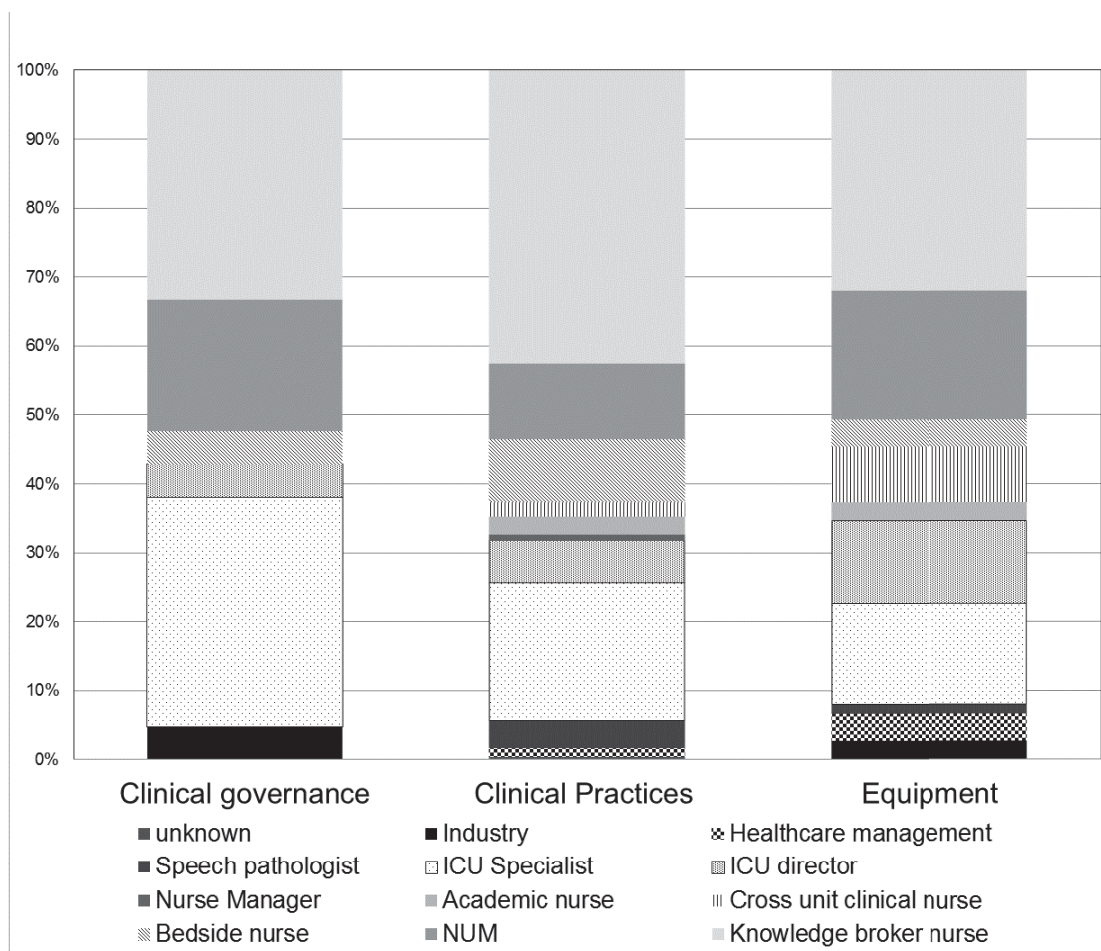
Unsurprisingly, 'clinical procedures' was the largest minor topic area (14 threads) covering almost 50% of all data. Members requested information regarding artificial airways (primary topic) and included queries regarding secondary topics such as tracheostomy care (five threads), securement of an endotracheal tube (four threads), and suctioning (three threads). As an illustrative example, figure 14 lists the inter-related sub-topics covered in endotracheal tube securement.

Figure 8 Topics covered in discussions on endotracheal tube securement



What was also evident was that members asked questions and contributed to threads according to their job role and scope of practice (see figure 8). This was reflected in clinical leaders, including NUM, KB nurses, ICU directors and staff specialist, contributing to threads across all subject areas, while bedside nurses focused on clinical practices.

Figure 9 Subject area contribution by member type



These subjects and topics reflect key components of the practice domain of intensive care (Wenger 2004) and echo previous research indicating that sharing of domain specific knowledge is the most common activity across healthcare VCs (Brooks & Scott 2006b; Macdonald, MacPherson & Gushulak 2009; Morken, Bull & Moen 2009; Rodriguez-Recio & Sendra-Portero 2007). These findings also demonstrated how online discussions facilitate legitimate peripheral participation (LPP) for inexperienced members who may confine their participation to reading only (Dennen 2008). That is, expansion of a discussion thread through introduction of multiple interrelated topics provided members with both knowledge and illuminated the sophistication of practice. These findings suggest that ICUConnect has developed two key components of a successful VCoP. First, there was exchange of intensive care domain knowledge

between members from a range of settings and roles, providing members with diversity of experiences and views (Barnett et al. 2012; Chang et al. 2014; Hew 2009). Second, nursing and medical clinical leaders contributed the majority of input, suggesting a critical mass of experienced and expert members have developed vital community norms that ensure the availability of high quality content (Barnett et al. 2012; Chang et al. 2014; Hew 2009). These online practice norms include altruism (Cho, Chen & Chung 2010; Hew & Hara 2007a; Malinen 2015), reciprocity (Bock et al. 2005; Chiu, Hsu & Wange 2006), social interaction (Chiu, Hsu & Wange 2006), knowledge sharing (Bock et al. 2005) and trust (Hsu et al. 2007; Usoro et al. 2007).

Knowledge exchanged

Knowledge type coding identified 21 different types in the data: explicit (n=9); experiential (n=9); know-how; know-why; and clinical advice. Significant inter-coder agreement was achieved across:

- all data (Cohen's kappa [κ] =0.795; p=0.000; 95% CI 0.71-0.87)
- data corpora 1 κ =.695; p=.000; 95% CI 0.611-0.849
- data corpora 2- κ =.711; p=.000; 95% CI 0.757-0.950).

Knowledge types were then collapsed into six categories (see table 16).

Table 16 Knowledge types

Knowledge	Requested % of whole data set (n)	Supplied % of whole data set (n)
Experiential + explicit	33.3 (21)	16.6 (43)
Experiential	27.0 (17)	35.4 (93)
Explicit (i.e. guidelines or research)	39.7 (25)	17.1 (45)
Know-how (problem + solution/s with detail + rationale/s)	n/a	19.8 (52)
Know-why (problem + solution/s + rationale/s + evidence + situational application + reflection)	n/a	5.3 (14)
No knowledge	n/a	6.1 (16)

It was commonly noted that the initial poster requested both explicit and experiential knowledge, usually regarding product availability and other members' experiences. For example *'Does anyone have any information on any portable End Tidal CO2 equipment which is available? Good experiences etc; which we may find useful in determining the best product available'*.

According to knowledge requested, different job roles had different knowledge needs that reflected their scopes of practice. For example when requesting knowledge, enquiries from members who were in NUM roles were mostly about availability and experience with a product or service, while bedside nurses were more concerned with institutional practice experiences. In contrast, KB nurses requested all knowledge types, but asked for explicit knowledge most commonly (9/13 requests). It was also noted that there were no breaches of patient confidentiality or privacy across any of the 40 threads. An exemplar thread is illustrated in table 17.

Table 17 Exemplar thread - Endotracheal tube securement (page 1 of 4)

Post	Knowledge	Purpose	Concerns	VC work
<p>1 Initial email</p> <p>At XXX Hospital, we have had problems with pressure areas from endotracheal tube tapes (ETT). We use white tracheostomy tapes and reston foam, change them prn. Recently we have been changing them every shift. Does anyone have a protocol on ETT tapes and how to secure a tracheostomy. I have attended to an audit re securing/changing ETT tapes</p> <p>Bedside nurse</p>	<p>Combination</p> <p>Explicit – institutional guideline +</p> <p>Experiential – institutional practice experience</p>	<p>Benchmarkin g clinical practice</p>	<p>Ensuring best practice – prevention of adverse events (pressure injury)</p>	
<p>2 we have a protocol and use similar... <<Tracheal tube tying_ETT.doc>> (this was a guideline made available at the ICCMU website</p> <p>Knowledge broker nurse 1</p>	<p>Explicit – institutional guideline</p>	<p>Provide answer to request</p>		<p>Supply of artefact</p>
<p>3 Good protocol- although I have a few concerns regarding doing oral care during tape change:</p> <ol style="list-style-type: none"> 1. Re-tying the TT (tracheal tube) is not without risk, with the possibility of accidental dislodgement significant. I believe that this procedure should be done as expeditiously as possible. Brushing the teeth, rinsing the mouth and using a yankeur sucker with an unsecured TT poses a significant risk to the patient. 2. Mouth care which incorporates brushing the teeth, should be done at least twice a day (we aim for three times a day) because according to the literature,(Munro et al 2002, 11,3, 280-286) brushing is the best method of removing dental plaque which harbors oral bugs. Therefore if comprehensive mouth care was attended during TT change, it would be hard to justify changing the tapes tds or bd. <p>Cheers Knowledge broker nurse 2</p>	<p>Know-why</p>	<p>Promoting discourse – challenge</p>	<p>Ensuring best practice – prevention of adverse events (unplanned extubation</p>	<p>Cordiality – salutations</p> <p>Promoting VC – demonstratin g reading of thread</p>

Table 17 Exemplar discussion thread - Endo tracheal securement (page 2 of 4)

Post	Knowledge	Purpose	Concerns	VC work
<p>4 'interesting protocol, XXXX</p> <p>Why do you see the need to trim (endotracheal tube) ETT? They are not designed to be trimmed in situ and I can't think of a possible reason why I would want to trim a tube that is in a patient. Tube trimming risks complete loss of airway and confers no benefit. You have only a negligible effect on resistive work of breathing (and there are generally much more major factors which should be attended to first). The bit of tube sticking out of the patient is not the bit that gets kinked, it is the bit just adjacent to the teeth where any kinks happen. In addition if you use a closed suction system you have now created a dangerous device where the suction catheter extends much further down the bronchus than it was designed. Plenty of cases also of 'accidental' cutting of pilot balloons while trimming tubes, which is occasionally catastrophic, and also cases of tube tapes being cut with loss of tube.</p> <p>Interesting to think how a risk manager would respond - a protocol to do something that confers no benefit, with catastrophic potential complications!</p> <p>Now if only we could convince the ambulance service to stop shortening tubes before they insert them into patients. They trim them way too short for any big person, ony necked person and especially anyone with a face which is going to swell. We've all had "interesting" experiences changing ETT tubes inserted by paramedics in for example burnt patients, as the face swells and the too short tube comes out of the glottis!</p>	Know-why	Promoting discourse – challenge	Ensuring best practice – Prevention of adverse events - potential hazard with clinical practice	Promoting VC – demonstrating reading of thread
<i>Intensive care specialist 1</i>				

Table 17 Exemplar discussion thread - Endo tracheal securement (page 3 of 4)

Post	Knowledge	Purpose	Concerns	VC work
<p>5 interesting discussion XXX</p> <p>Cutting ETT (endotracheal tube) is a common timeless practice. I'm wondering if there is objective information to support the practice either way. the ambulance service practice has definitely caused problems for me in the past, as has cutting the tube shorter after a number of days. And am aware of critical incidents involved doing this. Near-misses are invaluable lessons to learn!</p> <p>I'd have to say I prefer a tube that has been trimmed BUT not to a minimum length. not so much for the decrease in resistance but because having it long provides an extra anchor for inadvertent dislodging by a restless patient. However if the tube is to be cut it should happen at intubation where objective evaluation of whether the tube is in the correct position is known thanks to an x-ray. never before because too short is worse than too long!!!</p> <p>Is there a clever person who could calculate the difference in resistance per extra centimetre?</p> <p>Not sure I agree with what you said about the in-line suction catheters though. all of the products I have seen are marked so shouldn't be inserted too far. as well there are occasions where you do want to go beyond the end of the ETT eg BAL, sputum plugs etc</p> <p>I concur somewhat with (Knowledge broker nurse 2) (re retying tapes and cleaning teeth at the same time). I think there are good arguments both ways.</p> <p>seems to me we might need to get some consensus on these issues via an expert panel type setup. Are we mature enough for this yet? I'd like to think we are!</p> <p>Knowledge broker nurse 3</p>	<p>Experiential – beliefs/opinions</p>	<p>Promoting discourse – agreement with previous posts</p>	<p>Ensuring best practice –</p> <p>Prevention of adverse events - potential hazard with clinical practice</p>	<p>Promoting VC – demonstrating reading of thread</p>

Table 17 Exemplar discussion thread - Endo tracheal securement (page 4 of 4)

Post	Knowledge	Purpose	Concerns	VC work
<p>6 Thanks (knowledge broker nurse 2) for your comments.</p> <p>I agree with your comments but I do not believe this constitutes a need to change advocated practice within this protocol - although with less experienced staff greater caution would be required - fortunately we do have (as you guys have) a good mentoring process. To do effective mouthcare - most appropriate during TT (tracheal tube) tape change. As for point 2: I don't get it? Have I written something confusing in the protocol? Tape changes are prn and per shift (12 hour) therefore minimum of b.d. Mouthcare is at least bd and often q 2nd hourly!!! - for vent and non-vent pts. Tape change and mouthcare are independent activities but mouthcare should be done when changing tapes (ease of access, viewing etc, obviously with caution and noting of TT position at lips/teeth) - seriously worried now that I have missed the point ... hmmm.</p> <p><i>Knowledge broker nurse 1</i></p>	<p>Experiential – beliefs or opinions</p>	<p>Promoting discourse – challenge</p>	<p>Ensuring best practice</p>	<p>Promoting VC – giving thanks</p>

These findings were similar to previous research where sharing of domain specific experiential knowledge was the most common activity across healthcare VCs (Brooks & Scott 2006b; Macdonald, MacPherson & Gushulak 2009; Morken, Bull & Moen 2009; Rodriguez-Recio & Sendra-Portero 2007). There were however a number of significant new findings, especially in relation to knowledge types. First, this is the first study to demonstrate use of a coding schema with high inter-coder reliability. Second, exchange of experiential knowledge was driven by members requesting this knowledge type. Third, explicit knowledge, independent or in combination with other knowledge types, was commonly exchanged. Fourth, higher order knowledge types (know-how and –why knowledge), were present across 25% of all knowledge supplied. These knowledge types, especially know-why, reflect a high level of clinical expertise within an EBP context (King 2009; Manley et al. 2005).

In this sample of discussion threads another key component of a successful VCoP was demonstrated. That is ICUConnect members were provided with relevant practical and valuable knowledge, especially know-how and know-why knowledge, by experienced clinicians and experts (Barnett et al. 2012; Chang et al. 2014; Hew 2009), and supported LPP by less experienced clinicians.

Analysis of latent content

As described earlier, identification and analysis of latent content requires the coder to look beyond the surface for clues regarding the meaning of the textual data (Krippendorff 2004; Rourke et al. 2000). In this section the findings in relation to latent content (knowledge work, the central construct of virtual community work) and the themes linking ICUConnect to the broader intensive care world, are discussed. The previous exemplar thread in table 17 is also provided for context of this section.

Knowledge work

Using the only available albeit un-validated tool (Brooks & Scott 2006b), this study found that 70% of discussions were characterised by knowledge work (see table 118). For data corpus 1, there was a 67% agreement between coders; a Cohen's kappa [κ] was not able to be calculated because of category asymmetry, and 10% of posts ($n=18$) were unable to be classified. This asymmetry occurred because the independent coders did not identify the same categories. On review, the category 'information work 7' was added to reflect the experiential nature of unclassified emails. For data corpus 2, all emails were classified with an 80% agreement between coders. Category asymmetry persisted and inter-coder reliability could not be evaluated, therefore this may have occurred due to chance.. While this study found that a large proportion of discussions were knowledge work these findings lack functional (internal) validity because of category asymmetry, as categories in the content analysis tool were not exhaustive and mutually exclusive (Krippendorff 2004).

Table 18 Knowledge work

Category	Descriptor	Data corpus 1	Data corpus 2	All data
		% (n=)	% (n=)	% (n=)
Knowledge work (KW)		66 (118)	75 (112)	70 (230)
KW 1	Discursive issue-raising	25 (45)	18 (27)	22% (72)
KW 2	Discursive debate	16 (28)	30 (44)	22% (72)
KW 3	Discursive support	12 (22)	19 (28)	15% (50)
KW 4	Discursive resolution	7 (12)	1 (1)	4% (13)
KW 5	Tacit and evidence display	4 (8)	3 (5)	4% (13)
KW 6	Narrative display only	2 (3)	5(7)	3% (10)
Information work (IW)		24 (42)	24 (36)	24 (78)
IW 1	Closed questions or requests for explicit knowledge	3 (6)	7 (10)	5% (16)
IW 2	Display of local explicit knowledge as an answer to a discursive question	8 (15)	1 (1)	5% (16)
IW 3	Display of local explicit knowledge as an answer to a closed question	3 (3)	3 (4)	3% (10)
IW 4	Display of explicit scientific or evidence-based knowledge.	2 (6)	2 (3)	2% (6)
IW 5	Information display only	3 (5)	1 2)	2% (7)
IW 6	Non-discursive simple responses, messages that were single statements	4 (7)	0	2% (7)
IW 7	Request for or Display of local experiential knowledge as an answer to a question	NA	11	5% (16)
Not able to be coded		10 (18)	NA	6 (18)

Healthcare professionals need to develop knowledge work competencies to effectively care for patients and contribute to the evolution of healthcare practice and services (Ayers LaFave 2008; Kothari et al. 2011; Orzano et al. 2008; Scott et al. 2004; Snyder-Halpern, Corcoran-Perry & Narayan 2001). Knowledge work involves HCP engaging in a dialogical process that includes critical reflection and learning to support professional practice and policy development (Brooks & Scott 2006b), however the literature review (chapter 3) found that this was a relatively unexplored research area which was further limited by the lack of a validated tool. Given the limitations to these findings presented here, further work is needed to develop a valid tool to evaluate knowledge work within a VC. This evolution will enable a more comprehensive evaluation of VCs as a knowledge management strategy when involving all members of the MDT in policy development.

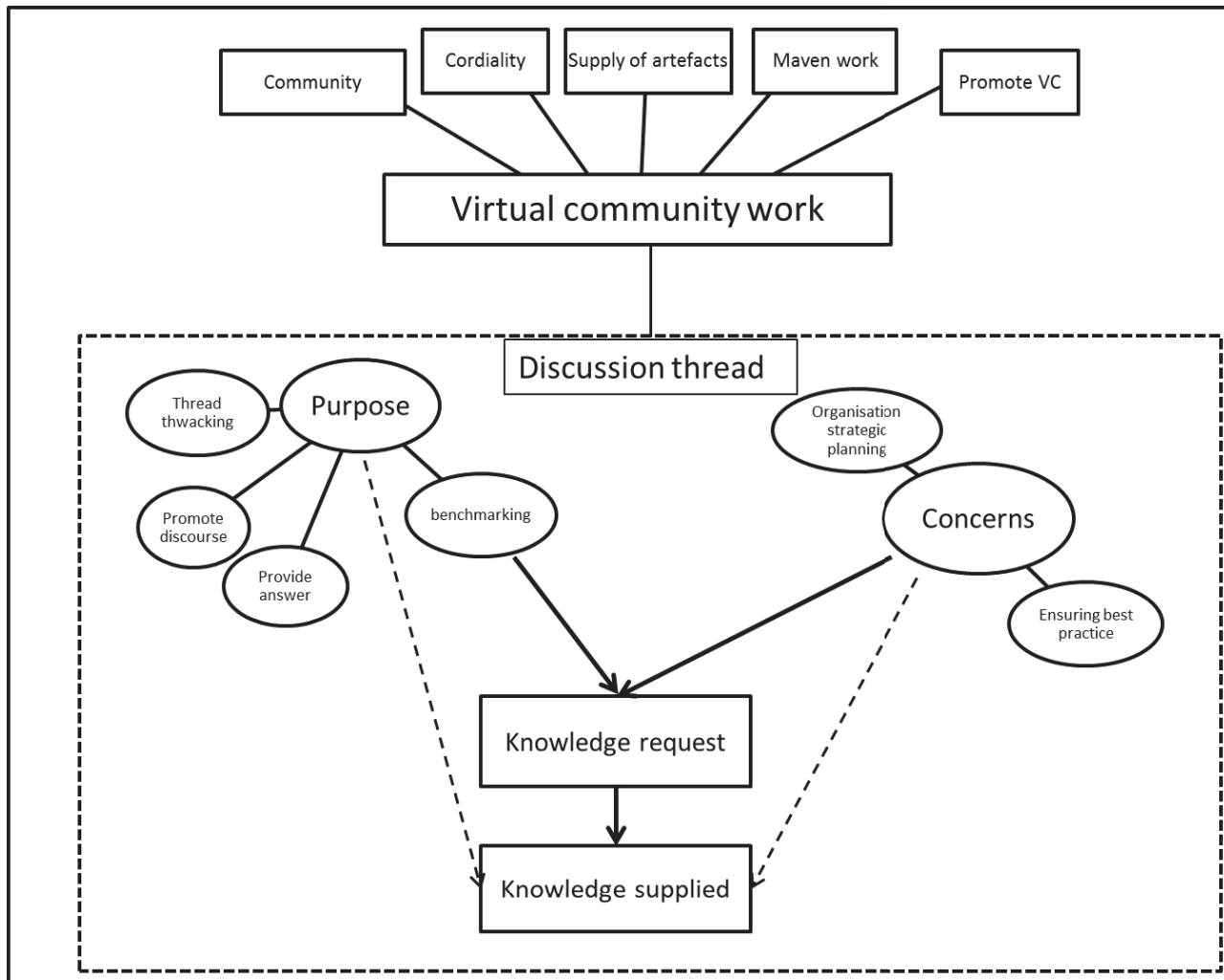
Virtual community work

The construct of 'virtual community work' emerged during refinement of final themes within the latter stages of data analysis. Virtual community work reflected any direct or indirect actions undertaken by members that contributed to creating a safe online space where VC members could trust that their questions would be received and answered in a collegial professional atmosphere.

Six elements were identified: 1) the discussion thread; 2) sharing of artefacts; 3) community; 4) cordiality; 5) maven work; and 6) promotion of the VC (See figure 10). While the discussion thread is the most visible component of virtual community work, the latter five components create the positive social environment that facilitates

knowledge exchange and development of the VCoP knowledge base (Barnett et al. 2012; Hew 2009; Preece 2001).

Figure 10 Virtual community work



Discussion thread

Posting within a discussion thread is the most direct action or work of VC members, with three major sub-elements noted: the request for and supply of knowledge (described earlier), the purpose, and concerns that motivate a member to post.

Purpose of parent / initial post

The purpose behind a post was illustrated by the reasons or motivations for a member posting. The purpose for all *parent* or first posts was therefore to 'benchmark' practice, while answers / replies were distributed between answering a question and promoting discourse (see Figure 10 above). For this specific dataset, members were interested in benchmarking across five areas including procedures (n=17 posts), equipment (n=19), clinical decision making (n=6), and one each for education and staffing. Nursing unit managers were almost exclusively interested in benchmarking equipment or products while KB nurses were interested across all areas except staffing. Physicians were broadly concerned with clinical decision making, equipment and procedures. Nurses providing direct clinical care were interested in procedures, equipment or products and staffing. These differences are illustrated in exemplar 1

Exemplar 1 Purpose - benchmark practice (page 1 of 2)

Type of member	Area	Quote
NUM	Equipment (n=9)	<i>'Does anyone have any information on any portable End Tidal CO2 equipment which is available, .good experiences etc; which we may find useful in determining the best product available.'</i>
	Procedures (n=1)	<i>'Out of interest, how many units regulate their wall suction to 150mmHg or less for adult ETT suctioning, (80 – 100Hg in neonates)?'</i>
Knowledge Broker nurse	Equipment (n=5)	<i>Just wondering what people are using for ETCO2 monitoring for out -patient cardioversions done in wards/ CCU.</i>
	Procedures (n=7)	<i>'In terms of infection prevention – how often do disposable BVM resuscitators get changed – do people practice daily changing of bags that have been opened for intubated and ventilated patients OR do they use them for the whole duration of admission OR is it a weekly change.'</i>
	Clinical decision making (n=2)	<i>'Our group is looking at Non-invasive ventilation. As part of this project we did send out a practice audit, but would like some clarification from ICU connect around an aspect of practice.'</i>
	Education (n=1)	<i>'What units have education programs around management of the difficult airway.'</i>
Clinical nurses	Equipment (n=3)	<i>'Does anyone use these Passey-Muir Valves for ICU ventilated patients?'</i>
	Procedures (n=7)	<i>'I am interested in what methods other units use to prevent patients Developing pressure areas from et tapes, particularly the corner of the mouth.'</i>
	Staffing (n=1)	<i>'I am currently in the process of putting together a submission for 5 staff per shift with the intention of having a free team leader. Currently we are level 4 and our ventilated patients can range from 1 to 2 and sometimes 3. At the present Bi-PAP patients are allocated on a 1:2 staff ratio however sometimes these patients require more time than ventilated patients, I am however unable to find literature so I can have this changed on acuity instead of a set 1:2 if a patient in on BiPAP. I would appreciate any assistance/guidance or tips on this submission'</i>

Exemplar 1 Purpose — benchmarking practice (page 2 of 2)

Type of member	Area	Quote
Medical staff	Equipment (n=1)	<p><i>'Having just reviewed the literature, in our local journal club, about endotracheal, and tracheostomy, tubes with a port to enable subglottic suctioning. I would like to know what common practice is.</i></p> <p><i>I would appreciate hearing your experiences.....</i></p> <p><i>Do units use ETT or tracheostomy tubes with a suction port above the cuff (Portex SACETT, EVAC, Suctionaid etc) routinely?</i></p> <p><i>What is your patient selection criteria?</i></p> <p><i>Do you do intermittent or continuous suctioning?</i></p> <p><i>Do the subglottic -suction-port-ETT's live in the ICU, ED, MET trolley, OT??</i></p> <p><i>Thanks'</i></p>
	Procedures (n=2)	<p><i>What do you use to secure tracheostomies in your ventilated patients?- white cotton tapes only</i></p> <ul style="list-style-type: none"> - white tapes with some variety of home made padding - a commercial device with velcro tabs [brand name please] - some other commercial device [brand name please] - sutures
	Clinical decision making (n=3)	<p><i>'I am interested to learn what is considered to be the best practice for oxygen delivery prior to ETT suction.'</i></p>
Facility management	Equipment (n=1)	<p><i>'I am interested to hear what the current trends are with the use of Inline suction systems.'</i></p>
Speech pathologist	Clinical decision making (n=1)	<p><i>'Does anyone 'out there' have any good evidence re patients with tracheostomies having ice to suck.'</i></p>

Comparing or benchmarking local practices is an essential benefit of VC membership (Cervantez Thompson & Penprase 2004; Hew & Hara 2008), enabling members to vicariously experience a product or practice and gain a broader understanding about

the essential elements of an innovation (Hara & Hew 2007). This is significant as peer-to-peer recommendations are highly influential for innovation uptake and practice change (Greenhalgh et al. 2005a; Rogers 2003). Further, and possibly more meaningful, the content of conversations between professional colleagues identify what clinical practices are important and relevant for a particular practice community (Duncan et al. 2014)

Purpose of child / response post

Three purposes were noted when members responded to an original post: 1) providing an answer: 2) promoting discourse; or 3) thread thwacking prompted by the initial topic. 'Providing an answer' were usually multi-dimensional responses, including descriptors of local practice, equipment or product use, description of the evidence base, provision of information, clinical advice, and / or supply of local resources such as guidelines and education packages. On occasion however a seemingly straightforward answer resulted in an animated discussion thread that evolved to encompass the breadth of a particular clinical practice (See Table 6.6).

When providing a response to a post, 'promoting discourse,' was the most common sub-purpose and characterised by either: 'agreement with', 'challenge to', 'clarification', 'broadening the discussion' through addition of other related issues, or 'summary of the discussion' to that point in the thread. Promoting discourse underscores the value of online discussions to draw attention to the complexity and changing nature of clinical practice whereby clinicians need to consider and balance multiple aspects of care (see figure and Table 6.6, previously). Contributions to

promoting discourse came mainly from physicians, KB nurses and NUM members.

Introduction of a new unrelated topic (thread thwacking) rarely occurred.

Concerns

Posts reflected one or more concerns, issues or potential problems related to the discussion thread topic. The dominant concern expressed by all posters was 'ensuring best practice', reflecting a core value of the speciality and the VC. Conversely, organisational 'strategic planning' was described only once. Sub-concerns in this context were reflective of dimensions of best practice. Given the sample, a frequent discussion thread topic was securement of an endotracheal tube, and while posters were initially 'concerned' with preventing facial pressure injuries, discussions often expanded to include a number of other issues and practices (as illustrated previously in figure 7

Within barriers for ensuring best practice, a lack of research evidence was commonly described by posters, followed by staff compliance with evidence based recommendations, failure to evolve practice, organisational barriers and difficulties in describing best practice. The sub-concern of 'lack of research' may have been a reflection of the frequent topic of ETT or tracheostomy securement where the evidence base is limited (Gardner et al. 2005; Rolls & Elliott 2008). Company recommendations for appropriate product use were the next most common sub-concern. Here posters were troubled by what were the appropriate recommendations, the research basis supporting these recommendations, and the consequences of non-adherence. When posters were concerned with 'balancing the evidence', they usually listed at least two evidentiary areas for consideration prior to making a clinical practice

decision (for example does the contamination of a yankeur sucker lead to actual cross-contamination and infection?).

The issue 'improving patient outcomes' was concerned with direct improvement in a patient's condition (for example reducing length of ventilation or effective discharge of a ventilated patient to home). Where a specific state or national professional standard was available, members indicated the need to comply. For example '*ETCO2 for every intubation is utterly NON negotiable, and is clearly written in the Minimum Standards for Intensive Care*' (intensive care physician and maven).

The most common concern for all member types was *prevention of adverse events*, often with warnings of possible unintended negative consequences of a practice and other concerns related to scope of practice. Nurses in bridging roles (that is KB nurses and nurses who worked in liaison or outreach roles) and physicians had concerns covering the whole practice spectrum, whereas NUMs were concerned with company recommendations and organisational strategic planning.

This discussion thread illustrates a model that represents collective knowledge creation, as various VC members work together to solve the knowledge need or local problem presented by the first poster (Nonaka, von Krogh & Voelpel 2006; Ward et al. 2014b). The conversations, discussions and conflict that occur online are a key attribute of a VCoP (Barnett et al. 2012; Chang et al. 2014; Hew 2009), enabling development of professional knowledge of individual members and the practice knowledge of the community, and leading to potential improvements in practice and innovation (Hara & Hew 2007; Wenger 2004).

Importantly, challenges to the veracity of VC posts are in stark contrast to transfer of knowledge in a localised clinical setting where clinicians may not question what they have been directly told (Marshall, West & Aitken 2011). Questioning local practices can be challenging despite having strong contrary evidence (Rycroft-Malone et al. 2013) or being an experienced clinician (Copnell 2008), contributing to inertia in clinical practice (Copnell & Bruni 2006). These discussions also provided members, especially novice clinicians, with access to a broad range of experience and clinical expertise, facilitating LPP (Barnett et al. 2012; Wenger 2004).

Creating a safe collegial environment

These findings suggest that members of ICUConnect have established a safe collegial environment, through synergism between the five components of: 1) community; 2) cordiality; 3) supply of artefacts; 4) maven work; and 5) promotion of the VC. The 'community' is created by a shared reality for members, is established by the two sub-elements of 'homophily' and 'temporality of issues'. Homophily was illustrated in this sample by comments such as '*back to the grind*' or '*Hi troops*', which reinforced that members shared similar goals, values and experiences (Rogers 2003). A 'temporality of issues' was revealed as members 'admitted' they too were presently grappling with similar problems as an original poster, as illustrated in exemplar 2:.

Exemplar 2 Temporality of issues

'In response to a post regarding use of non-invasive ventilation mode on ventilators predominantly used for invasive ventilation ...

'Interesting thread as we are currently looking at new ventilators here at H-9 AICU. In our consensus meeting we did not feel that any of the "invasive" vents [mechanical ventilators] performed as well as the Brand X (we own 5), hence it is not one of our major criteria to evaluate ventilators. We agreed conceptually that it would be great if invasive vents performed well in NIV.'

In response to a post on nurse-patient ratio for patients receiving non-invasive ventilation

I would be interested in responses to the list.

The reflection of cordiality creates the necessary supportive and professional social atmosphere that sustains online participation and is comprised of four characteristics: 1) salutations (noted in n=71 posts); 2) humour (n=26); 3) sarcasm (n=4); and 4) discussion of VC rules (n=3). Salutations, seen at both the opening and closing of posts, were common, lending a polite tone to discussions. Humour was used more commonly than sarcasm in this dataset; for example, *'Off the horse and back to work!!! No shares in XXX company :)'*. These textual elements serve to reduce tension and add informality to discussions adding an integral component of the necessary camaraderie in an online forum (Thomas & James 1999).

The use of emoticons was uncommon although this may have been a function of using software that limited functions to standard keyboard keystrokes. Virtual community etiquette and rules were illustrated by the following comment, *'FYI in general we shouldn't post PDFs onlist UNLESS they are freely available and this one was.'*

Significantly, despite the high level of replies focussing on promoting discourse and the use of sarcasm, discussions were managed collectively in a professional manner with

no hostile or insulting posts (flaming or trolling) noted, rather interactions reflected those observed at professional conferences.

The remaining components of virtual community work (as shown earlier in figure 10), including 'sharing artefacts,' 'maven work' and 'VC promotion,' worked together to highlight the value members were able to find in the VC. Artefact sharing (n= 41) included posting of resources (e.g. clinical practice guidelines, reports, articles, images or URLs linking members to online resources such as videos. Development and sharing of artefacts are essential components of a CoP (Wenger 2004). Maven work (posting by key members who take the time to provide complex lengthy answers) were usually coded as know-why knowledge. Virtual community promotion is exemplified by the following quote; *'Thanks for the advice on the CPAP / BiPAP last week, M-59 (a maven). The educators say thanks, our shout'*. Inclusion of direct thanks for knowledge received reinforces to members that the VC is an important source for key information and knowledge.

The components of Virtual Community work, the discussion thread and creation of a safe collegial environment, demonstrate that ICUConnect has developed several more elements of a successful VCoP. The dialogical interactions within the discussion thread illustrate how members are able reach out to colleagues for key knowledge, vicariously experience innovations and importantly gain varying perspectives. Members have created the necessary VCoP element of a respectful risk-free online environment where members are able to post without negative consequences (Barnett et al. 2012; Chang et al. 2014; Hew 2009; Sharratt & Usoro 2003). Critically, knowledge exchanges are characterised by cordial professional exchanges, reinforcing acceptable online

behaviours to all members, and especially to new members. This positive e-professionalism supports knowledge exchange (Hew 2009; Usoro et al. 2007) and retention of members (Irvine-Smith 2009). Further role modelling of appropriate intra- and inter-professional communications facilitates development of a shared understanding of knowledge and roles within the multidisciplinary team (Dias & Escoval 2015; Dopson et al. 2002).

Broader intensive care context

Two important themes emerged from this sample of threads that link to a broader intensive care practice context: the 'complexity of clinical practice' and 'loss of corporate memory'. Numerous threads unpacked the nuances of clinical practice in three key ways: 1) through the types of knowledge displayed; 2) introduction of related topics; and 3) the purpose of promoting discourse. In combination, these illustrated to members how complex clinical practices are, and that practices actually change over time (see figure 9).

The loss of corporate memory with an ICU emerged as discussions evolved concerning three clinical practices for which the original theoretical, scientific or safety rationale was no longer valid (see Table 19). The most conspicuous example were two threads posted in 2010 concerning the routine deflation of tracheostomy cuffs to prevent tracheal necrosis; a clinical practice not required since the 1980s, when low pressure high volume cuffs replaced high pressure low volume cuffs on tracheal tubes (Haas et al. 2014; Powaser et al. 1975). The concept of corporate memory (the historical knowledge underpinning how practices or processes developed within an organisation) can be linked to organisational performance, competence and innovation (Alyahya

2012). Further, failure to incorporate emergent knowledge into practice places organisations at risk of not delivering best practice (Marabelli & Newell 2012). Critically, the discussions that developed indicated not only were these practices no longer required, they were also potentially dangerous for patients.

Table 19 Discussion thread topics illustrating loss of corporate memory

Year of discussion	Topic
2005	ETT securement with reference to routine trimming of tube in pre-hospital setting (Patel, Mahajan & Ellis 1993)
2006	Routine manual hyperventilation to prevent hypoxia secondary to airway suction (Barnes & McGarry 3rd 1990; Woodgate & Flenady 2001)
2010	Routine deflation of tracheostomy cuff to prevent tracheal necrosis (Haas et al. 2014; Powaser et al. 1975)

The failure of HCPs to cease using or organisations disinvesting in outdated, unsafe or non-evidence based practices is of significant concern in healthcare (Elshaug et al. 2012; Garner & Littlejohns 2015; McClellan et al. 2008). These practices are often referred to as ‘sacred cows’ due to their significant tenure and difficulties in challenging and discontinuing their use (Mick 2011). These practices may continue to linger due to ‘corporate memory loss’ incurred by organisations, which is further reinforced by clinical practice silos created by ineffective social networks. If clinicians do not have communication channels beyond local social networks, they may be under the illusion that local practices reflect the majority view (Duncan et al. 2014; Lerman, Yan & Wu 2015) and fail to evolve practices.

Rigour of the study

Strategies for enhancing study rigour were previously described in Chapter 3. The trustworthiness of this study was established by creating and describing a clear audit trail and providing a thick description of the research process, including procedural steps and members involved in online discussions. The robustness of this process for development of the knowledge categories was demonstrated by achieving a significant inter-rater reliability using an independent coder with significant contextual knowledge. A systematic process was demonstrated, with categories based on theory and application of the tool to two substantial datasets.

Methodological Strengths and Limitations

A number of key design and methodological decisions were made to address limitations of previous studies so that a clear and comprehensive exploration of ICUConnect was possible. A key strength was the use of a summative content analysis technique that enabled identification of both knowledge exchanged and the context within which this exchange occurred. This facilitated development of a novel construct virtual community work model, enabling more clarity about why members posted, and the social context of the VC in supporting participation and knowledge exchange.

Maintaining the unit of analysis within its contextual unit provided an explanation for the high rate of experiential knowledge exchanged on nursing VCs, a previous criticism of these communities (Abrahamson, Fox & Anderson 2013; Reutzler & Patel 2001). An acceptable inter-rater reliability was achieved for categorising knowledge types which was a crucial element missing from other HCP VC studies (see appendix D Quality assessment table for studies using content analysis)

The sampling plan gathered a substantial data set for a considerable time period, however the purposive approach limited generalisability of findings to other areas of practice. The focus on ventilation and airway management may have restricted responses to those with needs or expertise in these clinical practice areas as well as reducing the participation of allied health professionals or healthcare care managers. A random or census sample would have gathered discussion threads more reflective of the scope of these online discussions, however these sampling methods were not possible due to the current archival arrangements of the VC. The use of threads with three or more posts may also be giving an overly positive view of discussions and knowledge exchanged. Thus members who posted in these discussion threads may not be reflective of membership in general; which is compounded by the inability to complete a comparison against general membership because a contemporary social network is not available. In addition without a survey of all members or social analysis techniques, findings regarding the possibility of LPP and an online environment conducive to participation should be considered to be preliminary. It should be noted however the exploratory nature of this study did not require a representative sample of threads or members.

Finally the level of knowledge work could not be determined because of the tool lacked internal validity (Krippendorff 2004). Therefore the functionality of a listserv to support knowledge work remains unknown. This maybe because a listserv may not create a chronologically threaded discussion making knowledge work more difficult.

Conclusions

This qualitative retrospective descriptive study explored the nature of knowledge exchanged on an exemplar VC between 2004-2013; or 'what' members talk about on ICUConnect. The social network study (Chapter 5) found that the VC had evolved into a multi-organisational online professional community for all HCP involved in the care of the critically ill. In this present study the main finding was that the online culture of this broader and diverse social network actively facilitated exchange of important clinical knowledge and professional development of members. The case for ICUConnect as a successful VCoP and as an effective innovation distribution and diffusion mechanism is developing. What is not known however are the direct voices of members regarding 'why' they belong to ICUConnect. This final aspect of the study program is explored in Chapter 7.

Chapter 7 - Exploring 'why' members belong to an intensive care virtual community

'I joined ICUConnect because the ICU world is a small one, and it is difficult to gain different perspectives and insights solely from the team you work in (as everyone tends to regress to a virtual mean, or at least common principles of practice). I feel this can be very limiting professionally, and I gained this perspective from working in a very solid, highly effective team at a single health service ICU for eight years.'

Physiotherapist

Introduction

A significant potential exists within multi-disciplinary virtual communities (VC) to facilitate transfer of research knowledge and best practice (Burrell, Elliott & Hansen 2009; McGowan 2012) and support the professional development of clinicians (Barnett et al. 2012). At present however the questions of why healthcare professionals (HCP) join or how they use a virtual community (VC) have been largely ignored in the literature, especially regarding the motivations of the majority of members who do not post.

This chapter reports a study that sought to develop an understanding of 'why' HCPs join a practice based VC and how they use it. An earlier version of this work was previously published as a study protocol paper (Rolls et al. 2016b). Similar to Knowledge exchange study presented in chapter 6, a short overview of the relevant literature is provided prior to a thick description of research methods. Study findings are presented within the context of Diffusion of Innovations (DoI) theory and the relevant literature. A brief discussion of the methodological strengths and limitations of this present study are provided.

The following Discussion chapter incorporates a synthesis of study findings from chapters 5-7, discusses relevance of this synthesis to policy and practice, provides recommendations for further research, and discusses contributions of this present study to the research methods literature.

Background

This section provides: 1) a brief overview of the current research in relation to why HCPs use social media; 2) an overview of online focus groups including how they have been applied in healthcare and VCs; and 3) an overview of interviews and how they have been used to examine social media use by HCPs.

Virtual community use by healthcare professionals

Like the rest of the broader community, HCPs have adopted social media in their professional lives, although uptake varies considerably (Kim et al. 2014; Lulic & Kovic 2013; Rolls et al. 2014; Widemark 2008), and despite positive attitudes this has not translated to significant professional use of social media (McCrea 2012). There are some data suggesting this is influenced by individual characteristics (McGowan et al. 2012), peers (Archambault et al. 2012; Gagnon et al. 2012; McGowan et al. 2012) and perceptions of the media as an innovation (McGowan et al. 2012). It has therefore been suggested that a comprehensive understanding of VCs requires a mixed methods approach that includes a member survey, content analysis and social network analysis (Li et al. 2014).

The current research base on why or how HCPs use virtual communities or social media is limited, as online observations reveal only the activities and perspectives of a minority of actual VC members – the ‘posters’ (Brooks & Scott 2006a, 2006b; Morken,

Bull & Moen 2009; Rodriguez-Recio & Sendra-Portero 2007). Methodological limitations are also noted with measurement [e.g. (Cook-Craig & Sabah 2009; Deen, Withers & Hellerstein 2013)] and sampling [e.g. (Apostolakis et al. 2012; Tunnecliff et al. 2015)] bias in surveys. Social network analysis has demonstrated that members have more complex reading than only posting behaviours and interactions between members (Stewart & Abidi 2012); however this information does not reveal member motivations, especially the non-posting majority, and is limited to platforms where these data are available.

Given this, what is it that motivates HCPs to join a VC, and what do they value that influences them to remain members? As described previously, the absorption and diffusion of knowledge or innovation into and around a healthcare organisation is the role of clinical leaders such as boundary spanners [e.g. nursing unit managers or project officers) (Long, Cunningham & Braithwaite 2013), or knowledge brokers (KB) (e.g. nurses in education or advanced practice roles) (Gerrish, Guillaume, et al. 2011), or doctors. Do these individuals see membership as part of personal professional development or as a tool for their substantive position, as preliminary data suggests (Cervantez Thompson & Penprase 2004)? Understanding these phenomena will assist healthcare leaders in making decisions regarding use of social media to improve knowledge translation through distribution of best practice, and by extension patient care.

Online focus groups

Focus groups have enabled researchers to gather qualitative data on specific group experiences by capitalising on group dynamics to synergistically develop a deeper and

richer understanding of a phenomenon of interest (Kambereilis & Dimitriadis 2011; Liamputtong 2011). This collective conversation between participants facilitates gathering of both individual and group voices, may uncover an understanding not available via other data collection modes (e.g. surveys or individual interviews), and democratises research process and findings by de-centering the researcher (Kambereilis & Dimitriadis 2011). A moderator facilitates discussion between participants using a guide based on the core research questions and objectives, and evolves as data emerges (Liamputtong 2011). While face-to-face focus groups are acknowledged as a strong method for gathering qualitative data (Liamputtong 2011), there can be significant logistical challenges, such as convening the focus group on a specific date and time and at a location that facilitates maximal participation, particularly if members are geographically dispersed.

In response to these limitations, online or virtual focus groups are becoming more common as they enable participation of geographically distributed and time-poor individuals, and are less expensive to conduct (Liamputtong 2011; Williams et al. 2012). Online focus groups have been used to examine a diverse range of health related questions, but with considerable variation in methods used across studies (see table 20). While the term 'virtual focus group' is more commonly used, the term 'online focus group' has been used in this thesis to avoid confusion with the term 'virtual community'.

Table 20 Use of virtual focus groups in health (page 1 of 2)

Author, country	Aim	Focus group + participants	Running the VFG	Data Analysis
Murray, International (Murray 2001)	To test method and gather data to inform interviews;	2 FG - Educators and listserv experts (n not provided); 4 weeks	Asynchronous using listserv	Not explained
Adler, USA (Adler & Zarchin 2002)	Develop understanding of lived experience of women confined to bed rest because at risk of preterm labour	1 FG (7); four weeks	Asynchronous using listserv; Question guide – 6 (semi structured, open ended)	Content analysis for thematic coding
Kenny, Australia (Kenny 2005)	Whether active engagement and group interaction could be captured in an online environment in an EN conversion program	1 FG with census sample	Asynchronous using Web CT starting with one question; ran for 2 months	Thematic analysis
Alonzo, USA (Alonzo 2009)	What motivates associate degree diploma prepared RN to pursue a degree through an RN-to-BSN program.	4 FG with 2-6 participants; nurses; 2 weeks	Asynchronous using discussion forum and a question guide (11)	Inductive content analysis
Tates, Netherlands (Tates et al. 2009)	Determine what constitutes good quality communication with a diagnosis of childhood cancer	3 FG grouped by type (7 current patients, 11 parents of these patients; 18 survivors)	Asynchronous using discussion forum; daily questions over 1 week	Not described
Hanson, USA (Hanson 2011)	To explore fieldwork educator motivations for working with students and the kind of support needed from the academic institution	2 FG based on stratification to paediatric & adult practice settings 10 participants; purposive sampling; over two weeks;	Asynchronous using discussion forum; students respond to each trigger question plus 2 peer responses	Content analysis
Levine, USA (Levine et al. 2011)	Involve youth of colour in design of programmatic content and formats for an Internet intervention for sex education	4 synchronous FG (7,5,4,2 participants) 1 asynchronous (18 participants)	Synchronous using chat room (4 by 1 hr) ; switched to asynchronous due to low numbers – 7 days with daily questions (9 in total)	Not described

Table 20 Use of virtual focus groups in health (page 2 of 2)

Author, country	Aim	Focus group + participants	Running the VFG	Data Analysis
Brubaker, USA (Brubaker et al. 2013)	Gather information about women's knowledge and attitudes regarding research participation.	2 FG grouped by research-experience or research-naive (12 in total); study protocol also include 14 face to face FG	Synchronous using Semi structured discussion guides	
Harmsen, Holland (Harmsen et al. 2013)	Gain insight into factors which influence parents to not vaccinate their children	8 focus groups ; 5 non-vaccinators (n=39; 7-9); 3 partial (n=21; 7 each); random selection by postcode; running over 5 days	Asynchronous using discussion forum; predetermined topics introduced daily with open questions; anonymous	Thematic analysis
Pechak, USA (Pechak & Black 2014)	Develop recommendations for implantation of ICE in physical therapist education to promote ethical practice	1 with 6 based on workplace type; 2.5 hrs	Synchronous using Blackboard; anonymous; highly structured feedback on predetermined script	Not described
Synnot, Australia (Synnot et al. 2014)	To understand the needs, experiences, preferences and values of people with MS & relatives when integrating evidence based health information into decision-making	Four F2F; VFG 33 participants over 2 months	Asynchronous using discussion forum; 10 question guide	Thematic analysis
Tuttas, USA (Tuttas 2015)	Capture travel nurses' perceptions of boarding experiences	4 FG with 2-5 participants; registered nurses	Synchronous using Web conferencing and a question guide (5 questions) ; over 45-60 minutes	Qualitative content analysis

Notes: BSN – baccalaureate science nursing; EN-enrolled nurse; F2F – face to face; FG- focus group; ICE - international clinical education; RN- registered nurse; HR – hour; MS- multiple sclerosis; VFG – virtual focus group.

Two modes of online focus groups are possible: synchronous and asynchronous. The synchronous mode closely matches face-to-face groups where participants meet in real time using chat rooms or discussion boards. This mode may promote a more dynamic discussion with high levels of interaction and feedback, however an individual's typing speed, connection bandwidth, and thought speed may negatively impact a participant's ability to effectively contribute in real-time (Liamputtong 2011). Asynchronous groups have been conducted using either listserv or discussion forum technology, providing participants with time to consider their posts or responses, and enable posting at a time of their convenience. Other advantages of the asynchronous mode include immediate creation of a threaded discussion, facilitating review by members as well as data collection and analysis (Kenny 2005; Liamputtong 2011). Importantly, study credibility is enhanced (Shenton 2004) by participant-controlled, real-time data collection.

While the asynchronous mode may facilitate development of more reflexive answers (Cresswell 2014; Williams et al. 2012), large participant numbers may create some potential problems. First, the quality of interaction, and therefore data, may be limited as the volume of posts is off-putting and/or too high for participants to thoroughly review. Second, moderation is more challenging because of the need to facilitate egalitarian input. Last, a high volume of data may be generated, increasing the complexity of data analysis.

As noted above, considerable variation exists regarding how researchers have structured online focus groups. This structure, including participant numbers, group characteristics (homogeneity versus heterogeneity), time, platform and question

guide, is crucial in gathering quality data that are generated by strong group dynamics and discussion (Liamputtong 2011). In addition, as most VC members do not actively post online (Edelmann 2013; Sun, Rau & Ma 2014), facilitating optimal participation conditions is vital if quality research output is to be achieved. Focus group participants may be more inclined to disclose their experiences and opinions where they feel they share values and beliefs with other group members and there is no group hierarchy (Acocella 2012). This homogeneity along with efficient moderation can lead to effective group interactions resulting in quality data (Liamputtong 2011).

The aim of moderation is therefore two-fold: to create an egalitarian, stress-free atmosphere where participants feel free to share their experiences, and to facilitate a discussion between participants rather than a question and answer session (Liamputtong 2011). The ideal moderator understands both the context of the research and the cultural world of participants (Barbour 2007; Bringsvor, Bentsen & Berland 2014). Effective online moderation however requires additional skills and interventions that socialises participants to the online space and encourages posting (Salmon 2011). Two other important considerations are that the selected platform is user-friendly (that is easy to access and use and aesthetically pleasing) (Hatten et al. 2014), and that posts are confidential to the group (Whitehead 2007).

A key component of a focus group is the discussion guide which frames and focuses discussions and ensures collection of rich in-depth data (Barbour 2007; Liamputtong 2011). Questions should reflect the study questions and funnel discussions through introductory, transition and key questions to ensure consistent data where multiple groups are used, and to aid data analysis (Halcomb et al. 2007). Introductory questions

encourage participation and provide participants and researchers with an understanding of individual perspectives (Liamputtong 2011). These are similar to activities undertaken as part of an e-moderation process to support effective online learning, including establishing an effective group, introduction of the research phenomena, and induction of participants to the online environment (Salmon 2011).

Focus groups and virtual communities

While focus groups are frequently used to collect data for qualitative or mixed methods studies, only two studies (Hoffmann, Desha & Verrall 2011; Murray 2001) were identified that examined HCP experiences of VCs or computer mediated communication. In a mixed methods study exploring how and why occupational therapists used a virtual community of practice (VCoP), two face-to-face focus groups (stratified by use or not of the VCoP) were used to develop a survey instrument (Hoffmann, Desha & Verrall 2011). In earlier work (Murray 2001), two online asynchronous focus groups were convened using listserv technology to explore how qualified nurses were using social media to meet their formal and informal continuing professional development needs. All questions were introduced at the beginning of the focus group, with the author later reflecting that this was overwhelming for some participants (Murray 1997).

While listserv technology is the most straightforward and accessible of all social media platforms it may not result in a chronologically ordered discussion thread. This may make it difficult for both the participants and moderator to follow the discussions, especially threads with multiple posts, and could therefore limit interaction and conversation development with probable negative effects on data quality. Importantly,

data analysis is also more complicated because of difficulties in understanding the chronology and/or evolution of a discussion.

Semi-structured interviews

Semi-structured interviews with key informants are a frequently used method of data collection in qualitative research, providing flexibility and an ability to develop interactions between the researcher and participants (Kallio et al. 2016; Richards & Morse 2013). Interviewees are selected purposely on the basis of their experience with the phenomenon under study (Creswell 2013). Key informants are individuals who hold specialised information by virtue of their social or professional position within a given context and are therefore able to provide researchers with knowledge not readily accessible via other means (Fetterman 2008). A question guide, based on fore knowledge of the research topic, facilitates interaction and collection of rich data (Creswell 2013; Kallio et al. 2016). Interviews, alone or as part of a mixed methods study, have been used frequently to examine the experiences HCPs regarding social media and virtual communities (See table 21)

Table 21 Use of interviews in virtual community research (page 1 of 2)

Author/country/HCP/social media type	Aim	Design	Sample/data corpus
Cervantez-Thompson USA ; Rehabilitation nurses Mailing list(Cervantez Thompson & Penprase 2004)	Why members use mailing list and describe their experience	Mixed methods survey + interviews	Purpose sample – online posters Interviews – self-nominated s
Brooks United Kingdom; Midwives Intranet -discussion forum (Brooks & Scott 2006a)	To evaluate whether midwives would function as knowledge workers in an online forum	Mixed methods - Case study Content analysis – thematic Participant Interviews	Data corpus –interviews – 15 online participants (purposive stratified sampling)
Hara International; Advanced practice nurses Mailing list (Hara & Hew 2007)	Examine the types of online activity types of knowledge shared factors that sustain knowledge sharing	Case study using mixed methods Triangulation CoP theoretical framework	Emails Interviews – semi-structured -27
Hew International -3 mailing list Advanced practice nurses, University web development , Literacy education (Hew & Hara 2007b)	Categorize the types of knowledge shared Identify the motivators of and barriers to online knowledge sharing	Mixed methods – comparative case study	Data corpus – weeks 1& 2 Interviews – semi-structured -57
Hew International; Advanced practice nurses (critical care) Mailing list (Hew & Hara 2008)	Gain an understanding of knowledge sharing among nurses on a mailing list	Interviews	Round 1 – 27 Round 2 – 10 most frequent online knowledge sharers of round 1
Hughes UK Physicians; Web 2.0 (Hughes et al. 2009)	Examine the use of Web 2.0 by junior physicians in clinical setting including motivations, direct use & how can tools be further used	Mixed methods Diaries Interviews	35 junior physicians 177 diaries days

Table 21 Use of interviews in virtual community research (page 2 of 2)

Author/country/HCP/social media type	Aim	Design	Sample/data corpus
Foong India; Plastic surgeons Discussion forum (Foong & McGrouther 2010)	To assess the value of discussions in relation to education and aiding patient management	Qualitative descriptive	Calendar year
Archambault Canada; Emergency specialty Wiki (Archambault et al. 2012)	To explore participants beliefs on the utility of wiki based reminder regarding best practice management of severe traumatic brain injury	Qualitative	3 sites 25 emergency physicians 25 allied health
Frisch Canada; Nurses VCoP (Frisch et al. 2014)	To evaluate whether VCoP from the perspective of users	Mixed methods Descriptive 2 Surveys –Interviews	Monthly website metrics from inception Census sample for survey Purposive sample for interviews
Tunnecliff Pacific researchers; Social media (Tunnecliff et al. 2015)	To explore health researchers and clinicians current use of social media and their beliefs and attitudes towards the use of social media in professional context	Mixed methods Online survey Interviews	Targeted distribution Interviews self-nominated then randomly selected

Aim and Objectives

The aim of this study was to explore 'why' HCPs belong to ICUConnect. The related research objectives were to: 1) understand why members join and remain a member; 2) identify what purpose the VC serves in in their professional lives; 3) identify how a member uses the VC; and 4) identify how members used the knowledge or resources shared on the VC.

Methods

In this section the following is presented: 1) design; 2) ethics; 3) setting; 4) participants and sample; 5) online focus groups; 6) key informant interviews; 7) data collection; 8) data management; 9) data analysis; 10) study quality; and 11) researcher bias and relationship with participants.

Design

A pragmatic realist design was developed to collect data using three asynchronous online focus groups and key informant interviews, with participants allocated to a group based on their posting behaviours in the past two years. The theoretical lens for the study was the Diffusion of Innovations theory (Rogers 2003).

Ethics

Two approvals were obtained from the Human Research Ethics Committee of the University of Technology Sydney (see appendices L and M). The first approval (UTS HREC REF NO. 2014000378) covered the online focus groups. For the online focus groups participant confidentiality was ensured by: 1) a group rule was developed, covering non-disclosure of participant names or sharing the content of posts, and

participants agreed to abide by this on registration; 2) focus groups being convened within a secure website using a closed, password protected discussion forum with the social media sharing function disabled. These layers were designed to ensure participant confidentiality and prevent forum posts from being searchable via the Web (Whitehead 2007).

An amendment to undertake key informant interviews (UTS HREC 2014000683) was later granted because of a shortfall in recruitment for the frequent poster focus group. These interviews were recorded on a mobile phone (without back-up to the Internet) or using Free Skype recorder (© Alexander Nikiforov) via Skype (Skype communications SARL, Microsoft Corporation, Luxembourg). Participant identifying information could not be removed from the online focus groups text, but were removed from transcribed interviews. All participants were given a unique identifier number to maintain a link with their original data. Confidentiality of participants was maintained by storing original data including focus group data and interviews (as mp3 files) within a university-authorized secure cloud server (Oxygen). Participant de-identification was maintained during reporting by describing participants using the taxonomy developed in Social Network study . Informed consent for participants was included as part of the online registration form.

Setting - Virtual community

At the time of data collection (July to December 2014), there were approximately 1600 members on ICUConnect who worked at more than 225 healthcare facilities, universities and industry partners. While these HCPs were from several countries, the majority were from Australia with nurses the largest professional group.

Participants and Sample

A purposive stratified sampling method (Cresswell 2014) was used to recruit all participants for the online focus groups and subsequently the key informant interviews. The aim was to recruit eight to twelve participants for each of the three focus groups, the current recommendation on sampling for both traditional (Liamputtong 2011) and online (Hatten et al. 2014) focus groups. ICUConnect members were invited to participate via a recruitment email that included all participant information, an invitation to contact the research team for further information, and a link to the online recruitment form (Google forms) (Google, Mountainview, California, USA). The online recruitment form included participant information, consent, participant demographics and a short survey covering group rules (Netiquette) (see appendix N). Once a potential participant had completed the online registration and consent, their posting behaviour was checked, assigned to a focus group and notified of the details regarding this focus group.

As the literature review had demonstrated that VC members can be grouped according to their online posting behaviours, three focus groups were structured around this attribute to develop understanding from a range of member behaviours. Participants were assigned to a focus group based on their ICUConnect posting activities between September 1 2012 and August 31 2014: 1) frequent (more than five times); 2) low (five times or less); and 3) non-posters. Registrations to participate were not restricted; drop-outs or inability to participate had been identified as limitations in earlier research (Alonzo 2009; Tates et al. 2009). The only exclusion criterion was non-availability during the three-week time frame for each focus group.

Recruitment challenges were anticipated and experienced (See appendix O) because, as noted in the literature, a minority of members post, thus reducing the number of potential candidates for the posting groups from ICUConnect. A limited review of twelve months activity identified at least 25 members eligible for each of these groups. While there were a high number of potential participants for the non-posting group, these members are generally reluctant to post for a variety of reasons, especially about how their contribution might be received by members of the virtual community. It was anticipated that by convening focus groups where the shared characteristic was posting behaviours, the online environment would be comfortable for members and they would feel confident that their contributions would be welcomed in a positive and supportive environment (Williams et al. 2012).

A shortfall in recruitment for frequent poster group was subsequently identified, and the protocol was revised for this group to include key informant interviews. Members were then recruited from the initial list of members who fulfilled the criteria of being a frequent poster. Initially five individuals were sent an email inviting them to participate with a further two contacted to achieve an appropriate amount and quality of data.

Online focus groups

Each focus group was conducted over three weeks using a closed discussion forum (IPBoard version 3 © Invision, Powerboard, Forest, Virginia, USA) hosted on a secure jurisdictional health department website. The host site was chosen as it was accessible and useable across fixed and mobile technologies for all participants.

A question guide (see table 22) was used, with items based on the study questions and informed by the theoretical framework of 'Diffusion of innovations' (Rogers 2003).

Each question formed a discrete discussion thread around a specific aspect of the virtual community that was explored. A standard schedule was used with new questions posted every two-three days depending on how asynchronous discussion threads were developing.

This schedule allowed for the question guide to be refined based on data from the previous group (Turner III 2010). Changes were discussed between the candidate and the supervisor. For each focus group, there were two weeks of active discussions with each forum kept open for another week to allow participants to add any further comments. The focus groups were held in the following order 1) low posters; 2) non-posters; and 3) frequent posters, with the low- and non-posting groups overlapping by a week.

Table 22 Index question guide

Question type	Questions	Possible aspect of Diffusion of Innovations¹⁻²
Introductory	1. Please introduce yourself and tell the group about your professional role and experience	
Transition	2. You were invited to this focus group because you are a member of ICUConnect. Could you explain what prompted you to join?	Type of adopter; homophily; influence of peers
Transition	3. Do you use any other social media or online communities for professional networking and development?	Type of adopter; External orientation; interconnectedness; Innovation characteristics of social media
Key	4. What do you value most about ICUConnect?	Access to colleagues (Homophily, External orientation; interconnectedness ; Innovation characteristics of social media
Key	5. What are the least valuable aspects of ICUConnect	Innovation characteristics of social media
Key	6. What advantages or disadvantages does ICUConnect have over other social media?	See above
Key	7. Current research indicates that there are active users of virtual communities (individuals who post) and passive users (individuals who mainly read &/or share). How would you describe how you use ICUConnect?	Type of innovator: role of individual in local social network
Key	8. Do you share ICUConnect posts with other professional colleagues?	Role of individual in local social network; external orientation
Key	9. Is there a post in the past 3 months that has been of high relevance to you?	Knowledge (innovation) on IC-VC is credible
Key	10. Have you been able to use any posts from the last 6 months of discussions?	As above
Concluding	11. Are there any other important aspects of ICUConnect that we have not discussed?	As above

1 (Greenhalgh et al. 2005a; Rogers 2003)

2 see figure 2 and table 2

Moderating the focus groups

The approach to focus group moderation was based on principles from moderating traditional focus groups (Liamputtong 2011), and facilitation of learning online or e-moderating (Barbour 2007; Bringsvor, Bentsen & Berland 2014; Salmon 2011). The candidate was the focus group moderator and an experienced intensive care nurse, and the previous moderator of the VC; the principal supervisor acted as a non-participant observer. An approach was developed to maximise conditions for the development of rich data by facilitating optimal participation and interaction, and safeguarding participant confidentiality. These conditions also supported moderation and effective data collection.

A discussion forum was chosen as the technology platform for a number of reasons. Discussion forums are asynchronous and create a chronological electronic record that enable participants to review what has been posted, have time to consider and formulate a response, and then post at a time convenient to them (Kenny 2005). This egalitarian online atmosphere ensured that all focus group participants had the opportunity to provide input, increasing participant control and encouraging detailed and reflective answers, and thus richer data (Liamputtong 2011). As discussions evolved, a chronological record was created providing participants with discussion points allowing them to review and consider other participant inputs and add their own. Data collection for the online focus groups was therefore automatic.

Following e-moderating (Salmon 2011) and focus group principles (Alonzo 2009; Liamputtong 2011; Tates et al. 2009) the following actions were undertaken during the focus groups:

- To promote access to the technology and motivation for participation, consenting VC members were provided with technical support (including a how-to-guide delivered with the first email), and any questions were directly responded to and feedback provided. In addition, each participant was welcomed as they joined the focus group and made aware of moderator actions and the level of online presence expected, namely logging in on a regular basis.
- To promote socialisation and engagement, ongoing technical support was provided, and to enhance participant confidence posts were acknowledged and responded to (where appropriate) using supportive language and emojis. This acknowledgement served to indicate to all participants that all contributions were valuable.
- To encourage participant input and interaction (information exchange), and facilitate study visibility when a new question was posted, a concurrent email using a standardised subject heading was sent to participants; sign post, contextual and update information were also included
- To promote development of a shared understanding of the question and encourage contributions (knowledge construction) clarifying questions were asked on a regular basis
- To ascertain whether a shared understanding or group consensus was developing, discussions were summarised and the group was asked whether the summary reflected their experience.

Key informant interviews

Four frequent posters were purposively recruited and interviewed to address the shortfall in the number of participants in the frequent poster focus group. Three interviews were face to face as participants were located in metropolitan Sydney, and one was conducted via Skype as the participant was located outside this area. The interview guide used was the final list of questions that evolved from the three focus groups (see table 23)

Table 23 Final question guide for online focus group and key informant interviews

Type of question	Question
Introductory	1. Please tell me about your professional role and experience
Transition	2. You were invited to this interview because you are a member of ICUConnect. Could you explain what prompted you to join
Transition	3. ICUConnect is a listserv, one of the oldest kinds of social media platforms. <ol style="list-style-type: none"> a. Do you use any other social media or online communities for professional networking and development? b. Does ICUConnect have any advantages or disadvantages to these?
Key	4. What do you value most about ICUConnect? And What do you value least about ICUConnect?
Key	5. Current research indicates that there are active users of virtual communities (individuals who post) and passive users (individuals who mainly read &/or share). As an active/passive user how would you describe your use of ICUConnect?
Key	6. Have you been able to use any posts from the last 6 months of discussions to inform your practice?
Key	7. Can you describe a post in the past 3 months that has been of high relevance to you? Why?
Concluding	8. Are there any other important aspects of ICUConnect that we have not discussed?

Data collection

Data collected included: 1) demographic data describing participant characteristics; 2) categorical data describing discussion forum participation; 3) discussion threads documenting focus group discussion; 4) transcripts of key informant interviews; and 5) field notes and research diary. Field notes recorded what the researcher experiences during data collection and includes: 1) both a description of and reflection on what occurred; 2) a reflections on personal thoughts and feelings; and 3) any insights, judgments, and interpretations made in the field (Borbasi & Jackson 2012; Noble & Smith 2015). Once collected, data was stored in an NVIVO file (Versions 10 and 11, QRS International, Melbourne Australia).

Data from the three online focus groups was collected using a discussion forum (October to December 2014) while key informant interviews (February to June 2015) were completed either in person and recorded on a mobile phone (n=3) or via Skype (n=1) using MP3 Skype recorder

The online focus group data (discussion threads) were extracted from the forums using NCapture (QRS International, Melbourne Australia), and imported into NVIVO. Key informant interviews from MP3 files were transcribed via an online service available through NVIVO (Transcribe Me!, Berkeley, California, USA). Any personal identifying information was removed and the interview transcripts were also imported into NVIVO. Field notes were developed concurrently with the online focus groups and during data analysis using the memo function of NVIVO. An interview sheet was used to make notes during the interviews and this was scanned and imported into NVIVO.

Data management

NVIVO was used to manage data and facilitate analyses. An excel spreadsheet was initially developed using the demographic data provided by participants on enrolment. This was imported into NVIVO as a casenode classification sheet, which in turn enabled group and participant comparisons during data analyses. A casenode is a participant and enables linkage of data to its origin. Within NVIVO demographic data becomes an attribute or variable for a research participant (Bazeley & Jackson 2013). Backups of the NVIVO files were kept securely in the university-approved cloud.

Data analysis

In keeping with the pragmatic realist approach, analysis of focus group and key informant interviews was completed using a six-step thematic approach to enable systematic identification, interpretation and reporting of patterns and themes emerging from the data (Braun & Clarke 2006). Diffusion of innovations (Rogers 2003) was selected as the theoretical lens, as it aligned with both the broad problem of inadequate social networks limiting knowledge diffusion in healthcare and current gaps in the literature. Several behavioural models have been used in previous literature including theory of reasoned action (Lau 2011), theory of planned behaviour (Lau 2011) and technology acceptance model (McGowan et al. 2012) and have produced important insights. These were not used however, as their focus is on an individual's behaviour rather than collective behaviours as they occur within a social network.

The six-step data analysis process included:

1. Data immersion through active reading of discussion threads and interview transcripts to identify meanings or patterns. This familiarisation commenced during data collection in the dual role of researcher-moderator. As indicated earlier, the principal supervisor monitored focus group discussions as a non-participant observer.
2. Data was coded to the casenode (the participant source), the question node, and then inductive coding to a node. A node was a representation or abstraction of what the researcher perceived the participant meant by the data they provided (Bazeley & Jackson 2013). This process ensured that nodes remained linked to their context and source, informing the audit trail and facilitating evaluation based on participant attributes such as posting frequency and professional role. As nodes were identified a descriptor was included to support systematic coding of theory driven nodes (Richards & Morse 2013).
3. Nodes for each question were reviewed and collapsed into candidate themes. A theme is an abstraction that represents a consistent and significant pattern arising from the data as it relates to the research question/s (Braun & Clarke 2006; Richards & Morse 2013). A research report was developed and discussed at research team meetings until agreement regarding direction of analysis and nodes and themes was reached.
4. Candidate themes were reviewed to highlight coherent patterns supported by consistent data. An initial thematic map was developed using the key aspect of DoI as temporary groupings, and candidate themes were moved into these groups. Matrix coding was then used to compare and contrast themes and to identify if there were any consistent patterns between different types of

members (using attributes from the casenode classification sheet). During this process the whole data set was re-read to confirm consistency in the emergent themes; that is considering whether the data did or did not fit the assigned theme (Bazeley & Jackson 2013). As part of the research diary the memo function was used to describe each theme, to develop the story of its place within the broader narrative and add links across to other themes where applicable (Richards & Morse 2013).

5. Theme re-working and refinement was completed by identifying the essence of each theme and determining which aspect of the data it captured. This involved development of a detailed analysis of each theme and its associated sub-themes, and how these interacted to provide the overall structure of the overarching theme (Braun & Clarke 2006). A key aspect of this was consideration of how all the elements fitted into broader narrative being told by the participants (Braun & Clarke 2006).
6. Findings were synthesised in a final research report.

Study quality

Rigour in qualitative research is a contentious space (Borbasi & Jackson 2012; Porter 2007; Shenton 2004). The preferred terms of 'trustworthiness' or 'confirmability' reflect accuracy and comprehensiveness in how data was collected, analyzed and reported. For this study, a number of strategies were used. Credibility of data was enhanced as focus group participants had direct control over their contributions and this was collected in real time; meaning that member checking of data accuracy was not required (Cresswell 2014). Interview transcripts were compared with the audio

files to ensure accuracy. Finally, use of the NVIVO software as the major study file repository for all data and an excel workbook that collected demographic data established a clear audit trail (Noble & Smith 2015).

A thick description of the research context is provided by describing the participants (using the recruitment survey), virtual community, and research process (Shenton 2004). Auditability is supported by field notes, recording impressions arising from focus groups and interviews and incites developed during data analysis, and NVIVO to manage data analyses. Credibility of themes was facilitated by use of summarising and clarification questions during focus groups (member checking) and interviews, and recording a consensus node during data analysis. Unfortunately planned member checking of preliminary themes following formal data analyses was not possible due to the lengthy time period between data collection and analyses, and loss of contact with a number of participants.

Researcher bias and relationship with participants

The potential for bias in qualitative research may be significant when assumptions and biases of the researchers are not identified and managed (Cresswell 2014). In addition, where there is an unequal or prior relationship between the research team and participants, data collected may not reflect the reality of participant experiences (Karnieli-Miller, Strier & Pessach 2009). In this study, and as noted previously, the candidate was a long-term moderator of the VC and the principal supervisor was a member; however, other supervisors were not members or associated with the VC. To manage any potential for bias during data collection and analyses and establish a welcoming non-hierarchical atmosphere, a number of procedures were implemented:

- The candidate withdrew from the moderator role several months prior to VC members being informed of the planned research (all stages of the study)
- To minimise coercion, in all communications, the candidate used non-authoritative language and did not make any direct communications with individual members
- The candidate completed a bracketing process prior to the first focus group, outlining the researcher position by documenting any assumptions and therefore identifying potential sources of bias (Ahern 1999; Hanson 2011). This formed part of the research diary and these assumptions were revisited during data analyses
- During the focus groups, the roles of researcher and moderator (candidate) and non-participant observer (principal supervisor) were made explicit; and
- To minimise bias and enhance credibility, all researchers were responsible for data analysis.

Member checking of early themes was undertaken during focus groups and was accomplished by summarising responses where responses were converging.

Findings

This section reports study findings within the context of the Diffusion of Innovations.

The participants, including the participants as innovators, are initially described, followed by ICUConnect as social media, and then presentation of the overarching theme of why HCP belong to the VC. Participant contributions are reported verbatim except for correction of spelling and removal of participant names (where included).

Participants

Recruitment

Focus group recruitment success was mixed with 16 and nine respectively registering for the low- and non-poster groups; only four frequent posters registered (See appendix N). As discussed earlier this limited recruitment triggered inclusion of key-informant interviews. In the first round of recruitment for interviews, three of five frequent posters responded and agreed to be interviewed, however only two of these occurred. The next two frequent posters were contacted and completed interviews.

Participant characteristics

Of the 29 members who enrolled for the focus groups, 23 actually participated (three frequent posters; 13 low posters; and seven non posters). Overall there were 27 participants (seven frequent posters; 13 low posters; seven non-posters) (see table 24) As only three of four registrants participated in the frequent poster focus group, there were four subsequent key informant interviews.

Table 24 Participant description

Participant code	No of VC posts	Healthcare professional type	Professional member type	Primary workplace
Frequent posters (focus group 1 and key-informant interviews)				
FG1-1	9	Nurse	^a NUM	Adult ICU
FG1-2	19	Nurse	^b Knowledge Broker	Local health district
FG1-3	17	Nurse	^b Knowledge Broker	State-wide public health service
KI-FP-1	23	Physician	^c Staff specialist	Adult ICU
KI-FP-2	26	Nurse	^a NUM	Adult ICU
KI-FP-3	10	Nurse	^b Knowledge Broker	Adult ICU
KI-FP-4	18	Nurse	^b Knowledge Broker	Adult ICU
Low posters (focus group 2)				
FG2-1	4	Nurse	^d Nurse Academic	University
FG2-2	2	Nurse	^e Clinical nurse-internal	Adult ICU
FG2-3	1	Nurse	^d Nurse Academic	University
FG2-4	4	Nurse	^d Nurse academic	University
FG2-5	3	Nurse	^f Clinical nurse-external	Hospital specialty service
FG2-6	1	Nurse	^a NUM	Coronary care
FG2-7	1	Physician	^c Staff specialist	Adult ICU
FG2-8	1	Nurse	^e Clinical nurse-internal	Adult ICU
FG2-9	1	Nurse	^e Clinical nurse-internal	Adult ICU
FG2-10	1	Nurse	^a NUM	Adult ICU
FG2-11	2	Nurse	^b Knowledge Broker	Adult ICU
FG2-12	1	Nurse	^b Knowledge Broker	Adult ICU
FG2-13	4	Nurse	^d Nurse Academic	Adult ICU
Non posters (focus group 3)				
FG3-1	0	Nurse	^f Clinical nurse-external	Retrieval service
FG3-2	0	Allied Health	Physiotherapist	Adult ICU
FG3-3	0	Nurse	^a NUM	Adult ICU
FG3-4	0	Healthcare manager	^g Healthcare manager	Data Analyst
FG3-5	0	Nurse	^d Nurse Academic	University
FG3-6	0	Nurse	^b Knowledge Broker	Office
FG3-7	0	Nurse	^b Knowledge Broker	Adult ICU
^a Clinical nurse-internal - provides clinical services within a clinical unit				
^b Clinical nurse-external - provides clinical services across multiple clinical unit				
^c Knowledge Broker - job role could include advanced practice, education, research or practice development				
^d Clinical unit manager – manages a defined ward or clinical area				
^e Nurse academic– employed by a tertiary education institution				
^f Healthcare manager - employed in a non-clinical or managerial role in health service				

A large majority were nurses (85.2%; n=23/27), with KB nurses the largest single type of member (29.6%; 8/27). Academic nurses and nursing unit managers (NUM) were the next largest groups (5/27 each). Only two physicians and one allied health professional participated. Sixty-three percent (17/27) worked in NSW, and 37% were employed in a public hospital. The other ten participants were from Western Australia (n=4), South Australia (n=3), Victoria (n=3) and one each from Queensland and Ontario, Canada. All participants had significant experience as HCP and intensive care clinicians with frequent poster participants the most experienced (see table 25). There were limited meaningful differences in these attributes according to member type (see appendix P). Length of professional experience suggests that all participants were digital immigrants, that is born before 1980 (Tapscott 2000), although generational differences in technology use and competence are now under question (Helsper & Eynon 2010; Margaryan, Littlejohn & Vojt 2011).

Table 25 Professional and intensive care experience of participants

	Frequent posters (n=7) mean (SD; range)	Low Posters (n=13) mean (SD; range)	Non-posters (n=7) mean (SD; range)	All participants (n=27) mean (SD; range)
Intensive care experience	23.00 (2.70; 20-27)	17.46 (6.46; 7-27)	21.14 (7.96; 12-34)	19.85 (6.44; 7-34)
Professional experience	30.29 (4.25; 23-36)	23.77 (7.24; 12-32)	25.14 (8.13; 15-34)	25.81 (7.26; 12-36)

Participants as innovators

Personal characteristics of participants emerged over the course of discussions and interviews, with some differences emerging between focus groups. All participants

could be categorised as engaged committed professionals, although participants from the posting groups exhibited stronger external orientation or boundary spanning than non-posters. The latter was evident by the frequency with which they described sharing ICUConnect discussions with colleagues inside and outside their local working environment. These behaviours were personified by the following quote:

'If we don't keep in contact with other similar health professionals, we become insular and end up not providing best care to our patients. ICUConnect recognises our differences and allows/ encourages me to communicate my concerns, questions and insights to the rest of the ICU world. This provides a sense of being part of something bigger than just my own unit. Its a way of contributing to best practice and great patient care without the publishing requirement.'

NUM FG1-1

Low and non-posters shared some similar characteristics, including a lack of knowledge self-efficacy, a preference for offline communication, and being an observer.

Knowledge self-efficacy or lack of (a feeling of not having the experience or knowledge to add to a discussion) is demonstrated by the following quote:

I am an observer for a number of reasons. -as FG2-10 said the posts are often elaborated on and made more complex by senior medico's. I do not feel I can contribute at that level and often have nothing new to add. I have worked for a number of years away from the floor of the ICU in roles such as CNM (still in a Crit Care area but not ICU) and After Hours management and feel that I am not right up to date with the latest clinical information in the area. In my general workplace demeanor I am reserved but definitely not a passive person. I speak up on most topics and make sure that my opinion is taken notice of. I save my voyeurism for ICUConnect! **NUM FG2-6**

A number of participants from these groups also revealed they tended to post directly and privately to a fellow member, often citing a preference for one to one or

synchronous communication. Being a lurker (non-poster) or observer was described by low posters only.

The use of other social media for professional networking and education revealed one difference between poster or member types. Overall, 60% (n=16/27) indicated they used other social media, four indicated a limited use and five said no (two did not respond to this question). A majority of frequent posters (71.4%; 5/7) indicated professional use of other social media whereas just over half of low (53.8%; 7/13) and non-posters (57.1%; 4/7) did. Other speciality-specific VCs (discussion forums or listservs) were the most common extra social media used (7/27) followed by Researchgate (n=6); twitter (n=5) and podcasts or You-tube (n=4). Facebook was commonly used for personal networking only (13/27).

These findings reflect the current literature that HCPs prefer closed speciality- or discipline specific VCs (McGowan et al. 2012), although this is counter to evidence suggesting limited professional use of social media by HCPs (Apostolakis et al. 2012; Deen, Withers & Hellerstein 2013; Hughes et al. 2009; Klee, Covey & Zhong 2015; Kukreja, Heck Sheehan & Riggins 2011; McGowan et al. 2012). While there are inadequate data in this present study to specifically categorise participants, by virtue of their membership of ICUConnect, they possibly belong to the left side of the innovator curve (See figure 2), as they demonstrate communication channels outside their immediate professional social network.

Almost two-thirds of this small group of experienced HCPs exhibited strong cosmopile behaviour (Rogers 2003), with the use of multiple social media channels. There was also a signal that frequent posters demonstrated different usage behaviours, reflecting

previous research that frequent posters participate in more boundary spanning activities (Hara & Hew 2007). This suggests these HCPs are open to new ideas, which was consistent with a population-based study (United States; random sample of 10000 stratified for age and gender) that reported a significant relationship between being open to new experiences, age and social media use (Correa, Hinsley & De Zuniga 2010). In summary, this group of HCPs were oriented towards change and the broader heterogeneous social network of ICUConnect, which provided them with significant access to novel information thus increasing their ability to innovate locally.

ICUConnect as social media

ICUConnect, a non-internet based listserv, was perceived by participants to be superior to other social media in terms of compatibility, complexity and relative advantage (see table 1 in Chapter 2). Importantly, other social media were not as compatible with their professional values and beliefs because of the volume of information and the intrusiveness of non-professional information, as described by the following participant:

“Truthfully I am not so keen on social media it tends to be quite intrusive. I know. My colleagues share a lot of information on Facebook which can be risky”

Clinical nurse-Internal FG2-2

Additionally the use of language was seen as problematic:

‘Not a fan of Twitter as I am old school & don't like abbreviation as can be misinterpreted especially with medical terminology.’

Clinical nurse-Internal FG2-8

ICUConnect also had a relative advantage over other media because it was (mostly) specific to the Australian intensive care context and queries were answered quickly. A

limited number of participants indicated they could not see the relevance of using other media. Lastly ICUConnect was perceived as being less complex to use, especially for non-tech savvy older members, as described in the following quote:

'As an email listserv, it is much easier for people to follow and archive the conversation, as FG3-1 mentioned in the last question, compared to Twitter, where it is less easy to follow conversations (or at least all the people commenting on the conversation) - other than setting up reports in Sympur etc, which requires much more planning and attention than just receiving an email.'

Physiotherapist FG3-2

These findings suggest that ICUConnect was adopted by these participants because the VC provided a superior way of communicating with colleagues, was congruent with professional values and beliefs, and was relatively easy to use in comparison to other social media. These data align with previous evidence indicating that HCPs have a preference for closed professional VCs (McGowan et al. 2012) with perceived high usefulness (Lau 2011; McGowan et al. 2012) and low complexity (Hew & Hara 2007b; Tunnecliff et al. 2015). Early research on use of Internet technologies by different generations suggests that a contributing factor might be that all participants were digital immigrants and therefore perceive newer platforms as more difficult to use (Tapscott 2000). As noted earlier however, more recent research has questioned the assumption that those born before the Internet was established are less technological capable than digital natives (born after 1980) (Helsper & Eynon 2010; Margaryan, Littlejohn & Vojt 2011).

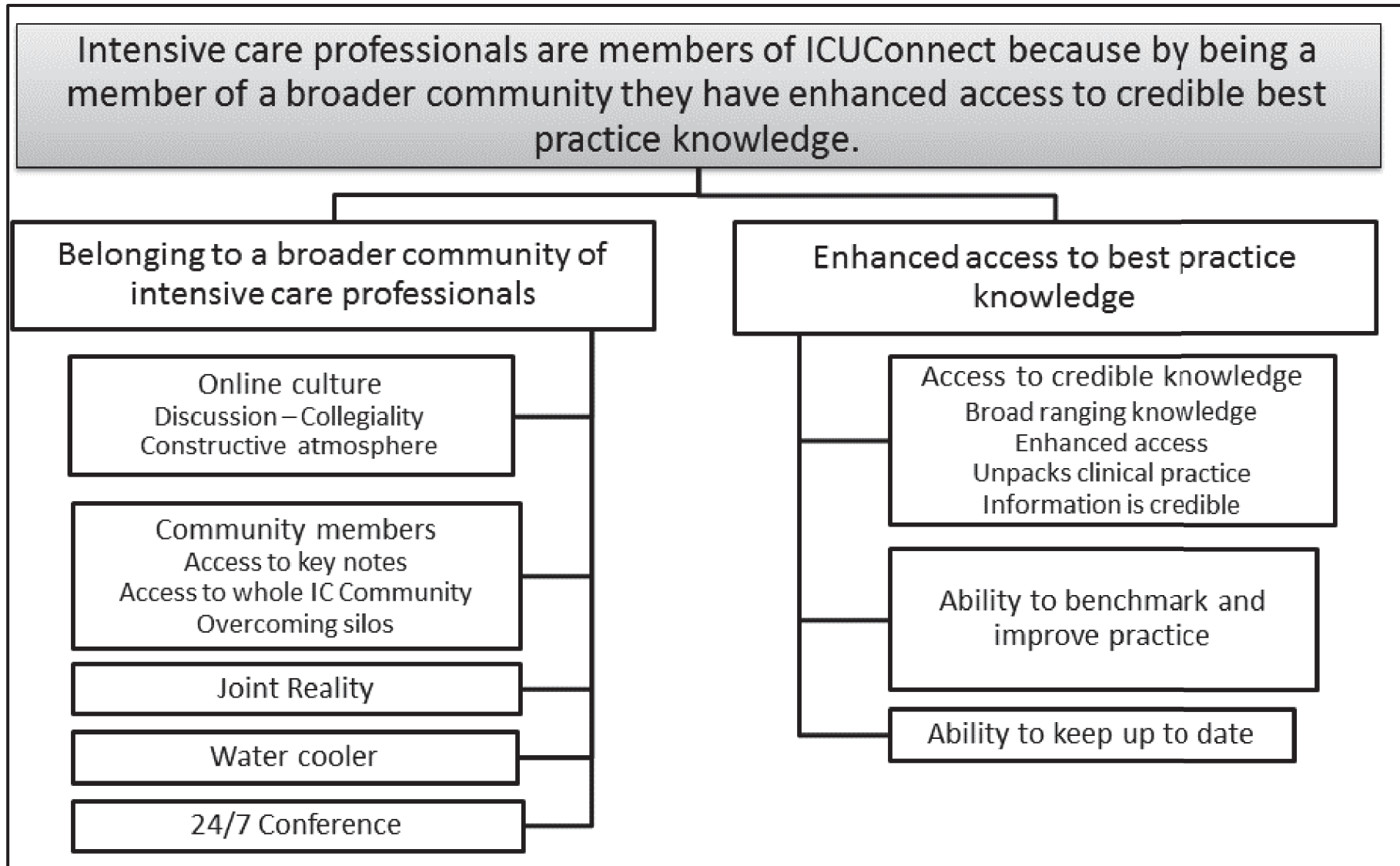
Also noted was that closed VCs may be a function of the need for privacy and psychological safety in a professional VC (Amichai-Hamburger et al. 2016), with communities also favoured by teachers (Booth 2012). Useability (how intuitive and easy it is for members to interact within a VC) is also an integral component of ongoing

success (Liao & Chou 2012; Preece 2001), with an important difference between non and high posters (Liao & Chou 2012). While user needs drive individuals to experiment with social media, the perceived innovation characteristics of that media will influence final adoption decisions (Amichai-Hamburger et al. 2016; Zolkepli & Kamarulzaman 2015).

Why we belong - Theme

The over-arching theme identified from these findings was that these HCPs are members of ICUConnect because being a member of a broad intensive care community enhanced their access to credible best practice knowledge. This Theme was divided into two sub-themes, each with elements that provided structure and context for the Theme (See figure 11). Within the lens of DoI, the first sub-theme of 'Belonging to a broader community of intensive care professionals' (short name Belonging to a community) embodies the social system of ICUConnect while 'enhancing access to best practice knowledge' (short name – Access to knowledge) represents how the VC facilitates innovation access for members.

Figure 11 Thematic map



Sub-theme-Belonging to a broader intensive care community

This sub-theme was complex and displayed five elements: the online culture of ICUConnect, community members, the joint reality of member experiences, and with ICUConnect likened to a water-cooler, and a 24/7 professional conference. These elements are discussed in further detail below.

Online culture

The online culture of ICUConnect was the largest element of this sub-theme and was highly valued by members regardless of posting level / behaviours. This culture was characterised by discussions, collegiality and informality. Discussions were the dominant characteristic described and were viewed as being both highly and least valued by participants. When described positively, discussions were portrayed as informative and entertaining cross-disciplinary debates that provided valuable perspectives not available locally (See exemplar 3).

Exemplar 3 Online culture – positive discussion

Poster type	Participant / quote
Frequent	<p>Equipment manager KI-2</p> <p><i>I think it's the opportunity to speak to other colleagues, be that medical or nursing, and to drill down to some of the points, ...at the time, you know, we all had this good debate, and I think it-- I think as the debate progressed, more people came in on that discussion, um, and I think the wider community hopefully benefited from that. So, I think having a dialogue is of benefit.</i></p>
Low	<p>NUM FG2-10</p> <p><i>'I think the debate come from having so many different clinicians/ managers/ DRs that there are so many different points to so many questions. The discussion often illuminates all these areas. Being from a rural hospital gives you a different perspective then our city cousins'</i></p>
Non	<p>Nurse academic FG3-5</p> <p><i>'I also value most of the discussions, and like FG3-2 would like comment s to go to the whole list as they're interesting to read. I don't mind if old topics get dredged up-more because I'm curious what the latest is.'</i></p>

Conversely, concerns were noted that on occasion discussions were limited by a lack of robust argument, or answers were not evidence based or well-informed, and that some members used discussions for self-aggrandisement. Several participants voiced a reluctance to participate in ICUConnect discussions because of concerns about how posts might be perceived or received. While others felt that limitations on participation were due to nurses being unwilling to take part in robust or challenging discussions (see exemplar 4).

Exemplar 4 Online culture - negative discussion

Poster type	Participant / quote
Frequent	Staff specialist KI-1 <i>That's slightly disappointing with ICUConnect. The majority of peoples tend not to want to engage in a discussion ... think the majority of members of ICUConnect are clinical nurses, , who may not be so willing to put their heads up</i>
Low	Clinical nurse – external FG2-5 <i>Sometimes I feel that the conversation gets 'hijacked' by Senior MO's who get into a 'my way's better than your way' contest which actually becomes quite amusing reading at times</i>
Non	Healthcare manager FG3-4 <i>In terms of negatives, all i can think of (and I really had to think!) is that some posts can be misunderstood if you do not know the person posting (especially for those who are new to ICUConnect). One might say that some would be discouraged from posting, fearing a "not so favourable" reply that is FOREVER there for the whole .</i>

Another characteristic of online culture that members cited as a reason to join and was also valued was the collegiality found within ICUConnect. This collegiality was exemplified by altruism (expressed by frequent posters), the willingness of members to share with colleagues and that help was available when asked for. Significantly this collegiality extended beyond nursing and medicine to include allied health members (See exemplar 5).

Exemplar 5 Online culture - Collegiality

Poster type	Participant / quote
Frequent	Knowledge broker nurse FG1- <i>'So I most value the knowledge flow and the collegiality of knowledge sharing.'</i>
Low	Clinical nurse external FG2—5 <i>'Since my role has changed, I have used ICU Connect a little more to seek out advice and ideas from other areas. Much of the responses have been very positive and I have enjoyed the sharing and caring.'</i>
Non	Physiotherapist FG3-2' <i>I find the ICUConnect group very willing to share expertise, resource links and comment, so as an engaged group I feel this is a good example of a virtual community (similar to Twitter in that respect Kaye - it helps us connect to likeminded individuals and participate in the conversation (or at least observe it) in bites of time that may otherwise not be useful for much).'</i>

The final characteristic of online culture was a constructive atmosphere or tone that expedited access to knowledge. This atmosphere was perceived to be respectful and informal, and importantly lacking malicious interactions, such as flaming or disparaging comments (see exemplar 6). It should be acknowledged however that several participants remained concerned regarding the reception of their posts (see exemplar 5, above).

Exemplar 6 Online culture - Constructive atmosphere

Poster type	Participant / quote
Frequent	<i>Knowledge broker KI-3</i> <i>'and I think I like principally the respectful way that people-- or that they visibly deal with queries and questions and so on. And I've seen a few kind of attempts to correct direction through the years, and they've all seemed to be received well and I've agreed with them all. So I guess that it's a respectful environment that people feel really free to ask questions, sometimes over and over and over again.'</i>
Low	<i>Nurse academic FG2-1</i> <i>'I value the ideas/views of the Connectors. It is like having a conversation with someone either in person or phone. There is no formality in that you don't have to read the abstract lit review etc before you get to the information.'</i>

Overall participant perceptions were that the online culture was constructive, collegial and informal, with informative and entertaining cross-disciplinary debates that provided valuable perspectives. These findings are congruent with current data which emphasises how important the relationship between a positive online culture and a knowledge sharing ethos is for the continued success of a VC (Blanchard, Welbourne & Boughton 2011; Lin, Fan & Wallace 2013; Sun, Fang & Lim 2012). Important characteristics influencing culture noted by other studies included the tone of discussion (Rolls et al. 2008; Widemark 2008), unprofessional behaviour (Tunnecliff et al. 2015; Widemark 2008) and a non-competitive environment (Hara & Hew 2007).

There were however varying perceptions, also similar to previous research (Irvine-Smith 2009; Widemark 2008), that influenced participants' experiences in ICUConnect.

Community members

The second element of the 'belonging' sub-theme was community members, characterised by access to keynotes, access to the whole of the intensive care community, the ability to network, and overcoming the silos. The ability to access intensive care experts ('keynotes') was highly valued by members and was cited as a reason to read a post (see exemplar 7).

Exemplar 7 Community members - access to keynotes

Poster type	Participant / quote
Frequent	Equipment NUM KI-2 <i>'I think the value is-- uh, it's also the value of-of resource people, knowing regular posters, I suppose, and people that then become resource for areas of expertise.'</i>
Low	Nurse academic FG2-3 <i>'So, what I like about ICU connect is the opportunity for those with specialised knowledge or opinion in a specific area to share that with others and help raise the standard of practice and patient care. So what do I value most - the opportunity to raise the standard of care for patients in ICU'</i>
Non	Clinical nurse – external FG3-1 <i>'If I see a topic I may not be interested in particularly, but I see one of these people have commented, I may then read the original message and a few other comments - this gives me a quick gist of the flow of the topic ,I then read the keynote response. ...I value the high calibre of expertise in the contributors to ICU connect, thereby I am able to rely on information provided, or at least follow their guidance to view recommended sites to research.'</i>

Another important characteristic of community members was that because ICUConnect included the whole of the intensive care community, the VC made members feel a part of a broader community that facilitated their ability to network (see exemplar 8).

Exemplar 8 Community members - whole of intensive care community

Poster type	Participant / quote
Frequent	Knowledge broker FG1-3 <i>'I joined ICUConnect because I have many friends and colleagues in critical care across NSW and the idea of an online discussion group sounded innovative and a good way to talk and share ideas etc with colleagues across the state, as well as ask questions around practice, staffing issues, educational resources, guidelines etc.'</i>
Low	Knowledge broker FG2-11 <i>'Accessibility to a huge pool of fellow clinicians,'</i>
Non	Physiotherapist FG3-2 <i>ICUConnect provides me exposure to the ICU community; their thoughts; interests; discussions and topics, free of charge and easily accessible from work.'</i>

The final characteristic of community members is that the presence of a broader community allowed members to overcome any clinical or practice silos created by local organisational structures (see exemplar 9).

Exemplar 9 Community members - overcoming clinical silos

Poster type	Participant / quote
Frequent	Knowledge broker nurse FG1-3 <i>the very small number of dedicated children's hospitals and PICUs doesn't easily lend itself to groups like this, so we are forced out into the big wide world. Personally I have always felt this was a good thing as its easy to become a bit insular. Groups like ICUConnect are great for helping avoid that.</i>
Non	Clinical nurse external FG3-1 <i>'We all can get caught up in our " own world" and then we never progress , so this world allows QI to progress via discussion and research among like groups in a more timely manner.'</i>

Joint reality

The next element of *Belonging to a broader community* was joint reality, where participants expressed feelings of being connected to the Community, particularly when colleagues disclosed that they were experiencing similar clinical practice issues. For frequent posters this then engendered a sense of contributing to improving patient care on a broader scale (See exemplar 10). This element symbolises perceived homophily; that is a sense of belonging to a like-minded group with shared values and experiences (Rogers 2003).

Exemplar 10 Community members - Joint reality

Poster type	Participant / quote
Frequent	Knowledge broker nurse FG1-3 <i>'I would have to say its the professional one I use the most, unquestionably. I actually like the feeling of professional connectedness it brings with it - its always good to know you're not alone and we all struggle with the same conundrums.'</i>
Low	Clinical nurse FG2-2 <i>'Innocent questions arise all the time and it is comforting know that others are thinking along those same lines and asking those same questions. Some of the problems other units have made me realise I am not alone.'</i>
Non	Healthcare manager FG3-4 <i>'I can say that the issues being discussed are definitely state-wide, if not world-wide... '</i>

Watercooler

The next element of *Belonging to a broader community* was that ICUConnect functioned like discussions around a watercooler or an informal meeting place (Fayard & Weeks 2007; Siu 2015), where participants described using discussions to initiate conversations with work colleagues and reflect on local practices. This element was described most often by low posters but only occasionally by frequent or non-posters. As a watercooler space, ICUConnect was seen as an extension of their local unit with information that could be used locally or sparking and informing informal local discussions with new perspectives, ideas and contemporaneous practice trends (see exemplar 11).

Exemplar 11 Community members - Watercooler

Poster type	Participant / quote
Frequent	Equipment NUM KI-1 <i>'There are often interesting topics of discussion and I find that questions I have may have already been answered or ideas posed that I then take to the next level of investigation. Because I work in a small unit, with very limited resources, I find the discussions useful for formulating plans of where we should be heading. The value of this type of information sharing cannot be overstated, particularly for smaller units.'</i>
Low	Clinical nurse FG2-2 <i>'I remain impressed with this forum concept and I am sure it is valuable. While I have not been able to apply any of the posts in a physical sense this is not to say that they do not inform my practice or interactions with my colleagues during our discussions regarding the performance and appraisal of clinical questions.'</i>
Non	Clinical nurse External FG3-1 <i>'It has allowed discussion and ideas that I may never have thought of and also current trends in care.'</i>

When considering the organisational literature on watercooler conversations (Vaast & Kaganer 2013), implications extend beyond this sub-theme; that is it could be viewed as a metaphor for or a descriptor of how ICUConnect functions. The term 'virtual

watercooler’ was previously used to describe how teachers similarly used a listserv to span the barriers of time and professional isolation to provide on-demand professional development, moral support and specific resources (Siu 2015).

24/7 Conference

The final element of *Belonging to a broader community* was where a small number of participants described ICUConnect as a 24/7 conference that provided immediate access to colleagues, research and evidence; a circumstance normally limited to structured professional events such as annual conferences or seminars. (See exemplar 12). The VC was therefore seen as superior or having a relative advantage over traditional professional events as it was always available and required no money or time to attend. Similar to the watercooler element and when considering other elements of the ‘Broader community’ and ‘Enhanced access to knowledge’, the 24/7 element could also be considered a descriptor of or metaphor for ICUConnect.

Exemplar 12 Community members - 24/7 conference

Poster type	Participant / quote
Low	<p>Nurse academicFG2-13</p> <p><i>‘The sharing of knowledge has never stopped at the peer reviewed journals, it has been at the bedside, at inservices, at conferences and educational days, in information journals that don't have peer review...I think this is another forum and one that is highly regarded as a place to get immediate help, not have to wait six to 12 months to get an article on research published.’</i></p>
Non	<p>Physiotherapist FG3-2</p> <p><i>‘Joining ICUConnect allows me to do this (gain other perspectives) from those working in the field, without having to take time out from work (I can access limited PD/study leave with virtually no funds available for this), and allows me to make a contribution where appropriate on topics I can contribute to, sharing my expertise.’</i></p>

The *Belonging to a broader community* sub-theme therefore embodied the social network of ICUConnect, and was a key reason to join and stay a member of the VC. Further, this present study identified that belonging to or being a part of a broader community of like-minded HCPs was an integral and highly valued component of VC membership for all members. This social network was characterised by an online culture that was highly regarded by members because of the quality of discussions, collegiality and informality. The social network also facilitated access to the whole of the intensive care community and especially to expertise from key individuals, enabling members to overcome the limitations of local clinical silos.

As social animals humans are conditioned for optimal cognitive and mental function within a social group, where they develop relational bonds and feel a sense of belonging (Baumeister & Leary 1995; Levett-Jones et al. 2007). Similar to Rogers' homophily (2003), 'belongingness' is a contextual experience where individuals feel: 1) accepted, valued and secure within a social group; 2) connected or important to the group; and 3) their professional values are in accordance with group norms (Levett-Jones & Lathlean 2008). Belongingness is therefore an important mediating factor influencing participation in interest communities (Lin, Fan & Wallace 2013; Zhuang, Chen & Zhang 2014), professional development (Levett-Jones & Lathlean 2008; Smart 2016; Widemark 2008) and proactive information-seeking behaviour and socialisation by new employees (Nifadkar & Bauer 2016).

Belonging is also an integral component for a 'sense of virtual community' (Blanchard 2008; Lin, Fan & Wallace 2013; Sun, Fang & Lim 2012) which influences how members of a VC develop trust and then participate in knowledge sharing activities online

(Blanchard, Welbourne & Boughton 2011; Lin, Fan & Wallace 2013; Sun, Fang & Lim 2012). ICUConnect therefore has appeared to have developed into a diverse MDT social network that facilitates group affiliation by promoting a collegial professional online experience. Importantly, this VC has appeared to have overcome structural, cultural and professional silos that adversely impact on knowledge exchange and creation between HCPs in contemporary local practice settings (Currie & White 2012).

Enhanced access to best practice

The second sub-theme, '*Enhanced access to best practice*' (from figure 10), represents how ICUConnect facilitates innovation access for members. This sub-theme comprised three elements: access to credible knowledge, being able to benchmark practice, and keeping up to date.

Access to credible knowledge

Access to knowledge was a minor reason cited by participants when initially asked why they joined the VC, although its prominence increased over the course of discussions.

This element had four characteristics: 1) broad ranging knowledge; 2) enhanced access; 3) unpacking of clinical practice ; and 4) credible information. For a number of members an added bonus was the opportunity to access the expertise of intensive care leaders, referred to as 'keynotes' (also previously discussed p221). No consistent patterns were identified when comparing responses from different types of member or clinician type for this element.

The dominant characteristic was access to a broad range of knowledge, including exposure to reported research, that enabled participants to develop local practices and resources. When asked for what specific knowledge they had obtained from the VC

within the last three to six months, participants identified a comprehensive list of knowledge that included recent practice ('craft') knowledge, organisational processes, conference information, equipment and jurisdictional newsletters. Several participants also reported that they archived discussions for use at a later date.

For some members, discussions unpacked clinical practices by introducing nuances of practice that were previously unknown or not considered (see exemplar 13).

Exemplar 13 Credible knowledge - Broad ranging knowledge

Poster type	Participant / quote
Frequent	NUM FG1-1 <i>I have used posts - I have also kept some of them. ... I do recall a lot of discussion on high flow oxygenation - pros & cons etc. I found this particularly interesting as we have seen a reduction in the bipap numbers and in some instances, ventilation, because of this modality.</i>
Low	Nurse Academic FG2-13 <i>My passion is healthcare ethics, so some of the commentary and amazing research that is posted on ICUConnect is great fodder for my brain.</i>
Non	NUM FG3-3 <i>The newsletters from your governing body have been excellent and the document on Failure to Rescue has informed our risk management team here as we developed a new "escalation of care policy and procedure". Because I saw the document in ICUConnect I was able to bring it forward to our steering group on Escalation of Care.</i>

The second characteristic was that ICUConnect enhanced access to knowledge; where the VC was a superior knowledge source (relative advantage) relative to other methods, because of the easy access to experts, and information 'simply arrived' in their email box and they could learn from the experience of others (see exemplar 14).

Exemplar 14 Credible knowledge - enhanced

Poster type	Participant / quote
Frequent	<p>Knowledge broker KI-4</p> <p><i>'I mean as good as CIAP is, sometimes it great to hear things just in basic terms from people who have already applied particular practices, that have already gained the knowledge, rather than starting from scratch. I think that's one of the fantastic things about ICU connect is that you don't actually really have to start anything from scratch.'</i></p>
Non	<p>Clinical nurse external FG3-1</p> <p><i>'Those letters or conferences that come via the post for me tend to pile up until I get to them, but on computer , email, forums etc are readily available to me at work in down time, I do tend to get to them before I miss the application final date - or I flag them to come up so I don't forget them. So those that come in the post are often missed as I don't carry them all with me to request the day off so I can go to them, but I can request the day off immediately when looking at emails at work.'</i></p>

The final characteristic of *'enhanced access to knowledge'* was that participants considered the information credible. This credibility was a function of access to experts or keynotes and that the VC was sponsored by a health department and moderated (See exemplar 15).

Exemplar 15 Credible knowledge - credibility

Poster type	Participant / quote
Frequent	<p>Knowledge broker FG1-2</p> <p><i>'As a knowledge bowerbird I value the knowledge that flows across without me having to go search for it! As I have said previously it allows me to keep a finger on the pulse and what's happening. In my current role I am on the LHD Policy and Procedure Committee and I find I call on a lot of information from ICUConnect or the ICU Best Practice Project to rebut some of the out of dated practices that people insist on - it gives me the knowledge that things have changed so I can suggest that what they are proposing is now outdated and that they need to do a literature search.'</i></p>
Low	<p>Academic nurse FG2-1</p> <p><i>I probably would not have been keen to join if ICUConnect was not monitored by people knowledgeable about ICU (and who were prepared to step in to intervene when discussions got out of hand).</i></p>
Non	<p>Physiotherapist FG3-2</p> <p><i>(Moderator)s role and the role she has played comprise a big part of why I value ICUConnect. I think this is very important. If there was not a strong, linking voice, starting discussions; emailing up-to-date literature; threads; talking points from time to time; there is a big risk that the forum could become defunct or less valuable/accessed by others.</i></p>

Ability to benchmark practice and improve practice

The next element, the ‘*ability to compare or benchmark local practice or equipment and then improve practice*’ was another common motivator to join ICUConnect and also continued to arise over the course of discussions. It was clear participants understood that it was important to gain this knowledge, including alternative perspectives, from external knowledge sources to ensure local practices reflected broadly accepted best practice. This extended beyond clinical practices to include equipment, resources and cultural issues (see exemplar 16).

Within this element members sought to understand whether an innovation was worth implementation by using the experiences of fellow members; or vicariously evaluating the observability and relative advantage of an innovation (see table 1).

Exemplar 16 Benchmark and improve practice

Poster type	Participant / quote
Frequent	NUM FG1-1 <i>‘generally I put the question out there when I am interested in new equipment or when I want to get more resources – i.e. more staff etc. I always read the responses and although I might not always agree with opinions, I do take them into account when formulating my plans’</i>
Low	Nurse Academic FG2-1 <i>‘It was also a way of better understanding how practice differed in other ICUs and how we might improve the treatment and delivery of care in our own unit’</i>
Non	Knowledge broker FG3-7 <i>‘It is always helpful (and a relief) to Ill be posting a new question tomorrow & look forward to your thoughts around these items. thanks Unlike know that what your unit is wanting to implement and change is on par with other practices and it is always paramount to explore why certain options are not adopted.’</i>

Ability to keep up to date

When asked why they joined ICUConnect, many participants cited wanting to keep up to date with contemporaneous and topical knowledge (see exemplar 17). This was especially important for members who did not currently work in an ICU because it maintained a strong on-going link to the clinical setting. For example, nurse academics used discussions to ensure they were incorporating relevant materials in their teaching activities.

Exemplar 17 Keeping up to date

Poster type	Participant type/quote
Frequent	<p>Knowledge Broker KI-FP-4</p> <p><i>'Initially it was just as an extra resource, and the more I used it, the more I actually found I was getting a lot more up-to-date information from talking and chatting to people on ICU connect, then I could ever find in a book or an article, or doing a literature search or anything of the sort. So that's what initially brought me to it, and that's what's maintained my interest in it, I think.'</i></p>
Low	<p>Knowledge broker FG2-11</p> <p><i>'I saw ICUConnect as an active forum where current issues/topics would be discussed; it would be a way to keep abreast of what was going on. I think it was some time before I rustled up the courage to reply or ask for anything!'</i></p>
Non	<p>Nurse academic FG3-5</p> <p><i>'Therefore my link to ICU goes back a ways. I keep up to date via reading and regular conference attendance (ICE & the ASM plus others) but I joined ICUConnect as means to facilitate keeping up to date with hot topics and to see what the buzz is at the coalface. To date I haven't been disappointed.'</i></p>

The sub-theme of *'enhanced access to credible knowledge'* represents how ICUConnect afforded members a superior knowledge source compared to traditional sources. This finding adds to the current evidence which suggests that HCPs establish and/or belong to VCs to augment their access to best practice knowledge so they remain clinically current with relevant and quality information, develop workplace resources and benchmark practice (Cervantez Thompson & Penprase 2004; Hara & Hew 2007; Hew & Hara 2008; Rodriguez-Recio & Sendra-Portero 2007; Schoch & Shooshan 1997) . Moreover, access was seen as vital and important by all member types, not just posting members who were the focus of and participants in previous research. This reflected the external orientation required of organisational leaders, which enabled them to identify innovations to incorporate into local settings (Aarons, Hurlburt & Horwitz 2011; Greenhalgh et al. 2005a; Purcell & McGrath 2013; Soo, Devinney & Midgley 2007).

While not all participants were in formal clinical leadership roles, all appeared to view VC membership as an integral component of professional practice because it facilitated maintenance of a contemporaneous knowledge base. Superior access to credible knowledge was significant because accessibility and perceived credibility strongly influences the choice of information sources (Curran et al. 2013; Ebenezer 2015; Kostagiolas et al. 2014; Meagher-Stewart et al. 2012; Panahi, Watson & Partridge 2015), as well as innovation trial and final adoption decisions (Greenhalgh et al. 2005a; Rogers 2003) (see table 2). ICUConnect members were able to vicariously experience an innovation through colleagues, which may in turn contribute to

overcoming the problem of sticky knowledge or resistance to knowledge developed outside a local work setting (van der Weide & Smits 2001).

An alternative perspective

This study uncovered a complex relationship between members of ICUConnect and the VC with several factors influencing joining, subsequent modes of participation and views of the VC (see figure 11). In addition while more than half used other social media participants expressed a preference for listserv technology. While DoI was the theoretical lens applied and reveals some reasons for member behaviours it is unable to fully account for the complex, synergistic and multi-directional relationship between members and ICUConnect. One theory that might be better able to unpack this relationship is Actor-network theory (ANT) (Callon 2006; Mützel 2009; Walsham 1997). Actor-network theory is concerned with how humans and information technology (IT) co-exist in networks and posit that IT are not passive, rather are active agents in how a social network interacts and develops (Booth et al. 2016; Callon 2006). The theory can be used as a theoretical lens and as a method to examine social phenomena (Walsham 1997); moreover is well suited to exploring social media use (Keith & Van Belle 2014). This theory will be discussed further in Chapter 8 as an alternative perspective to DoI and CoP.

Study Methods Strengths and Limitations

There were several strengths and limitations of the study. Two elements limited generalisability to the broader population of HCPs, namely the qualitative design using focus groups and interviews and the Australian intensive care setting. As indicated in the literature review however, the level of generalisability for previous surveys was also limited by an inability to obtain a representative sample. This current design leveraged the advantages of online focus groups with learnings from virtual tertiary education (Salmon 2011) and interviews to facilitate participation by a broad range of members.

A significant challenge encountered during the online focus groups that threatened the quality of data included a lack of interaction in the non- and high-posting groups. The asynchronous nature of the focus groups enabled a dynamic and partially successful response by the moderator, including reminder emails, further encouragement to posts and revision of the question guide to reduce participant burden. Despite this the small number of participants in the high-posting focus group (Hatten et al. 2014) did reduce the contributions and interaction of this important cohort, which may have impacted on data quality. To a limited extent the key informant interviews may have counteracted this problem; however development of a shared understanding of VC membership by frequent posters remains an area of further exploration.

The data collection method, namely discussion threads, was another key strength and contributed significantly to study credibility and trustworthiness. The real-time participant controlled data collection ensured complete and accurate data because

recording and transcription of responses was not required, thus contributing to data quality and credibility. The asynchronous online focus groups enabled participants to contribute when they wished, unlike face to face focus groups where dominant talkers and experts may take over discussions (Liamputtong 2011). Further, participants had time to consider their own and previous responses, contributing to reflexive rich responses. As noted previously the planned member checking was unable to be complete therefore

The asynchronicity and timeline of the focus groups supported moderation, researcher reflexivity and data analysis. The moderator was able to discuss focus group function, especially participant responses and group dynamics, with the non-participant observer (primary supervisor). This enabled an agile and considered response to emerging threats to data quality because of limited interaction or responses. Additionally researcher development was supported because the novice researcher was able to reflect on their performance and discuss with and learn from an expert researcher (supervisor).

Data analysis was enhanced because there was more time to record field notes and early data immersion. As previously noted field notes are an essential component of qualitative data however during a face to face focus group recording of field notes may be challenging, especially if the researcher is the moderator. Field notes were collected on group responses to every question and enabled comparison and contrasting of responses. Data immersion is an essential component of qualitative data analysis, enabling the researcher to develop a rich and in-depth understanding of the data (Braun & Clarke 2006; Cresswell 2014). The candidate was able to review and reflect

on responses and where appropriate refer these reflections back to participants, facilitating early development of themes. Overall the use of online focus groups enabled the candidate to develop an extensive understanding of the experiences of all types of members, especially the previously under-researched non-posting majority.

Conclusion

There were three key findings from this study that explored 'why' HCPs belong to ICUConnect. Participants were oriented towards change because they demonstrated communication channels outside their local working and professional environments. Use of the listserv ICUConnect was perceived to be superior to other social media as it was easier to use, congruent with professional values, and specific to the Australian intensive care context. The main finding was that these HCPs belong to the VC because by being a member of a broader intensive care community they have enhanced access to credible best practice knowledge. This study therefore supported earlier studies in this program of research, which found that ICUConnect was an effective innovation distribution and diffusion mechanism, supporting best practice within the Australasian IC community.

Key findings from all studies are synthesised in the following Discussion chapter to answer the overall research question: What is the nature and value of HCP VCs?

Chapter 8 - Discussion

Introduction

The research program reported in this thesis was a qualitatively driven multiple methods concurrent design, underpinned by pragmatism, employed to evaluate whether an exemplar healthcare professional (HCP) virtual community (VC) facilitated knowledge and clinical expertise exchange within a broader professional social network. This was based on three rationales. First, an understanding that inter-professional conversations are integral to professional development, information sharing and uptake (or not) of new knowledge or practices within a healthcare organisation and local CoP. Second, prevailing healthcare structures and cultures limit the development of effective social networks for HCPs. Third, a VC is not limited by time, organisational structure or geography.

The thesis was positioned within the context of Australian healthcare, a universal health care scheme publically funded by the Federal government and delivered by independent state governments. This was because the exemplar VC was the initiative of a state government clinical network for the purposes of facilitating communication among the state's intensive care units (ICU). See the Social network study (chapter 4) for a fuller explanation of how intensive care services are delivered in Australia.

The literature review, reported in Chapter 3, revealed the complex symbiotic nature of HCP VCs. The overarching research question was 'what is the nature and value of a HCP VC?' The research program comprised three original studies that examined inter-related components of the exemplar VC, ICUConnect:

1. the social structure (social network study)
2. interaction (knowledge exchange study) and
3. individual level (why we belong study).

Findings from these three studies were presented in the preceding chapters (5-7) and are visually represented in figure 11. In this chapter these findings have been synthesised using a parallel-results convergent synthesis design (Bt Maznin & Creedy 2012; Hong et al. 2015; Thomson et al. 2014). The chapter is divided into three sections. In the first section the key findings from each of the studies will be described. In the second section a synthesis of key findings is presented within the context of related literature. In the last section the implications of these findings are discussed as well as implications for policy and practice, and suggestions for future research.

Summary of findings

Figure 12 is a visual representation of the findings from the three studies completed for the thesis research program. A brief summary of each study and the main findings are presented below.

The Social network study

The social network study (chapter 5) used a retrospective descriptive design to evaluate how membership of ICUConnect had evolved without direct interference between 2003 and the end of 2009. This study uncovered the social structure of the VC. Between 2003 and 2009, 1340 healthcare professionals subscribed to the VC with 78% of these (n=1042) retaining their membership. The VC had moved beyond the borders of NSW and its 43 intensive care units (ICU) to become Australian-wide multi-

organisational multi-disciplinary communication network. Further ICUConnect was valued by members because they chose to remain members and recommended the VC to colleagues.

The Knowledge exchange study

The knowledge exchange study (chapter 6) was a qualitative retrospective descriptive study which explored the nature of knowledge exchanged ICUConnect, between 2004 and 2013, using summative content analysis methods, thus evaluating how members interacted online. While the purpose was not to demonstrate the existence of a virtual community of practice (VCoP) the main findings aligned with or modified key attributes of a VCoP identified previously and introduced another (see figure 11).

These were:

1. Administration and moderator who establishes and maintains the VC. This was Intensive care coordination and monitoring unit (ICCMU);
2. Stable acceptable technology that is easy to use and includes an archive.
3. Voluntary membership with individuals free to choose mode of participation.
4. A community with a common interest that provides access to a diversity of experiences and views. The data corpus examined consisted of 40 discussion threads with contributions from 133 members across 80 organisations (67 hospitals, five health departments six universities and two healthcare companies. For each thread the most frequent number of members interacting was five.

5. This attribute was revised when it was identified that the respectful risk-free environment that facilitated interaction was found to be an outcome of positive e-professionalism;
6. There was a critical mass of online participants including experts. Clinical leaders contributed the majority of posts [that is knowledge broker nurses (34.6%), nursing unit managers (14.3%) cross unit clinical nurses (6%) and physician 14.3%)] (see table 14);
7. This attribute was revised to include knowledge creation as a feature of discussion as well as them being responsive and relevant discussions (see figure 8) with high quality content (see table 14). The majority of discussions were related to clinical practices to ensure the safe delivery of airway and ventilation; and
8. A new attribute was added: opportunities for professional development including legitimate peripheral participation are demonstrated.

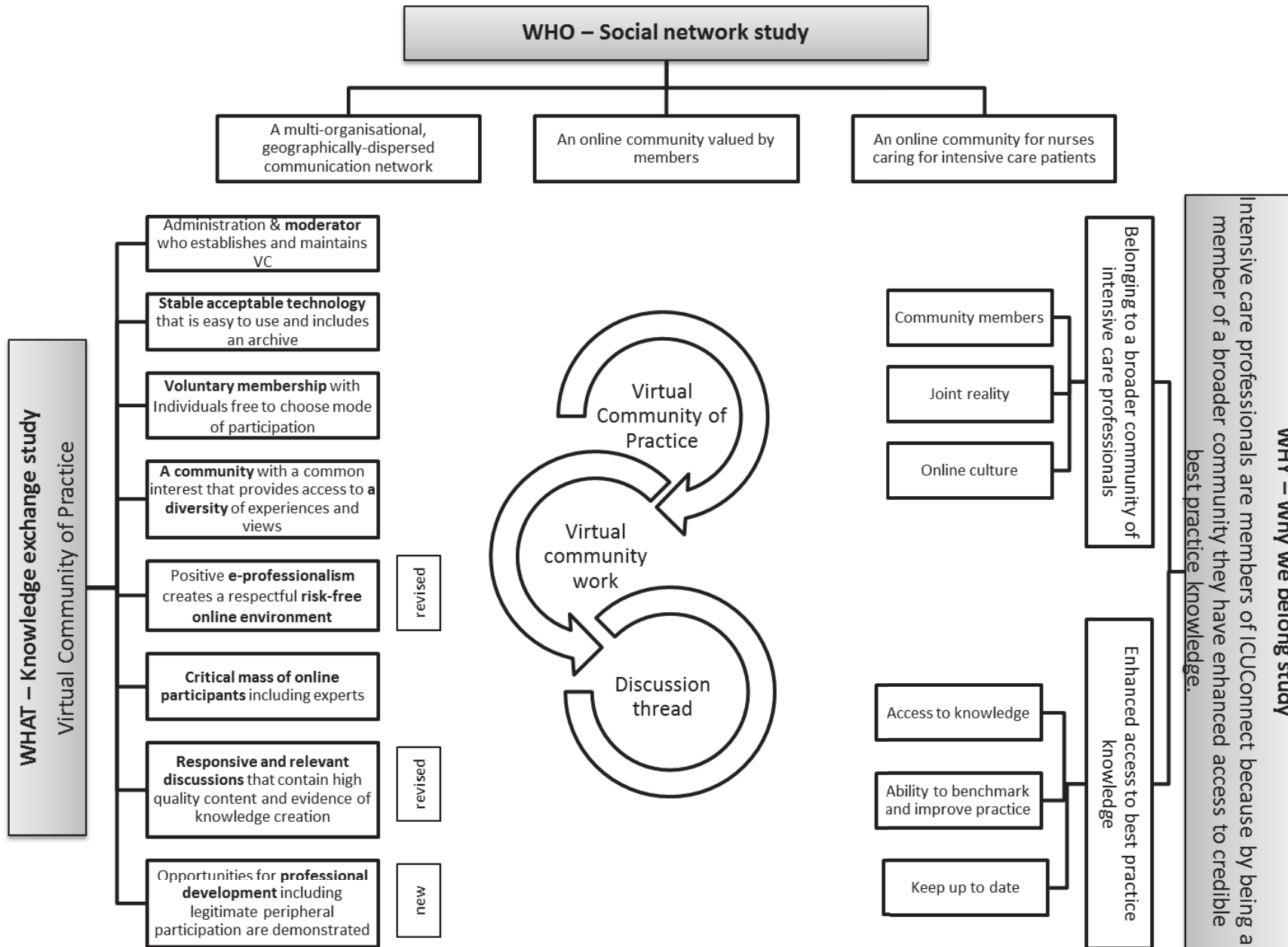
A new construct, virtual community work, was developed to explain how the online interaction occurred. Virtual community work contributes to VCoP attributes 5-8.

The Why we belong study

A qualitative study using three asynchronous three online focus groups and key informant interviews was conducted to explore 'why' HCPs belong to ICUConnect. The main finding was that these HCPs belong to the VC because by being a member of a broader intensive care community they have enhanced access to credible best practice knowledge. There were two secondary findings. It was found that it was likely that participants were oriented towards change because they demonstrated

communication channels outside their local working and professional environments, including use of other social media channels. Additionally ICUConnect was perceived to be superior to other social media as it was easier to use, congruent with professional values, and specific to the Australian intensive care context.

Figure 12 Summary of findings

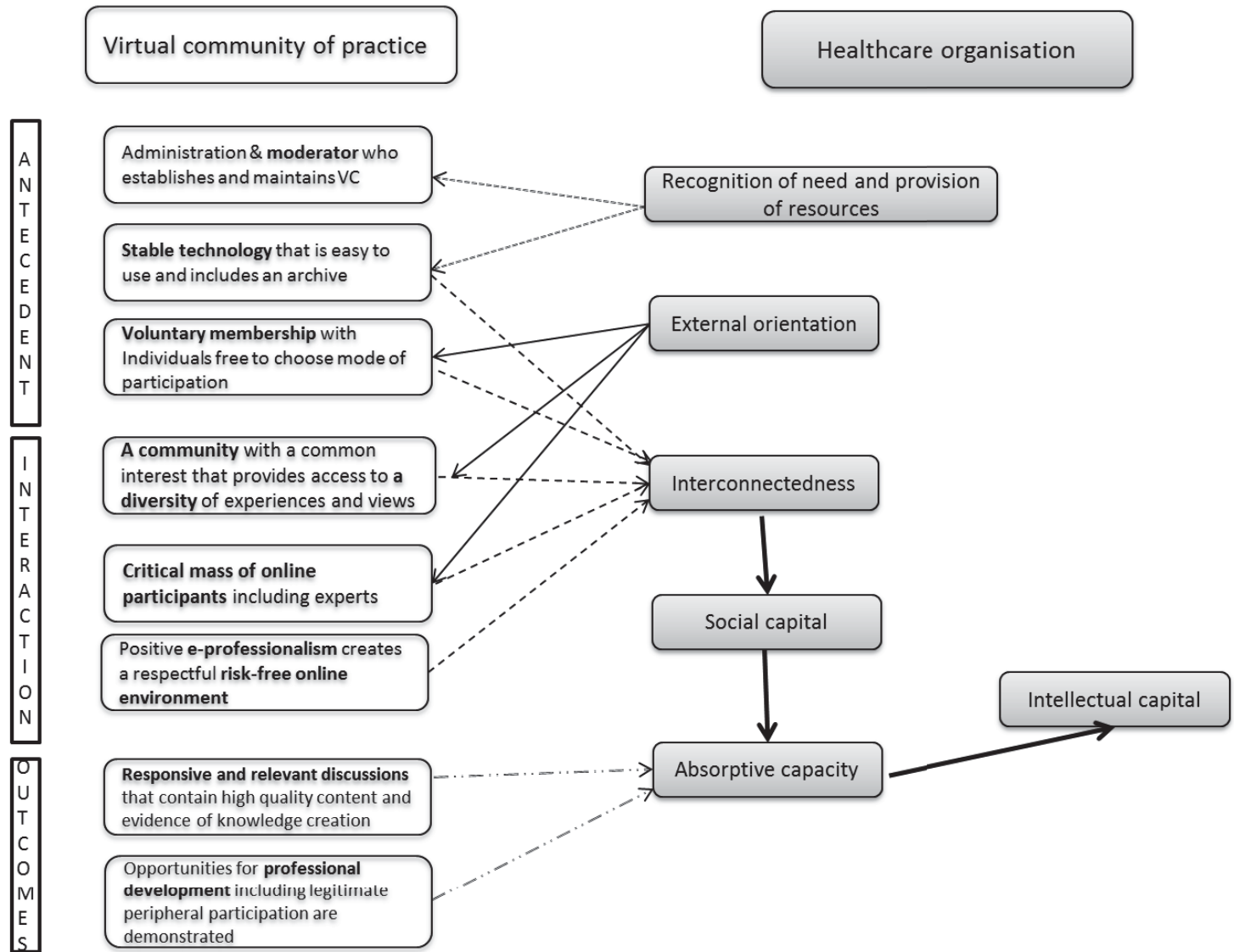


The nature and value of ICUConnect

The nature of a thing refers to 'its innate or essential qualities' (p936) and its value is 'the worth, desirability or utility' (The Australian Concise Oxford Dictionary 2004, p. 1858). The exemplar VC, ICUConnect, was found to operate as a VCoP (nature), with findings across one or more studies supporting each of seven VCoP characteristics identified from the literature as well as identifying a new characteristic (see figure 13).

The value of ICUConnect exists across micro, meso and macro levels: at individual member (micro; knowledge access, professional development and benchmarking of practice), VCoP and professional (meso; practice development) and organisational (macro; innovation access, benchmarking, interconnectedness, absorptive capacity and intellectual, and social capital). The intrinsic value of ICUConnect is created by the virtual community work (see figure 10), undertaken by members when they contribute to online discussions and/or share or create knowledge. This important boundary work contributes to organisational interconnectedness and intellectual and social capital; reflecting necessary conditions if knowledge is to move across structural, professional and pragmatic boundaries (Oborn, Barrett & Racko 2013; Vakkayill 2012). This phenomenon of a HCP VC and its relationship to the broader professional and organisational context is further described below in terms of antecedent factors, consequences of interactions and the outcomes or value that may accrue.

Figure 13 Interaction between VCoP and healthcare organisation



Antecedent factors supporting the development of a VCoP

There were two antecedent factors or conditions that supported the emergence of ICUConnect as a VCoP. From an organisational perspective these were the recognition of a need for connecting HCPs and the resultant provision of resources by a state health unit, and the external orientation of clinical leaders (physicians, nurses in knowledge brokering, management or boundary spanning roles) in the State's ICUs.

Recognition of need and provision of resources

ICUConnect was established by a statewide clinical network, ICCMU, in response to requests from key stakeholders to establish a method of communication with colleagues across the 43 ICUs in the State. While clinical networks are valuable mechanisms for continuous improvement in quality of care, through the translation of research into practice across a clinical specialty, bureaucratic hierarchical structures create significant barriers to achieving this (Braithwaite 2010). A fundamental problem is that these networks may not be successful because they rely on specific individual champions to be the key contact or hub between facilities (Mayrhofer, Goodman & Holman 2015). An effective VC overcomes this problem because it has the potential to establish multiple links and is available anytime. Further, while professional boundaries inhibit development of a shared understanding of knowledge in the clinical setting (Currie & White 2012; Shah et al. 2015; Williams 2011), when HCPs are taken out of their local social network they exhibit cooperative problem solving behaviours (Braithwaite et al. 2016).

A listserv platform was chosen for the VC because it was at no cost, easy to manage and used email, a communication technology familiar to the target population (HCPs

working in NSW ICUs). The earliest indication of the suitability of that decision was the immediate and ongoing uptake of membership by the target population (including 20% of NSW ICU nurses in 2009), a similar population uptake to VCs for occupational therapists (Morken, Bull & Moen 2009) and nurse practitioners (Widemark 2008). Additional data supporting the choice of platform was the strong retention of membership over time (Social network study: 78%). This was in line with findings from the Literature review indicating HCPs prefer closed specialty specific VCs. The rapid adoption can, in part, be explained by the finding that members perceived listserv technology to be superior to other social media in terms of compatibility, complexity and relative advantage. While neither Facebook nor Twitter were available in 2003, in 2014 ICUConnect members continued to prefer the listserv platform. This antecedent factor contributed to the emergence of ICUConnect as a VCoP by establishing the beginning structure; administration and moderation of the VC, and a stable acceptable technology (see figure 12).

Healthcare professionals in the target population have an external orientation

Other factors also influence uptake of a HCP VC, as developing a bespoke platform may not ensure acceptance by a target population (Barnett et al. 2013a, 2013b; Brooks & Scott 2006b; Curran & Sibte Raza Abidi 2007). The key theme arising from the Why we belong study (Chapter 7) was that participants were members specifically to be a part of a broad intensive care community. Therefore the second antecedent condition identified is that members of the target population must have an external orientation; that is an active desire to communicate outside their local professional network for the purposes of gaining new knowledge and understanding the delivery of care across a broader speciality community. This is in line with the Literature review findings which

identified common reasons for establishing other HCP VCs including: 1) create a professional forum where relevant professional and academic issues could be discussed and information and knowledge shared; 2) address professional isolation; 3) facilitate networking; and 4) foster peer collaboration and mentoring.

An external orientation reflects being open to change and new ideas, and it is likely that ICUConnect members are located on the left side of the innovator curve (i.e. innovators, early adopters and early majority ; see figure 2, table 26) (Rogers 2003), given they are communicating outside their local social network and many use multiple social media channels (Correa, Hinsley & De Zuniga 2010). The literature review established that this important characteristic is not limited to intensive care professionals with VCs identified for:

- international professional society for travel medicine clinicians (Macdonald, MacPherson & Gushulak 2009)
- Norwegian professional society for occupational health clinicians (Morken, Bull & Moen 2009) and
- Spanish speaking radiation medicine clinicians (Rodriguez-Recio & Sendra-Portero 2007).

This external orientation contributed to HCPs voluntarily joining ICUConnect, creating a diverse community with a common interest and a critical mass of online participants and this is the first study to describe this important characteristic of organisational leaders in relation to participation in a VC. These latter two characteristics are discussed below in relation to interconnectedness.

Table 26 Research findings mapped to Diffusion of Innovations

Innovation	
Relative advantage	ICUConnect was a superior way of communicating with colleagues
Compatibility	The listserv platform was congruent with the values of members
Complexity	The listserv platform was easier to use relative to other social media
Observability	Members were able to see how an innovation had worked for colleagues
Trialability	Members were able to vicariously experience an innovation through the experience of other members
Communication Channel	
Intrapersonal - Person to person contact Mass media	ICUConnect is a mixture of both types of channels because it is both personal (e.g.Established links with experts) and multiple
Time	
Type of adopter	On left side of curve (ie innovators, early adopters or early majority with frequent posters being more cosmopile
Social System	
Structure	Multi-disciplinary, multi-organisational and geographically distributed network
Norms	Altruism Respectful cordial professional online behaviours
Characteristics	Balance between homophilly (shared specialty knowledge base) and heterophilly (ie structure) High interconnectedness and social capital External orientation of individuals Enhanced absorptive capacity due to shared specialty knowledge base

Virtual community work is key to establishing the interconnectedness between the VCoP and the clinical setting

Establishing interconnectedness or interactive credible communication channels between the VCoP and the related clinical setting is fundamental if patients in individual ICUs are to benefit from knowledge shared and created on the VC.

Communication channels were established by the two antecedent VCoP characteristics of a VCoP platform and voluntary membership. More important to achieving interconnectedness however was the dialogical interaction, the ‘virtual community

work' of online participants. Virtual community work grows mutuality, or the quality of social capital of the VCoP (Wenger 1998).

A construct virtual community work emerged in the Knowledge exchange study, and was comprised of six components; the most visible of which was the discussion thread, while the remaining components creating the positive social environment (see figure 10). These five elements, community, cordiality, supply of artefacts, maven work, and promotion of the VC, contributed to development of three interactive characteristics: a diverse community, a critical mass of online participants, and positive e-professionalism.

A multi-disciplinary, multi-organisational geographically dispersed social network

In each study it was demonstrated that that the membership of ICUConnect was a diverse community, representing all healthcare disciplines who contribute to care of ICU patients. Importantly, this diversity extended beyond organisational boundaries, with members employed in over 225 facilities, distributed throughout Australia, New Zealand and several other countries. As noted above, this diverse community reflected the external orientation of the intensive care professionals who joined the VCoP. This conferred three important benefits. First, increasing access to a broader range of knowledge and exposure to experiences from boundary crossing opportunities (Dahlander & Frederiksen 2012; Dube, Bourhis & Jacob 2006; Wenger & Snyder 2000). Second, reducing the risks of homophily (i.e. group think) and confirmation bias (Matthews & Simon 2012) as members are provided with alternate views on clinical practices. Last, because these clinicians will share a common specialty knowledge

domain, multidisciplinary networks are more likely to be effective in knowledge transfer and creation (Newell et al. 2003; Nieves & Osorio 2012).

As noted earlier, one key finding was that HCPs join ICUConnect because this broader professional community facilitated access to and the maintenance of a contemporaneous knowledge base, and allowed them to benchmark and improve local practices (figure 11). Clinicians with highly bounded social networks with limited links to external colleagues are less likely to adopt current evidence based practices (Mascia & Cicchetti 2011). To innovate locally, it is important that clinical leaders (such as nurses in management or knowledge brokering positions) behave as boundary spanners, and position themselves across social networks, so that they can access external knowledge to assimilate into their local setting (Greenhalgh et al. 2005a; Grossan & Apaydin 2010; Oborn, Barrett & Racko 2013; Rogers 2003).

It would appear that ICUConnect acts as venue for professional development of all members and particularly as an information neighbourhood for clinical leaders (Burnett 2000; Burnett & Buerkle 2004; Irvine-Smith 2009). There are two dimensions to everyday information seeking: practical and orienting to information seeking (Burnett 2000). Where members post on a question on a VC they are seeking to fulfil a specific local knowledge deficit whereas an orientation to information seeking means participation in everyday activities where new information may be sourced (Burnett 2000). While clinical leaders are overrepresented on ICUConnect and dominate discussions (see chapter 6, table 14), all members of the multi-disciplinary team belong to ICUConnect with nurses delivering direct clinical care the largest discipline represented. Membership and activities of this VCoP therefore established a critical

mass of online participants who were looking for answers to local problems, with other members willing to respond to offer their own experiences, knowledge and expertise.

Positive e-professionalism creates a respectful risk-free online environment

Online interactions identified in the Knowledge Exchange study (chapter 6) were characterised by positive e-professionalism; creating a respectful online environment where ICUConnect members were able to participate actively, and there were no transgressions of patient privacy were identified. The online interactive behaviours of members, whether they be collaborative or hostile, will create and maintain the tone of a VC as members accept and display the most common behaviours perceived to be acceptable (Burnett 2000). The term e-professionalism is increasingly used to describe online behaviour and has the same attributes as traditional professionalism (Cain & Chretien 2013). This finding adds to the evidence base emphasising the significance of the symbiotic nature between civil online culture and knowledge sharing (Booth 2012; Chiu, Hsu & Wange 2006; Hew & Hara 2007b, 2008; Lin, Hung & Chen 2009; Rolls et al. 2008; Widemark 2008).

Healthcare professionals are held to high standards regarding professional behaviour, especially in relation to patient interactions and maintenance of privacy, social behaviours and interactions with other HCPs (Green 2017). A social media review is becoming an increasingly common component of employee recruitment, specifically in relation to anti-social behaviours that might be contrary to a professional image (Cain & Chretien 2013). The dangers of HCPs behaving unprofessionally on social media have been a common theme in the literature (Currey & Leslie 2010; Milton 2014; Spector et al. 2010). While a number of significant transgressions by HCPs have been reported

(Aase 2010; Cain & Chretien 2013; Green 2017), the focused literature review for this thesis and another review (Hamm et al. 2013) did not identify a systemic problem. The tone of online discussions was generally perceived to be positive by members, and similar to discourses observed at professional conferences. Online interactions serve to create an effective collegial online culture, including role modelling on how to engage in respectful inter-disciplinary debates.

Virtual community work drives discussions

Virtual community work is the sine qua non of VCoPs; without online discussions and knowledge sharing, there would be no VCoP. This is a novel characterisation of online participation. Similar to previous research (Brooks & Scott 2006a, 2006b; Morken, Bull & Moen 2009; Rodriguez-Recio & Sendra-Portero 2007; Stewart & Abidi 2012) this present research identified that this work is undertaken by a small number of ICUConnect members (see chapter 6 table 14). Thus demonstrating a key characteristic of a successful VCoP; namely that a critical mass of experienced and expert members who have developed vital community norms (e.g. altruism, reciprocity, social interaction, knowledge sharing and trust) that ensures availability of high quality content (Barnett et al. 2012; Chang et al. 2014; Hew 2009).

Virtual community work is in effect boundary or joint work; the work of boundary spanners which transforms and transfers knowledge or practices across boundaries (see figure 12) (Akkerman & Bakker 2011). ICUConnect is positioned at the intersection of many organisational, professional and semantic barriers that can impede movement of knowledge into a local CoP (Hara & Fichman 2014; Oborn, Barrett & Racko 2013). In the absence of alternative perspectives clinicians may be under the illusion local

practices reflect the majority (Duncan et al. 2014; Lerman, Yan & Wu 2015) and fail to evolve practices thus contributing to clinical practice variation (Braithwaite & Donaldson 2016). This problem was highlighted by the finding of corporate memory loss (see table 19), where outdated and possibly dangerous practices were continued. When HCPs cross organisational boundaries, to engage with colleagues who share a common knowledge domain, they will have access to broader and contrasting perspectives (Brynjulf Hjertø, Merok Paulsen & Petteri Tihveräinen 2014). This engagement facilitates the development of a shared understanding of knowledge facilitating the transfer of innovation and knowledge (Hara & Fichman 2014; Rau, Neyer & Möslin 2012).

Knowledge and practices move across boundaries as boundary objects (Hara & Fichman 2014; Nicolini, Scarbrough & Gracheva 2016) as the outcomes of joint work. Boundary objects are therefore negotiated, elucidate practice, and can be physical, such as guidelines, images or presentations, or discussions (Probst & Borzillo 2008). Boundary objects in relation to virtual community work and discussion threads are discussed further in the following sub-section.

Achieving VCoP outcomes

Interactions between members of a CoP develop the professional knowledge of individuals, the practice knowledge of the community, and the intellectual capital of the organisation (Gunawardena et al. 2009; Hara & Hew 2007; Wenger 1998; Wenger, McDermott & Snyder 2002). As previously described VCoP members are looking for high quality practical content to address a known or unknown local knowledge deficit (Agrawal & Joshi 2011), that is provided quickly by experts and experienced clinicians

(Barnett et al. 2012; Chang et al. 2014; Hew 2009). These represent the level of learning energy within the CoP, reflected by the evolution of knowledge and professional development of members (Wenger 2004). In a VCoP, discussion threads become a boundary object for knowledge transfer and creation, and professional and practice development.

Responsive and relevant discussions are boundary objects transferring knowledge

The Why We Belong study (Chapter 7) found that HCPs belong to the VCoP because they have access to credible best practice knowledge. The Knowledge Exchange study (Chapter 6) identified the interactive model of discussion threads, where knowledge transfer and creation occurs. As reported, discussion threads comprised both manifest (the request for and supply of knowledge) and latent content (the purpose and concerns that motivate members to post) (see chapter 6, figure 10).

Members commonly requested explicit knowledge, followed by a combination of explicit and experiential, then experiential knowledge (see Chapter 6, table 16).

Discussion that followed these initial requests provided high quality content within the context of a discourse that uncovered the complexities and nuances of practices and the essential nature of an innovation. Members were provided with relevant practical and valuable knowledge on airway and ventilation practices, including know-how and know-why knowledge, from a diverse range of members including clinical leaders (see chapter 6, table 14, figure 7). Members then used this knowledge to evaluate whether local practices reflected broadly accepted best practice, keep up to date and to develop local resources (see figure 11). This is the basic human desire to know what their social group accepts as truth in fact and in practice (Goldman 1999) and conforms to a

pragmatic world view where clinicians require both veracity in evidence (Nieves & Osorio 2012) and verifiability in practice (Matthews & Simon 2012). While clinical or professional experience is highly valued (Salter & Kothari 2016) access to professional colleagues (Berwick 2003; Bostrom et al. 2008; Halford & Leon 2003) and knowledge brokers and boundary spanners (Estabrooks et al. 2005; O'Leary & Mhaolrunaigh 2011) currently limits the translation of research into practice. ICUConnect fulfils this significant deficit.

Discussion threads are important narrative devices that help innovations to cross cognitive, semantic and pragmatic boundaries (Rau, Neyer & Möslin 2012). For example the exemplar thread (see chapter 6, table 17) illustrates how a discussion thread can add value to a physical boundary object through online debate and is similar to the knowledge creation spiral model (Nonaka, von Krogh & Voelpel 2006). The debate regarding new knowledge or practice reveals its inherent innovation characteristics and allows other members to vicariously experience the innovation. This lends authority to knowledge / practice and facilitates uptake because a credible colleague recognised the value of the innovation (Mors 2010).

ICUConnect capitalises on HCPs preferences for an information source that is homophilous, accessible and credible by providing a safe practical location for interdisciplinary conversations among intensive care professionals. Unlike information transfer in the clinical setting (Marshall, West & Aitken 2013) however the veracity of content was commonly contested by clinical leaders and the knowledge source (i.e. ICUConnect) was perceived to be credible . Further the VCoP overcomes another impediment to innovation and knowledge transfer by increasing access to knowledge

brokers and boundary spanners (Estabrooks et al. 2005; O'Leary & Mhaolrunaigh 2011).

Facilitating professional development and legitimate peripheral participation

As a VCoP, ICUConnect supported the professional development and legitimate peripheral participation of members by facilitating conversations among the broader Australasian intensive care community. Social learning theories, including CoP (Wenger 2004) and connectivism (Siemens 2008), focus on collective learning processes within social groups or networks. Facilitating professional development (Burg, Adorno & Hidalgo 2012; Murty et al. 2012; Reutzel & Patel 2001) and improving clinical practice through research and evidence translation (Dieleman & Duncan 2013; Frisch et al. 2014) have been given as catalysts for establishing a HCP VC. The literature review also established that a member's perception of their learning may be influenced by whether they had developed a sense of community (Widemark 2008). Transition from inexperienced to experienced is facilitated where novices are able to interact with experienced professionals in a CoP (Burkitt et al. 2001; Cope, Cuthbertson & Stoddart 2000; Plack 2003; Ranmuthugala, Plumb, et al. 2011). In addition, becoming an expert includes mastery in both a specific bounded domain and boundary crossing through active participation in multiple social networks (Akkerman & Bakker 2011).

As indicated earlier connecting to a broader professional community was a common reason for joining ICUConnect and this external orientation of Australian intensive care HCPs was an antecedent factor in the emergence of the VC as a VCoP. ICUConnect supported the professional development and legitimate peripheral participation of members in several ways. First, positive e-professionalism, which emerged from virtual

community work, created both a safe place to participate but also demonstrated how to engage in respectful intra- and inter-professional discussions. Second, within these discussions members were provided with relevant practical and valuable knowledge, especially know-how and know-why knowledge, by experienced clinicians and experts (Barnett et al. 2012; Wenger 2004). Third, a discussion often expanded to include multiple interrelated topics, illuminating the sophistication of practice and building the practice knowledge of community and members. Lastly and importantly, because members were connected to a broader social network they were exposed to alternate perspectives and novel knowledge. This is significant because clinical practices are more likely to be considered where they are topics in contemporary professional conversations (Duncan et al. 2014). These findings add to the evidence base supporting the role of VC in the professional development of clinicians (Barnett et al. 2012; Burg, Adorno & Hidalgo 2012; Hew & Hara 2008; Murty et al. 2012; Reutzler & Patel 2001; Widemark 2008).

Two metaphors arose in the Why we belong study to illustrate professional development: a watercooler and 24/7 conference. ICUConnect functioned like discussions around a watercooler or an informal meeting place (Fayard & Weeks 2007; Siu 2015), where participants described using discussions to initiate conversations with work colleagues and reflect on local practices, as well as provide on demand professional development, moral support and specific resources (Siu 2015). Regular attendance at external education events such as conferences and seminars are seen as an integral component of maintaining professional competence however there are a number of constraints which restrict attendance including access to study leave, cost and attendance in personal time (Coventry, Maslin-Prothero & Smith 2015).

Participants viewed ICUConnect as a 24/7 conference that provided immediate access to colleagues, research and evidence because it was always available and did not require time or money to attend.

An alternative perspective - actor-network theory

The research program used the theories of DoI and CoP because of the underlying thesis problem, specifically how inadequate social networks contributed to clinical practice variation. While ICUConnect was found to be a VCoP and an efficient innovation diffusion mechanism these theories are unable to fully explain the symbiotic nature of the relationship between the VC, knowledge shared and participant choices. Actor-network theory (ANT) may be able to provide an explanation for several key findings of this research program.

Actor-network theory developed as sociologists sort to understand the role of social networks and the relationships between humans and the technologies they interacted with (Walsham 1997). As described in Chapter 7 according to ANT non-human elements of a network are viewed as having the ability to act on how that social network develops; that is they have agency. When viewed through the lens of ANT a social network evolves through a four stage process of translation towards a blackbox network, whereupon the social network is stable (Booth et al. 2016; Keith & Van Belle 2014). In other words a social network becomes stable and may be self-sustaining where there are a sufficient number of members who have joined and a critical mass of members are cooperatively engaged in the core business of the social network (Walsham 1997).

ICUConnect was established by ICCMU after NSW ICU clinicians requested a method to network with colleagues; this aligns with Stage one of translation problematisation where the actors with a common interest together and a dominant actor emerges (Booth et al. 2016). The role of ICCMU as the primary and dominant actor in the network and the importance of the moderator role is underlined by findings from Study 3, that is the credibility of ICUConnect and the knowledge shared is contingent on ICCMU being a sanctioned clinical network. The moderator and gatekeeper roles continue through Stage two, interestment, where ICCMU takes on the gate keeper role, including enrolment of members and establishing and enforcing group rules, and coordinator of activity (Rolls et al. 2008). This stage is demonstrated in Study 1 as membership grew and the structure of the social network began to resemble local clinical settings. Stages three (enrolment) and four (mobilisation) for ICUConnect emerged in Study 2 as different member types emerged and clinical leaders took on leadership roles, namely knowledge sharing duties on ICUConnect. Finally Study 3 reveals the symbiotic relationship between ICUConnect and members, demonstrating that the VC has agency and perhaps signalling that the Blackbox has emerged.

Actor-network theory however is also a research method and this research program may not have examined key elements to substantiate the emergence of ICUConnect as a Blackbox network and whether it had indeed reached a critical mass to make it self-sustaining (Crossley & Ibrahim 2012; Keith & Van Belle 2014). For example, at present the stability and sustainability of ICUConnect as a knowledge sharing and professional network appears to be reliant on the listserv platform because of the preference for this social media platform by members. Counter to this threat is that online

participants do use other platforms, meaning that the VC may survive a change in platform.

Summary

The exemplar HCP VC, ICUConnect, was found to be a VCoP whose value is embedded professional development available to members and building of intellectual capital for the organisation. The two antecedent conditions, a state clinical network providing HCP-appropriate online platform and the external orientation of intensive care HCPs, contributed to the HCP VC being established and gaining traction within the Australian intensive care community. Once established the online participation or virtual community work by members created the interconnectedness and built the social capital of broader community of intensive care clinicians. This would not have been possible without the positive online environment which emerged from the respectful professional online behaviour of ICUConnect members. The outcomes of this were professional development for members and building intellectual capital of the community by facilitating knowledge distribution across a broader social network.

Implications for policy and practice

Healthcare organisations, professional associations and HCPs should consider using multidisciplinary VCoPs to ensure patients receive optimal care based on a contemporaneous knowledge base. The literature review found that most VCs evaluated were for a single HCP discipline in a clinical speciality and that HCPs prefer to participate in speciality specific closed communities. Single-discipline social networks can create strong boundaries that inhibit inter-professional learning and knowledge sharing (Dopson et al. 2002). Sharing knowledge and adoption of innovation is

enhanced where there is homophily (shared within a multi-disciplinary clinical specialty domain such as emergency or intensive care) and credibility (Dopson et al. 2002). Since patients are commonly cared for by a multi-disciplinary team and these clinicians generally share a common specialty knowledge domain, multidisciplinary networks, such as ICUConnect, are more likely to be effective in knowledge transfer and creation (Newell et al. 2003; Nieves & Osorio 2012). Table 27 is provided as a summary of the lessons learnt from this research program.

Healthcare professionals

Healthcare professionals can use VCoPs for professional development and innovation access. This is especially important for clinical leaders because in order to obtain and understand effectiveness of novel knowledge and technology they need to position themselves across multiple social networks (Greenhalgh et al. 2005a; Grossan & Apaydin 2010; Rogers 2003). Where HCPs are unable to identify a VCoP that suits their needs they can launch their own using free social networks such as Facebook or Twitter. For example the Critical Care Mailing List (DeWitt et al. 2004) was created in 1994 and continues today. Another example is @WeNurses (Moorley & Chinn 2014) which was created by Chinn and has evolved into #weCommunities and hosts an array of communities including @weParamedics , @WeMHNurses and @WePharmacists among others (Chinn 2016).

Table 27 Lessons learnt from ICUConnect

Creating a VCoP

- Developers should establish if potential members have a strong desire to communicate with similar healthcare professionals (external orientation. That is will it be discipline or speciality specific?)
- Establish credibility for the VCoP through a sponsoring organisation, (e.g. clinical network or professional organisation).
- Identify a group of leaders to be early adopters and are willing to assist in early development of VCoP, participate online and champion the VCoP at a local level.
- Maximise a positive user technical experience by
 - Identifying a platform that is 1) acceptable to the HCP group (i.e. complexity and compatibility) and 2) accessible at a location they are most likely to use (i.e. at work or at home) and across multiple devices (e.g. fixed or mobile).
 - Includes multiple functionalities such as knowledge repositories for shared artefacts, blogs and online polls.
 - Allows members to control their online profile and experience.
 - Invest trust in members by allowing direct posting
- Create circumstances that promote a positive social experience by
 - Identify early goals regarding key purpose/s VCoP and develop strategies to address but keep key performance indicators to a minimum
 - Development of the netiquette
- Create a launch event where potential members can learn how to use and ‘trial’ the software, and enrol a substantial number of early members

Building a VCoP

- Use the leader group to demonstrate the value of the VCoP by 1) delivery of knowledge on a regular basis by creating a roster of posting and 2) creating a knowledge repository.
- Use events to promote VCoP to user group, ideally have a local leader speak about their experience of membership
- Moderation
 - Keep overt moderation to a minimum
 - Ensure moderation is highly responsive including enrolment of new members and addressing online behaviour issues
 - Provide online recognition and off-line positive reinforcement for contributing members

Maintaining a VCoP

- Continue work outlined above
 - Promote VCoP via human and other social channels
 - Develop promotional materials
-

Professional Associations

A number of professional associations have established long term VCs to facilitate communication among their members for the purposes of improving evidence translation and practice development (Cervantez Thompson 2002; Dieleman & Duncan 2013; Kim et al. 2014; Macdonald, MacPherson & Gushulak 2009; Morken, Bull & Moen 2009; Rodriguez-Recio & Sendra-Portero 2007; Widemark 2008). The literature review identified data to support effectiveness of these communities as VCoPs including the exchange of domain-specific experiential knowledge. Four studies demonstrated VCoP characteristics within two single discipline VCs (Hara & Hew 2007; Hew & Hara 2007b, 2008; Widemark 2008) however limiting communication to a single discipline may contribute to the creation of barriers to knowledge transfer. This can be overcome by tasking specific individuals with participation in other CoPs so that novel knowledge and practices can be brought over and replenish the knowledge base and practice of a local CoP (Wenger 1998). On the other hand this research has demonstrated that ICUConnect has realised the potential that multi-disciplinary clinical speciality VCoPs have for knowledge transfer across physical and professional boundaries (Burrell, Elliott & Hansen 2009; McGowan 2012).

Healthcare organisations

Healthcare organisations should include multidisciplinary VCoPs for clinical specialities as part of a comprehensive knowledge management strategy that supports the development of social and intellectual capital, and organisational absorptive capacity, thus establishing a learning organisation (Kothari et al. 2011; Nicolini, Scarbrough & Gracheva 2016; Oborn, Barrett & Racko 2013). A central tenet of healthcare organisations is to continually evolve local clinical practices and support the

professional development of clinicians, so that patients receive the best clinical care. At this present the knowledge management strategies used by healthcare organisations are ineffective because they are static and do not support knowledge sharing, devalue tacit knowledge and some strategies are isolated initiatives limiting their effectiveness and sustainability (Kothari et al. 2011; Oborn, Barrett & Racko 2013). One example is the Clinical Information Access Portal from NSW Health. This is an online knowledge portal which includes a wide variety of peer-reviewed journals among other resources. Use of this portal has been limited because facilities have not encouraged use by all clinicians (Westbrook & Gosling 2001).

Ideally these VCoPs would be managed by a clinical network that was embedded within the clinical speciality so that the VC had credibility with the target population. Unlike other CoPs established by healthcare organisations, ICCMU demonstrated balanced managerialism (Bolisani & Scarso 2014; Ferlie et al. 2012) with a natural evolution (Wenger, McDermott & Snyder 2002) to establish a VCoP with strong connections to the broader organisation context. The ICUConnect example has demonstrated how a VCoP managed by a clinical network was able to establish interconnectedness across the broader Australian intensive care community with the resulting social capital, enhancing the absorptive capacity of ICUs and building intellectual capital.

A key organisational challenge is to mobilise the expertise of HCPs (Ward et al. 2014a) and maintenance of a contemporaneous knowledge base. This can be achieved by building social capital which is the ability to harness knowledge resources through structural or connections between HCPs, the quality of these relationships and shared

representations of knowledge (Nahapiet & Ghoshal 1998). Thus social capital is created by establishing active networks, a trusting climate, helpful relationships and effective communication structures (Ranmuthugala, Cunningham, et al. 2011). This research program demonstrated that the social capital of a VC, or belonging to a broader community, is why this sample of HCPs join and remain a member.

Novel knowledge is accessible via weak ties or structural holes, however knowledge transfer will only occur where the source and knowledge are deemed credible and local intellectual capital can absorb the knowledge. In theory all members of a VC are connected to each other, implying there are no structural holes, however VC members have differential reading patterns (see Chapter 3 table 5) , so some structural holes may exist (Björk et al. 2011). In this current study, the Why We Belong study demonstrated that VC knowledge was viewed as coming from a credible source, and the Knowledge Exchange study established the quality of the knowledge and the importance of access to clinical expertise.

The knowledge that was transferred or developed in the discussion thread contributed to the professional development of members and the intellectual capital of their local professional network. Intellectual capital of an organisation or an intensive care unit is the personal and collective knowledge of HCPs (Salter & Kothari 2016) and important know-how knowledge is embedded with negotiated norms of a profession or ward (Atherton 2013). This will be however contingent on the absorptive capacity of an organisation or social group (Oborn, Barrett & Racko 2013).

A VCoP can develop the absorptive capacity of an organisation and internal facilities through providing professional development for members and developing links to

external networks to obtain and understand novel knowledge. Absorptive capacity refers to an organisation's capability to identify and acquire external knowledge and assimilate this new knowledge by transforming it into working organisational knowledge (Oborn, Barrett & Racko 2013; Zahra & George 2002). Knowledge acquisition is mediated by external networks (Nystrom, Ramanmurthy & Wilson 2002) however assimilation will not occur unless the local knowledge base is adequate (Greenhalgh et al. 2005a).

Healthcare organisations have experienced varying levels of success when using VCoPs. A VCoP which was set up for Canadian emergency clinicians had some success in engaging the target population however only a limited number of the training modules were completed (Curran et al. 2009). HOBE+ was a VCoP for Spanish public health professionals, for the purposes of fostering and facilitating innovation in primary care (Abos Mendizabal, Nuno-Solinis & Zaballa Gonzalez 2013). Thirty-one percent of the target population registered but only 5.5% of these participated.

Twenty-three of 133 ideas proposed online had been implemented. InspireNet was set up to increase the nursing capacity for research in British Columbia, Canada, and used a broad range of WEB 2.0 technologies including blog, private space for specific teams (currently 21) and shared document repositories (Frisch et al. 2014). VCoP membership reached 3000 in just over three years and two member surveys (with limited response rates) indicating positive opinions. A VCoP that was successful in establishing interconnectedness and knowledge sharing across a number of facilities was a discussion forum aimed at improving pain management in the paediatric setting (Stewart & Abidi 2012). Other key findings were development of network centrality

around a single institution and the medical profession with limited posting by nursing staff.

Study program limitations and recommendations for further research

While the trustworthiness of this multi-methods design, which evaluated three key aspects of an exemplar VC, was reflected in a rigorously developed methods, the qualitative nature of the sample and study of a single VCoP setting, which used dated social media technology, limits the generalisability of findings. The limitations of each study were discussed in the pertinent study chapters.

The VC investigated (ICUConnect) used dated social media technology, that is it is an email list or listserv (Crier & Campbell 2000) therefore the transferability of study findings to other VCs using contemporary platforms may be limited. This is supported by the finding that research participants preferred this platform to more recent social media technology. Counter to this is that similar to previous research there is a complex symbiotic relationship between ICUConnect members and the VC, and that 50% of participants in 'Why we belong' study (chapter 7) used other social media platforms. Nonetheless given the significant influence of the social media platform on VC user acceptance further research is required to evaluate whether the findings from this study program are reflective of a majority of VC members.

Two further studies are suggested. The content analysis tool developed as part of Knowledge exchange study (chapter 6) should be tested on other datasets, preferably a random sample of discussion threads from another VC. This would establish the

tool's reliability and validity as well as reveal whether the ICUConnect VCoP experiences are common across other VCs, or unique. If the tool demonstrated adequate reliability, and findings demonstrated similar high quality discussions on another VC, the case for using VCs to facilitate knowledge distribution in a clinical speciality would be strengthened.

This study program examined a broad range of member types, but not a representative sample of members. A survey of members using a validated instrument might demonstrate whether the experiences identified in this research program are representative of the broader membership base. The Classroom Community Scale (Rovai 2002; Rovai, Wighting & Lucking 2004) found a positive correlation between perceived sense of community and learning and has been validated in populations of HCPs (Riccio 2015; Widemark 2008). A survey of a representative sample of members using this tool might provide stronger evidence for the contribution of ICUConnect to professional development of the individual and intellectual capital of the broader Australian intensive care community.

Conclusions

The aim of this multi-methods research program was to explore whether HCP VCs facilitate knowledge and clinical expertise exchange, within a broader professional social network, using an exemplar VC. The series of three linked studies served to address some questions persisting in findings from the literature review (Chapter 3) which included how do HCP VCs evolve, do they effectively transfer quality knowledge and why do members join and remain a part of the VC.

The Social Network study (Chapter 5) found that the VC had evolved into a multi-organisational online professional community for all HCPs involved in the care of the critically ill thus creating boundary crossing opportunities for members. The Knowledge Exchange study (Chapter 6) identified a key construct, virtual community work, which created a positive safe online culture for members which then facilitated the exchange of important clinical knowledge and professional development of members. The main finding of the Why We Belong study (Chapter 7) was that these HCPs belong to the VC because by being a member of a broader intensive care community enhances their access to credible best practice knowledge.

When all results were synthesised ICUConnect was found to be a VCoP where the virtual community work undertaken by members was key to establishing the interconnectedness between the VCoP and the clinical setting. That is these outcomes were made possible by the virtual community work that facilitated the evolution of ICUConnect into a diverse MDT social network that facilitated group affiliation by promoting a collegial professional online experience that in turn supported knowledge creation and transfer, and professional development. This achievement would not be possible however without the by external orientation of members, their openness to change, and above all their desire to ensure critically ill patients receive optimal care

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Appendices

Appendix A Detailed search strategy and results

Database	Key word OR word in abstract where not a MESH term in database	limits	years	hits	cull	repeats	reviewed
CINAHL1	computer mediated communication	abstract available English research article peer-reviewed	1/1/1990-31/12/2015	51	7	0	7
CINAHL2	listserv	abstract available English research article peer-reviewed	1/1/1990-31/12/2015	110	17	1	16
CINAHL3	online discussion forum	abstract available English research article peer-reviewed	1/1/1990-31/12/2015	25	3	1	2
CINAHL4	networking or social networking	abstract available English research article peer-reviewed	1/1/1990-31/12/2015	373	14	9	7
CINAHL5	discussion forum OR twitter OR social media OR Facebook	abstract available English research article peer-reviewed	1/1/1990-31/12/2015	459	14	1	13
CINAHL6	virtual community	abstract available English research article	1/1/1990-31/12/2015	81	15	13	2

Database	Key word OR word in abstract where not a MESH term in database	limits	years	hits	cull	repeats	reviewed
		peer-reviewed					
CINAHL7	social media	abstract available English research article peer-reviewed	1/1/1990-31/12/2015	97	2	2	2
pubmed1	social media	abstract available English research article peer-reviewed	1/1/1990-31/12/2015	677	32	3	25
pubmed2	social networking AND doctor or nurse or pharmacist or respiratory therapist or pharmacist or social worker or dietitian	abstract available English research article peer-reviewed	1/1/1990-31/12/2015	305	11	5	6
pubmed3	electronic mail AND doctor or nurse or pharmacist or respiratory therapist or pharmacist or social worker or dietitian	abstract available English research article peer-reviewed	1/1/1990-31/12/2015	447	3	0	3
pubmed4	virtual community AND doctor or nurse or pharmacist or respiratory therapist or pharmacist or social worker or dietitian	abstract available English research article peer-reviewed	1/1/1990-31/12/2015	132	10	3	7
pubmed5	online discussion forum AND doctor or nurse or pharmacist or respiratory therapist or pharmacist or social worker or dietitian	abstract available English research article peer-reviewed	1/1/1990-31/12/2015	192	7	2	5

Database	Key word OR word in abstract where not a MESH term in database	limits	years	hits	cull	repeats	reviewed
Journal search	JMIR - Journal of medical and internet research	abstract available English research article peer-reviewed	1/1/1990-31/12/2015	12	9	8	1
	JAMIA - Journal of medical informatics association	abstract available English research article peer-reviewed	1/1/1990-31/12/2015	3	3	2	1
	CIN - Computers, Informatics, Nursing	abstract available English research article peer-reviewed	1/1/1990-31/12/2015	4	4	3	1
Proquest Health & Medicine	social media; mailing list; discussion forum			2	2	1	1
				2970	153	54	99
						quality	5
						not on topic	26
						cull	31
						from journal articles	4
						total in review	72

Appendix B Overview of all studies included in final review

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
(Berman 1996) Israel Social workers Listserv	Study the potential of people as sources of information within an information technology framework, the Internet	Qualitative descriptive	Data corpus SOCWORK – 37 days ABUSE-L – 43 days	Online observation using Empireer Classification: Information transfer – IT Information request – IR Discussion of issues - IS	Content analysis - deductive	Fair
(Murray 1996) International Nurses Mailing list – internet based	Investigate the use of computer mediated communication technologies by nurses	Case study using mixed methods	2 days emails 5 self-selected	Online observation Interviews Email self selected	Discourse analysis	Moderate
(Schoch & Shooshan 1997) United States/international Mailing list Medical librarians	Determine demographic characteristics and use of mailing list	Survey	Random sample	Survey Electronic	Descriptive	Moderate
Roberts 1998 United Kingdom General Practitioners Listserv(Roberts & Fox 1998)	Explore the dynamics of internet based discussion group	Qualitative - ethnography	12 months emails	Online Observation	thematic	Fair
Murray 2001 International Nurses Mailing list – internet based(Murray 2001)	Examine whether there is evidence of reflection, and outputs of reflection (such as learning and changes in practice) arise through discussions on a	Online ethnography	Survey 1 – random sample Survey 2 – all members Email data corpus 2days (1994-2000) Stratified-purposive	Member surveys (2) stratified Online observation	Content analysis - inductive	strong

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
	mailing list		sample DT > 4 messages Identifies clinical practice issue			
(Reutzel & Patel 2001) United states School nurses mailing list	Obtain a preliminary understanding of the types of medication management problems that school nurses face as well as the strategies they use to solve those problems	Qualitative descriptive Content analysis of emails – deductive	Data corpus - 5/12 emails stratified sample Unit of analysis – Discussion thread focusing on medication issues	Coding schema – 7 categories with additional 3 arising	Content analysis - deductive	strong
Cervantez-Thompson 2002 United states Rehabilitation nurses Listserv (Cervantez Thompson 2002)	Identify the profile, postings and roles of nurses on a mailing list	Qualitative descriptive	Data corpus all postings May 1999- Nov 2000 Unit of analysis – individual emails	Online Observation Census sampling	Content analysis - deductive	Fair
Watson 2003 Australia Infectious disease specialists Mailing list(Watson 2003)	Determine level of user satisfaction with mailing list	Survey	All members of listserv	Not described	descriptive	fair
Cervantez-Thompson 2004 United states Rehabilitation nurses Mailing list(Cervantez Thompson & Penprase 2004)	Why members use mailing list and describe their experience	Mixed methods survey + interviews	Purpose sample – online posters Response rate 22% (76/343) Interviews – 41/76 self-nominated from survey 1 responses	Online questionnaire – 5 open questions Follow up telephone or email interviews	Survey – descriptive Interviews – grounded theory	moderate

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
Brooks 2006 United Kingdom Midwives Intranet -discussion forum(Brooks & Scott 2006a)	To evaluate whether midwives would function as knowledge workers in an online forum	Mixed methods - Case study Content analysis – thematic Participant Interviews	Data corpus – 3/12 posts Interviews – 15 online participants (purposive stratified sampling)	Online observation Discussion forum posts Interviews (face to face and semi structured)	Discussion forum Themes – knowledge work and relationships (collegial and leadership) Midwifery grade of poster	strong
Brooks 2006 United Kingdom Midwives Nurses Intranet -discussion forum(Brooks & Scott 2006b)	Explore the level of knowledge work displayed in three intranet based discussion forums	Mixed methods Intranet based discussion forums Obstetric (Obs) Older persons (OP) Coronary heart disease (CHD)	Data corpus Obs - 1.5/12 29 posters / 11 threads / 70 , posts OP - 7.5/12 11 posters / 6 threads / 18 messages CHD - 15/12 26 posters / 21 threads / 71 messages	Census sampling Knowledge work taxonomy (12 item framework) Semi structured interviews	DT - descriptive Interviews - grounded theory (Atlas.ti)	strong
Hara 2007 International Advanced practice nurses (critical care) Mailing list(Hara & Hew 2007)	Examine the types of online activity types of knowledge shared factors that sustain knowledge sharing	Case study using mixed methods Triangulation CoP theoretical framework	Emails Data corpus – Weeks 1 & 2 of each month 2005 Unit of analysis Knowledge – email Online activity - thematic unit Interviews – semi-structured -27	Online observation Interviews	types of knowledge - content analysis Types of online activities - Constant comparative Factors that influence knowledge sharing – constant comparative	Strong
Hew 2007 International	Categorize the types of knowledge shared	Mixed methods – comparative case study	Data corpus – weeks 1& 2	Online observation – types of knowledge	Emails – content analysis –	Strong

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
3 mailing list Advanced practice nurses [APN-I] University web development [WD-I] Literacy education [LE-I] (Hew & Hara 2007b)	Identify the motivators of and barriers to online knowledge sharing		3/2003-2006 1/2003-2006 2/2003 -2006 Unit of analysis – thematic unit Interviews – semi-structured 16; 18; 20	shared Semi-structured telephone Interviews – motivators & barriers to knowledge sharing	deductive Interviews – constant-comparative	
Rodriguez-Recio 2007 Spain Radiology clinicians Mailing list(Rodriguez-Recio & Sendra-Portero 2007)	Analyse mailing list during first 5 years of operation including content of posts and perception of members	Mixed methods Content analysis (deductive) Member survey Social network analysis	Data corpus – 5 years Survey Demographics Reading patterns Listserv management Networking ex-listserv Evaluation of reading list (functionality, usefulness and quality of email content	Online Observation survey anonymous & online Social network analysis	Descriptive Inferential	fair-moderate
Hew 2008 International Advanced practice nurses (critical care) Mailing list(Hew & Hara 2008)	Gain an understanding of knowledge sharing among nurses on a mailing list	Qualitative	Round 1 – 27 Round 2 – 10 most frequent online knowledge sharers of round 1	Semi-structured telephone interviews – 2 rounds	Constant comparative Baston – motivational theory	Strong
Rolls 2008 Australia Intensive care Mailing list (Rolls et al. 2008)	Explore the perceptions of members of mailing list	Mixed methods	Email data corpus – 6/2004-5/2005 Instrument – 25 item (piloted)	Online observation Survey	Descriptive Content analysis - deductive	Moderate
Widemark 2008 Arizona – US Nurse Practitioners	Evaluate the effectiveness of leaning in a situated learning	Mixed methods Survey - all Qualitative survey 10	Survey 1 – 650 – 146 Response rate -22% convenience	Survey 1 – Classroom community scale 20 items/5 point likert	Survey 1 – quantitative with correlation/regres	Survey - Mod-strong

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
Mailing list–closed(Widemark 2008)	environment		Survey 2 – 8/10 convenience	Survey 2 – 12 questions	sion analysis Survey 2 – inductive content analysis	Qualitative – Fair
Cook-Craig 2009 Social workers Israeli ministry (Cook-Craig & Sabah 2009)	Explore how social workers in Israel use virtual community of practices (VCoP) to support learning	Mixed methods Quantitative Survey	All online participation Survey – random sample 300 (Response rate 33%)	VCoP usage data Online Survey – 35 item		Admin data – moderate Survey - fair
Hughes 2009 UK Physicians Web 2.0 (Hughes et al. 2009)	Examine the use of Web 2.0 by junior physicians in clinical setting including motivations, direct use & how can tools be further used	Mixed methods Diaries Interviews	35 junior physicians 177 diaries days	Diaries Interviews	Thematic analysis	Moderate
Long 2009 Australia Paediatric occupational therapists Listserv - internet(Long et al. 2009)	Gain insight into the nature of communications o mailing list and determine whether topics and issues were congruent with current practice trends	Qualitative descriptive	Data corpus – 6/2003 – 5/2004	Content analysis deductive Coding schema – OT curricula Census sampling	Content analysis - deductive	Moderate
Macdonald 2009 International Listserv – professional society Travel medicine(Macdonald, MacPherson & Gushulak 2009)	Analyse patterns of information exchange on mailing list subscriber demographics participation rates	Qualitative descriptive	Data corpus – all emails 1/2006- /7/2006	Online observation Census sampling	Content analysis - deductive	Moderate

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
Morken 2009 Norway Occupational hygienists Listserv [internet] (Morken, Bull & Moen 2009)	Describe the activity on a mailing list	Qualitative descriptive	Data corpus – categorized all emails 1997-2006 Data corpus –2006 emails By discipline Type of email Completeness of online answer	Online Observation Census sampling	Content analysis - inductive	Fair- moderate
Shanahan 2009 Australia Medical radiation specialist Internet based tools(Shanahan, Herrington & Herrington 2009)	Establish professional use of internet-based tools by clinician and issues affecting access to Internet within the workplace	Qualitative	Random sample of medical radiation science practitioners	Survey	Descriptive	Moderate
Foong 2010 India Plastic surgeons Discussion forum(Foong & McGrouther 2010)	To assess the value of discussions in relation to education and aiding patient management	Qualitative descriptive	Calendar year	Online observation census	Deductive content analysis	fair
Franko 2011 USA Orthopedics surgeons Twitter (Franko 2011)	Analyse the type and prevalence of orthopedic surgery-related profiles on Twitter in regard to self-identified surgeons	Qualitative descriptive	All identified as orthopedic	Online observation	descriptive	NA
Hoffman 2011 Australia - QLD OT Website (Hoffmann,	Explore occupational therapists perceptions of the benefits of, barriers to and reason for using or	Mixed methods Focus groups Survey	FG – at national conference	Focus groups (n=2; user/nonuser) Survey (55/673)	FG – qualitative descriptive; member checking; thematic analysis	Moderate

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
Desha & Verrall 2011)	not using an online CoP				(blinded to origin of transcripts	
Kukreja 2011 USA Pharmacist Twitter facebook(Kukreja, Heck Sheehan & Riggins 2011)	To define the current use patterns of Facebook and twitter among pharmacy preceptors and assess perceptions regarding use of social media within professional practice	Qualitative	Convenience sample of pharmacy preceptors	Survey 27 item instrument – piloted	Descriptive	Moderate
Lau 2011 Hong Kong Nurses Web 2.0(Lau 2011)	to investigate how Web 2.0 tools can be applied for knowledge sharing leaning, social interaction and production of collective intelligence in the nursing domain and to investigate what behavioral perceptions are involved in the adoption of Web 2.0 by nurses	Qualitative	377 Registered nurses working in public hospitals in Hong Kong	Survey - Decomposed theory of human behaviour (DTPB);	Pearson's correlation coefficient, r, and t test	Strong
Valaitis 2011 Canada Nurses VCoP(Valaitis et al. 2011)	Explore community health nurses' viewpoints on whether a VCoP supported their practice	Qualitative	Statements 66 →44 Q-sort – 16 (10% members? Say n= 114 for membership)	Stage 1 – initial statements gathered using online survey (n=15) & focus groups (n=21) Stage 2 – statement refined Stage 3 - Q-sort 16 (following pretesting)	PQMethod 2.11, by-person factor analysis to identify participants with similar points of view Factor extraction – centroid method	Strong
Apostolakis 2012 Greece	Level of knowledge and use of internet and social	qualitative	Greek healthcare professionals	Survey 41 item instrument		Fair

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
Social media(Apostolakis et al. 2012)	media technologies acceptance and trust of social media for social, professional and general activities		graduates of single institution	Piloted Cronbach α 0.738		
Archambault 2012 Canada Emergency speciality Wiki(Archambault et al. 2012)	To explore participants beliefs on the utility of wiki based reminder regarding best practice management of severe traumatic brain injury	Qualitative	3 sites 25 emergency physicians 25 allied health	Semi structured interviews	Content analysis – deductive Coding based on Theory of planned behaviour	Strong
Burg 2012 USA Social workers Mailing list (Burg, Adorno & Hidalgo 2012)	to describe the general categories and themes of postings ; examine the process of facilitation of mutual support and information exchange among oncology social workers (OSW)	Qualitative descriptive	Dec 2010-Nov2011	Online observation of listserv	Content analysis - inductive	Strong
Chaudhry 2012 USA Oncology physicians Twitter(Chaudhry et al. 2012)	Explore how Twitter use had expanded over time	Qualitative descriptive	Census sample	Online observation Stratified	Deductive content analysis 3 coders – independent	Moderate
Desai 2012 Twitter – conference Nephrology (Desai et al. 2012)	content, citation, and sentiment analyses of tweets generated from Kidney Week 2011 would reveal a large number of educational tweets that were disseminated to the public.	Qualitative descriptive	5 days	Online observation	Deductive content analysis	moderate

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
McGowan 2012 United states Oncologist + primary care physicians Social media(McGowan et al. 2012)	assess factors related to social media use by physicians	Qualitative	Response rate 28.97% (485/1695)	Survey using Technology acceptance model Cronbach α 0.92 (average)	Descriptive Hierarchical regression	Strong
McKendrick 2012 USA Anaesthetic clinicians Twitter (McKendrick, Cumming & Lee 2012)	Describe the introduction and uptake of twitter at a conference	Qualitative descriptive	9 weeks	Online observation	Content analysis – deductive	Strong methods Limited sample
Murty 2012 USA Listserv Social workers(Murty et al. 2012)	Categorise content of posts on mailing list	Qualitative descriptive	Data corpus 1 - 8 months Data corpus 2 – 2 weeks Data corpus 3 – 3 random months	Online observation	Content analysis - inductive	Strong
Stewart 2012 Thailand Paediatric clinicians Discussion forum (Stewart & Abidi 2012)	To understand the dynamics of the knowledge sharing with the pediatric pain community	Social network analysis	27 months	Online observation	Descriptive & non-parametric Social network analysis	
Usher 2012 Australia Healthcare professionals Social media(Usher 2012)	Identifying the reason behind patterns of social media (Web 2.0) by 8 major healthcare professional groups	Survey	8 healthcare professional groups	Online survey 16 item instrument	Descriptive Correlational	Fair
Von Muhlen 2012 Clinicians	Review social media adoption by clinicians	Literature review	Pubmed To July 2011	Reviewed by primary author & scientific	Narrative Summary table 1	Fair

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
Social media (von Muhlen & Ohno-Machado 2012)				consultant; discrepancies resolved through discussion Articles categorized into Overviews Adoption surveys Reference use Educational impact and use Professional conduct	only	
Abrahamson 2013 International Discussion forum nurses(Abrahamson, Fox & Anderson 2013)	To evaluate Information exchange in an online discussion forum ; identify potential for CoP	Qualitative descriptive	1 month discussion threads	Not described	Content analysis – deductive	Fair
Brynolf 2013 Sweden Physicians Twitter (Brynolf et al. 2013)	to investigate if unethical or unprofessional online behavior had occurred in a population based sample of Swedish speaking physicians and medical students on twitter	Qualitative descriptive	Swedish speaking medical officers Last 100 tweets	Online observation	Content analysis – deductive	Moderate
Dieleman 2013 United Kingdom Occupational therapist Discussion forum (Dieleman & Duncan 2013)	Gain an understanding of the purpose and use of online discussion group	Case study	Data corpus – 8 years posts	Online observation Census sampling	Theoretical Thematic analysis	Moderate

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
Hamm 2013 Healthcare professionals Social media in general (Hamm et al. 2013)	What social media tools are being used by healthcare professionals and trainees? In which disciplines and specialties are social media tools being used For what purposes are social media tools being used What types of evidence and research designs have been used to examine social media tools	Literature review - scoping	11 databases 2000-2012	Data extraction by single reviewer with 10% cross checked for accuracy Data extracted Study & population characteristics Tool Objectives outcomes measure Authors' conclusions	Narrative Summary tables Demographics of studies Cross tabulation of tool type against objective of study Setting against tool Outcomes against tool	Strong
Lulic 2013 USA Emergency physicians Twitter (Lulic & Kovic 2013)	to identify and create the largest directory of emergency physicians on twitter; analyse their user profile and reveal details behind their connections	Exploratory descriptive	All twitter users self-identified as emergency physicians	Twiangulate, NodeXL, FollowWonk	descriptive	Fair
Moorhead 2013 Healthcare professionals social media(Moorhead et al. 2013)	to review the current published literature to identify the uses, benefits, and limitations of social media for health communication among the general public, patients, and health professionals and to identify current gaps in the literature to provide	Literature review - systematic	10 databases 2002-2012	study design, social media tool/application, study purpose, participants/sample and sample size, measurement tools, results, conclusion, and use of social media two reviewers	Summary tables Social media tools/applications Methodological qualities By method Uses of social media Benefits Limitations	Strong

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
	recommendations for future health communication research.			used Downs & Black		
Neill 2013 Twitter Emergency medicine Conference tweeting (Neill et al. 2014)	To examine if twitter was a resource for disseminating clinical information and promoting and facilitating the aims of a medical conference	Mixed methods	All tweets with #ICEM2012 stratified	Online observation	Descriptive Deductive content analysis	Strong
Anderson 2014 Australia Public health Twitter (Anderson et al. 2014)	Explore what Twitter users communication and how they interacted across the conference days	Prospective descriptive	Census sample (3 days)	Online observation (Storify)	Thematic	satisfactory
Ferguson 2014 Australia and New Zealand Cardiology clinicians Twitter(Ferguson et al. 2014)	To evaluate twitter use during a national scientific meeting	Qualitative descriptive	Census	Online observation	Descriptive	Moderate
Frisch 2014 Canada Nurses VCoP (Frisch et al. 2014)	To evaluate whether VCoP from the perspective of users	Mixed methods Descriptive – use of website 2 Surveys – member satisfaction Interviews – involvement in Action groups and perceptions of network’s activities and successes in achieving goals	Monthly website metrics from inception Census sample for survey Purposive sample for interviews	Online Electronic survey	Descriptive for website and survey Thematic for survey	Survey – fair Interviews - moderate
Fuoco 2015 Social media	Understand attitudes and practices of urologists	Qualitative	Census of active members of	Online and paper survey	Descriptive with Fisher’s exact test	Fair

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
Canada Urologists(Fuoco & Leveridge 2015)	with respect to social media use in personal and professional lives		professional association		to compare across demographics or use settings	
Hajar 2014 USA Pharmacists Twitter (Hajar, Clauson & Jacobs 2014)	To identify the number of pharmacists with twitter accounts, their usage characteristics and their professional networking patterns	Qualitative descriptive	Census 30 Tweets from 1/3 of accounts	FollowerWonk	Tweets – inductive content analysis SNA – NodeXL	Moderate
Hawkins 2014 International Radiology professionals Twitter (Hawkins, Duszak & Rawson 2014)	To assess and quantify the use of twitter during a radiology conference	Descriptive	Census sample 20 days (Meeting six days + 1 week either side)	Online using Symplur ¹	Quantitative	Satisfactory
Kim 2014 Korea Emergency physicians Facebook (Kim et al. 2014)	Examine use of facebook page over initial 12 months	Mixed methods Online observation Survey	Census	Online observation of posts Survey – paper, email telephone and facebook messaging	Posts – deductive content analysis Survey - descriptive	Moderate
Matta 2014 North America Physicians Twitter(Matta, Doiron & Leveridge 2014)	To analyze the content of twitter activity for 2 national urology meetings over two years	Qualitative descriptive	Census sample covering conference period only	Online using Symplur ²	Content analysis - deductive	Fair

¹ Symplur LLC Upland California USA

² Symplur California

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
Mishori 2014 USA Physicians Twitter(Mishori et al. 2014)	Characterize and understand information diffusion in social media (Twitter) by examining twitter networks of 4 professional medical societies	Descriptive	Three months Tweets – census sample – one month	Online observation Topsy	Descriptive Visualization	satisfactory
Mishori 2014 USA Physicians Twitter(Mishori, Levy & Donvan 2014)	Analyze conference tweets to see who is talking and what they are talking about	Qualitative descriptive Tweet analysis Interviews	Census sample (8 days; 3 pre/post conference + 5 conference days Top 9 tweeters	Online observation (Hootsuite and Hashtracking) Email interviews	Deductive content analysis thematic	Moderate (CA) Limited for interviews
Moorley 2014 UK Nurses Twitter (Moorley & Chinn 2014)	Evaluate the development, growth and positive experiences of using Twitter to create an online community including benefits, barriers and enablers	Qualitative descriptive	Census	Online observation	Descriptive	Fair
Rolls 2014 Australia Intensive care Listserv(Rolls et al. 2014)	Describe the social network of a listserv for intensive care clinicians	Retrospective descriptive	Database Census	Excel spreadsheet	Descriptive with some inferential	satisfactory
Ying Mai 2014 USA Nurses Social media(Ying Mai & Sanghee 2014)	Provide a preliminary review of the characteristics of nurses involved in social media use	Survey	160 professional advance practice nursing organizations and colleges of nursing	Survey, online	Descriptive with some inferential	Fair
Canvasser 2015 International	Examine use of Twitter by urologists by	Qualitative descriptive	Census sample 7 days (1 pre/post + 5	Online observation (Tweetreach)	Deductive content analysis (manual	Moderate

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
Urologists Twitter (Canvasser et al. 2015)	evaluating use during annual meeting		conference days)		and machine (Semantria)	
Benetoli 2015 Pharmacists Social media (Benetoli, Chen & Aslani 2015)	Review the literature on the social media use in professional pharmacy practice; and assess research designs used	Systematic literature review	Census			Adequate
Deen 2013 Mental health practitioners US (Deen, Withers & Hellerstein 2013)	Identify to current use of social media and electronic communication by psychiatrists and psychologists, and their attitudes towards these platforms that hinder or facilitate care in the future	Survey; online	Census sample of academic faculty	Online	Descriptive with comparisons across groups; especially in respect to age	Limited
Klee 2015 Family medicine USA Social media (Klee, Covey & Zhong 2015)	Provide insight into family physicians' use and acceptance of social media; assess current professional training	Survey; online	Census sample of one state	Online	Descriptive with comparisons across group with respect to years of experience	Limited
Lawson 2015 Radiology Australia Social media (Lawson & Cowling 2015)	What does the current literature report as common uses of social media for professional development in healthcare globally? How is social media used as professional development in	Systematic literature review	Academic literature post 2011		Descriptive	Limited

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
	healthcare?					
Grindrod 2014 Social media International Pharmacy (Grindrod et al. 2014)	Review how pharmacists and pharmacy students participate in social media and identify available guidance for professional behaviour	Scoping review; following framework	Medline, Embase, Google Scholar and International Pharmaceutical Abstracts for English articles published Pre May 2013		Thematic	fair
Tunnecliff 2015 Social media Pacific (Tunnecliff et al. 2015)	To explore health researchers and clinicians current use of social media and their beliefs and attitudes towards the use of social media in professional context	Mixed methods Online survey Interviews	Targeted distribution to via research centres, department heads, professional organisations, affiliates of Monash university Interviews self-nominated then randomly selected	Online researcher developed survey Semi-structured telephone interviews	Descriptive and exploratory analysis of survey Thematic analysis of qualitative data (Braun & Clarke 2006)	Survey – Fair Interviews – moderate
Awad 2015 Pharmacy Twitter USA (Awad & Cocchio 2015)	Evaluate the use of twitter by attendee and non-attendee participants in ASHPs 2013 and analyze the potential education utility	Qualitative descriptive	All tweets during conference	Symplur	Content analysis – deductive	Moderate
Loeb 2014 Physician - Urology Social media USA (Loeb et al. 2014)	To characterize the current status of social media among AUA members and participation at 2013 meeting	Mixed methods Survey Online observation (#AUA13)	Survey – random sample	Paper survey Symplur	Descriptive	Fair
Whitaker 2003	Classify the topics	Mixed methods	Survey – census	Online survey	Survey –	Survey

Author/country/Social media type	Purpose	Design	Sample/data corpus	Data collection	Data analysis	Quality
Pharmacy Listserv United Kingdom (Whitaker, Cox & Alexander 2003)	discussed during one month Survey the usage of and attitudes towards a mailing list for pharmacists Identify the benefits of membership Identify any changes in practice as a result of information from the list	Survey Content analysis	sample One month of discussion threads	Online observation	descriptive Content analysis – deductive	– moderate Content analysis – fair
Roberts 2015 Healthcare Twitter International (Roberts et al. 2015)	Evaluate status of social media facilitated journal clubs (twitter) as an example of continuing professional development	Systematic review + online observation	Medline, Embase, CINAHL, Web of Science, ERIC Online search of Twitter	Online	Descriptive	Adequate
Barnett 2012 GP training Virtual communities International (Barnett et al. 2012)	Critical review to determine if there is any evidence to support virtual communities of practice in GP training; Identify evidence-based guidelines for establishing VCoP	Literature review	Scopus, Psychlit and Pubmed		Thematic based on business virtual community framework (Probst & Borzillo 2008)	Adequate

Appendix C Quality assessment table for qualitative studies

CASP (CASP International 2013) criteria Was there a clear statement of the aims of the research?

1. Is a qualitative methodology appropriate?
2. Was the research design appropriate to address the aims of the research?
3. Was the recruitment strategy appropriate to the aims of the research?
4. Was the data collected in a way that addressed the research issue?
5. Has the relationship between researcher and participants been adequately considered?
6. Have ethical issues been taken into consideration?
7. Was the data analysis sufficiently rigorous?
8. Is there a clear statement of findings?
9. How valuable is the research?

Author	1	2	3	4	5	6	7	8	9	10	quality
Murray 1996 (Murray 1996)	yes	yes	yes	yes	yes	cant tell	yes	cant tell	yes	yes	satisfactory
Roberts 1998 (Roberts & Fox 1998)	yes	yes	yes	yes	yes	yes	cant tell	yes	yes	yes	satisfactory
Cervantez-Thompson 2004 (Cervantez Thompson & Penprase 2004)	yes	yes	yes	yes	yes	cant tell	yes	cant tell	yes	yes	satisfactory
Brooks 2006 (Brooks & Scott 2006a)	yes	yes	yes	yes	yes	cant tell	yes	cant tell	yes	yes	satisfactory
Hara 2007 (Hara & Hew 2007)	yes	yes	yes	cant tell	yes	cant tell	yes	yes	yes	yes	satisfactory
Hew 2007 (Hew & Hara 2007b)	yes	yes	yes	yes	yes	cant tell	yes	yes	yes	yes	satisfactory
Hew 2008 (Hew & Hara 2008)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	satisfactory
Hughes 2009 (Hughes et al. 2009)	yes	yes	yes	yes	yes	cant tell	cant tell	yes	yes	yes	satisfactory

Author	1	2	3	4	5	6	7	8	9	10	quality
Valaitis 2011 (Valaitis et al. 2011)	yes	yes	yes	yes	yes	cant tell	yes	yes	yes	yes	satisfactory
Archambault 2012(Archambault et al. 2012)	yes	yes	yes	yes	yes	cant tell	yes	yes	yes	yes	satisfactory
Dieleman 2013 (Dieleman & Duncan 2013)	yes	yes	yes	cant tell	cant tell	No	cant tell	yes	yes	yes	satisfactory
Anderson 2014 (Anderson et al. 2014)	yes	yes	yes	yes	yes	cant tell	cant tell	yes	yes	cant tell	satisfactory
Ferguson 2014 (Ferguson et al. 2014)	yes	cant tell	cant tell	yes	yes	yes	yes	yes	yes	yes	satisfactory
Frisch 2014 (Frisch et al. 2014)	yes	cant tell	yes	yes	yes	yes	cant tell	yes	cant tell	yes	satisfactory
Moorley 2014 (Moorley & Chinn 2014)	yes	yes	not sure	cant tell	yes	no	no	no	no	yes	Satisfactory
Tunnecliff 2015 (Tunnecliff et al. 2015)	yes	yes	yes	yes	yes	no	cant tell	cant tell	cant tell	yes	satisfactory

Appendix D Quality Assessment Table for studies using Content Analysis

Quality assessment of studies using content analysis techniques (Graneheim & Lundman 2004; Krippendorff 2004; Zhang & Wildemuth 2009) included:

- Data: appropriateness to research question, data corpus, sampling unit, unit of analysis and sampling plan (described and justified)
- Coding schema: appropriateness of approach, development, coders, training, theoretical underpinning of categories and reliability of coding schema
- Analysis: appropriateness of approach
- Score: × - criteria missing; ✓ - limited description of criteria; ✓✓ criteria described and explained; ✓✓✓ criteria fully explained and rationale provided

References	Approach	RQ	Data corpus	Sampling unit	Unit of analysis	Sampling plan	Appropriate approach	Development	Coders	Training	Theoretical underpinning of categories	Reliability	Appropriateness of approach	Overall score
<u>Berman 1996</u> (Berman 1996)	Deductive	✓	✓	×	×	✓	✓	×	×	×	×	×	×	✓
<u>Bowers 1997</u> (Bowers 1997)	Inductive	✓	✓✓	✓✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓
<u>Cervantez Thompson 2002</u> (Cervantez Thompson 2002)	Deductive	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓	✓	×	✓	×	✓	✓
Whitaker (Whitaker, Cox & Alexander 2003)	Deductive	✓✓	✓	✓	✓	✓	✓	✓✓	✓	✓	✓	✓	✓	✓

References	Approach	RQ	Data corpus	Sampling unit	Unit of analysis	Sampling plan	Appropriate approach	Development	Coders	Training	Theoretical underpinning of categories	Reliability	Appropriateness of approach	Overall score
<u>Smith 2004</u> (Smith 2004)	Deductive	✓	✓✓	✓✓	✓	✓✓	✓	✓	x	x	✓	x	✓	✓
(Rodriguez-Recio 2007) (Rodriguez-Recio & Sendra-Portero 2007)	Deductive	✓✓	✓✓✓	✓	✓	✓✓✓	✓✓	✓	x	x	✓	x	x	✓
<u>Morken 2009</u> (Morken, Bull & Moen 2009)	Inductive	✓	✓	✓	✓	✓✓	✓	✓	✓	✓	✓	✓✓	✓	✓
<u>Foong 2010</u> (Foong & McGrouther 2010)	Deductive	✓✓	✓✓✓	✓✓	✓✓	✓✓	✓✓	x	x	x	✓	x	x	✓
<u>Abrahamson 2013</u> (Abrahamson, Fox & Anderson 2013)	Inductive	✓	✓	✓✓	✓✓	✓	✓	✓	✓✓	✓✓	✓	✓	✓	✓
Matta 2014 (Matta, Doiron & Leveridge)	Deductive	✓	✓✓	✓✓	✓✓	✓✓	✓✓	x	x	x	✓	x	x	✓

References	Approach	RQ	Data corpus	Sampling unit	Unit of analysis	Sampling plan	Appropriate approach	Development	Coders	Training	Theoretical underpinning of categories	Reliability	Appropriateness of approach	Overall score
2014)														
<u>Murray 1996</u> (Murray 1996)	Inductive	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓	✓	✓	✓	✓✓	✓✓
<u>Long 2009</u> (Long et al. 2009)	Inductive	✓✓	✓✓✓	✓✓	✓	✓✓	✓✓	✓✓✓	✓✓	✓	✓✓✓	✓✓	✓✓	✓✓
<u>Macdonald 2009</u> (Macdonald, MacPherson & Gushulak 2009)	Deductive	✓✓	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓	✓	✓✓	✓	✓	✓✓
<u>Chaudhry 2012</u> (Chaudhry et al. 2012)	Deductive	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✓✓	✓✓	✓	✓✓	✓✓
<u>Hajar 2014</u> (Hajar, Clauson & Jacobs 2014)	inductive	✓✓	✓✓	✓✓	✓✓✓	✓✓	✓✓	✓✓✓	✓✓	x	✓✓	✓✓✓	✓✓	✓✓

References	Approach	RQ	Data corpus	Sampling unit	Unit of analysis	Sampling plan	Appropriate approach	Development	Coders	Training	Theoretical underpinning of categories	Reliability	Appropriateness of approach	Overall score
Canvasser 2015 (Canvasser et al. 2015)	Deductive	✓	✓✓✓	✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✓✓	✓✓
Awad 2015 (Awad & Cocchio 2015)	Deductive	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓	✓	✓✓	✓✓	✓✓	✓✓
<u>Mishori 2014 (Mishori, Levy & Donvan 2014)</u>	Deductive	✓✓	✓✓✓	✓✓	✓✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓	✓	✓✓	✓✓	✓✓
<u>Reutzel 2001(Reutzel & Patel 2001)</u>	Deductive	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓
<u>Brooks 2006a (Brooks & Scott 2006b)</u>	Deductive	✓✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
<u>Brooks 2006b(Brooks & Scott 2006a)</u>	Deductive	✓✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓
<u>Hara 2007(Hara & Hew 2007)</u>	Inductive	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓

References	Approach	RQ	Data corpus	Sampling unit	Unit of analysis	Sampling plan	Appropriate approach	Development	Coders	Training	Theoretical underpinning of categories	Reliability	Appropriateness of approach	Overall score
<u>Hew 2007 (Hew & Hara 2007b)</u>	Inductive	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
<u>Burg2012 (Burg, Adorno & Hidalgo 2012)</u>	Inductive	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓
<u>Desai 2012(Desai et al. 2012)</u>	Deductive	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓	✓✓	✓✓✓	✓	✓✓	✓✓✓
<u>McKendrick 2012 (McKendrick, Cumming & Lee 2012)</u>	Deductive	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
<u>Murty 2012 (Murty et al. 2012)</u>	Inductive	✓✓	✓✓✓	✓✓✓	✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓
<u>Neill 2014(Neill et al. 2014)</u>	Deductive	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓✓
<u>Brynof 2013 (Brynof et al. 2013)</u>	Deductive	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓	✓✓	✓✓✓	✓	✓✓✓	✓✓✓

References	Approach	RQ	Data corpus	Sampling unit	Unit of analysis	Sampling plan	Appropriate approach	Development	Coders	Training	Theoretical underpinning of categories	Reliability	Appropriateness of approach	Overall score
<u>Kim (Kim et al. 2014)</u>	Deductive	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓

Appendix E Quality Checklist for Surveys. (Greenhalgh et al. 2005b)

1	Research question and design
1.1	Was there a clear research question, and was this important and sensible?
1.2	Was a questionnaire the most appropriate research design for this question?
2	Sampling
2.1	What was the sampling frame and was it sufficiently large and representative?
2.2	Did all participants in the sample understand what was required of them, and did they attribute the same meaning to the terms in the questionnaire?
3	Instrument
3.1	What claims for reliability and validity have been made, and are these justified?
3.2	<i>Did the questions cover all relevant aspects of the problem in a non-threatening and on-directive way?</i>
3.3	Were open-ended (qualitative) and closed-ended questions used appropriately?
3.4	<i>Was a pilot version administered to participants representative of those in the sampling frame, and the instrument modified accordingly?</i>
4	Response
4.1	What was the response rate and have non-responders been accounted for?
5	Coding and analysis
5.1	Was the analysis appropriate (eg statistical analysis for quantitative answers, qualitative analysis for open-ended questions) and the correct technique/s used?
5.2	Were outcomes measure by 'blinded' observers or were they objectively verified (eg quantitative measure recorded prospectively and independently)?
6	Presentation of results
6.1	Have all relevant results ('significant' and 'non-significant')?
6.2	Is there any evidence of data dredging? (ie analyses that were not 'hypothesis driven')?
Score	× - criteria missing; ✓ - limited description of criteria; ✓✓ criteria described and explained; ✓✓✓ criteria fully explained and rationale provided

Author	1.1	1.2	2.1	2.2	3.1	3.2	3.3	3.4	4.1	5.1	5.2	6.1	6.2	quality
Apostolakis 2012 (Apostolakis et al. 2012)	✓✓✓	✓✓	✓✓✓	✓	✓✓	✓✓	✓	✓✓✓	✓	✓✓	✓	✓✓	No	✓
Cook-Craig 2009 (Cook-Craig & Sabah 2009)	✓✓✓	✓✓✓	✓✓	✓	✓	✓	✓	x	✓	✓✓	✓	✓✓✓	No	✓
Rodriguez-Recio 2007 (Rodriguez-Recio & Sendra-Portero 2007)	✓✓	✓✓	✓✓✓	x	x	✓✓	✓✓	x	✓	x	✓	✓✓	No	✓
Usher 2012 (Usher 2012)	✓	✓✓	✓✓	✓	✓✓	✓	✓	x	✓	✓✓	✓	✓✓	No	✓
Watson 2003 (Watson 2003)	✓	✓	✓✓✓	✓	x	✓	✓	x	✓✓	✓	✓	✓	No	✓
Frisch 2014 (Frisch et al. 2014)	✓	✓	✓	x	x	✓	✓	x	✓	✓	✓	✓	No	✓
Fuoco 2014 (Fuoco & Leveridge 2015)	✓✓	✓✓	✓✓	x	x	✓	✓	x	✓✓	✓	✓	✓	No	✓
Ying Mai 2014 (Ying Mai & Sanghee 2014)	✓	✓	✓	x	x	✓	x	✓	x	✓	x	✓	No	✓
Deen 2013 (Deen, Withers & Hellerstein 2013)	✓✓	✓✓	✓✓	✓	✓	✓✓	✓	✓	✓	✓✓	✓	✓	No	✓
Klee 2015 (Klee, Covey & Zhong 2015)	✓✓	✓	✓✓	✓✓	✓	✓	✓	✓✓✓	✓	✓	✓	✓	No	✓
Tunnecliff 2015 (Tunnecliff et al. 2015)	✓✓	✓✓	✓	✓	✓	✓✓	✓	⊞	⊞	✓	⊞	✓✓	No	✓
Loeb2014 (Loeb et al. 2014)	✓	✓✓	✓✓	✓	✓	⊞	⊞	✓	✓	✓	⊞	✓	No	✓
Cervantez Thompson 2004 (Cervantez Thompson & Penprase 2004)	✓✓	✓✓	✓✓✓	✓	✓✓	✓✓	✓✓	x	✓✓	✓✓	✓	✓✓	No	✓✓

Author	1.1	1.2	2.1	2.2	3.1	3.2	3.3	3.4	4.1	5.1	5.2	6.1	6.2	quality
Hoffmann 2011 (Hoffmann, Desha & Verrall 2011)	✓✓	✓✓	✓✓	✓	x	✓	✓	✓	✓	✓	✓	✓✓	No	✓✓
Kukreja 2011 (Kukreja, Heck Sheehan & Riggins 2011)	✓✓	✓✓	✓	✓	✓✓	✓	✓	✓✓	✓	✓✓	✓	✓✓	No	✓✓
Rolls 2008 (Rolls et al. 2008)	✓✓	✓✓	✓✓✓	x	x	✓✓	✓✓	✓	✓✓	✓✓	✓	✓✓	No	✓✓
Schoch 1997 (Schoch & Shooshan 1997)	✓✓	✓✓	✓✓✓	✓✓	x	x	✓✓	✓✓	✓✓	✓✓	✓	✓	No	✓✓
Shanahan 2009 (Shanahan, Herrington & Herrington 2009)	✓✓✓	✓✓	✓✓	✓✓	✓	✓	✓	✓✓✓	✓✓	✓✓✓	NA	✓✓	No	✓✓
Widemark 2008 (Widemark 2008)	✓✓	✓✓	✓✓✓	✓✓	✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✓✓✓	✓✓	✓✓	No	✓✓
Kim 2014 (Kim et al. 2014)	✓✓	✓✓	✓✓	✓✓✓		✓✓	✓✓		✓✓✓	✓✓	✓	✓	No	✓✓
Whitaker 2003(Whitaker, Cox & Alexander 2003)	✓✓	✓✓	✓✓	✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓	✓	✓	No	✓✓
Lau 2011 (Lau 2011)	✓✓✓	✓✓✓	✓✓✓	✓✓	✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	No	✓✓✓
McGowan 2012 (McGowan et al. 2012)	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✓	✓✓	✓✓✓	✓✓✓	✓✓✓	No	✓✓✓

Appendix F Quality assessment of Literature Reviews (SIGN Scottish Intercollegiate Guidelines Network)

Please note that not all studies claim to be a systematic review

Reference	Method used	1.1 RQ	1.2 methodology	1.3 Rigorous search	1.4 Study quality	1.5 Studies are sufficiently similar	score
von Muhlen 2012 (von Muhlen & Ohno-Machado 2012)	Literature review	poorly addressed	poorly addressed	poorly addressed	adequately addressed	poorly addressed	-
Barnett 2012 (Barnett et al. 2012)	Literature review	well covered	adequately covered	adequately covered	not addressed	well covered	+
Moorhead 2013 (Moorhead et al. 2013)	Systematic review	well covered	well covered	adequately covered	adequately addressed	adequately covered	++
Hamm 2013 (Hamm et al. 2013)	Scoping review	well covered	adequately covered	well covered	not addressed	well covered	++
Grindrod 2014 (Grindrod et al. 2014)	Scoping review	well covered	well covered	adequately covered	not addressed	adequately covered	+
Lawson 2015 (Lawson & Cowling 2015)	Systematic review	adequately covered	poorly addressed	poorly addressed	not addressed	adequately covered	-
Benetoli 2015 (Benetoli, Chen & Aslani 2015)	Systematic review	adequately covered	adequately covered	poorly addressed	not addressed	adequately covered	+
Roberts 2015 (Roberts et al. 2015)	Systematic review	adequately covered	adequately covered	adequately covered	not addressed	adequately covered	+

Appendix G Content of posts on Healthcare Social Media

Study	Manifest Content	Latent Content	Posting behaviour
Brooks Midwives United Kingdom Public Health organisation (Brooks & Scott 2006a)		Knowledge work Φ – 88% (172) - Tacit knowledge – 20% (39) - Explanatory force to suggested resolution 20% (39) Information work Ψ – 9% (16) Dispersed leadership and collegial support – 32.6% (63)	44 of 96 staff - 18 staff midwives posted 51% (36/70) - 6 graded \geq sister - 3 community midwives - 17 posted without demonstration
Brooks Cardiology and geriatric Nurses; Midwives United Kingdom Public Health organisation (Brooks & Scott 2006b)	Cardiology - 15 months - 21 threads with 71 posts Older persons – 7.5 months - 6 threads with 18 posts Obstetrics – 1.5 months - 11 threads with 70 posts	Cardiology - Knowledge work Φ – 30% - Information work Ψ -70% Older persons - Knowledge work Φ – 74% - Information work Ψ – 26% Obstetrics - Knowledge work Φ – 92% - Information work Ψ – 8%	Cardiology - 26 contributors - 15 RN (<2yrs); 8 RN- E; 9 experienced RNs; 1 nurse manager Older persons - 11 contributors - 1 RN <2yrs experience; 10 experienced RNs; 1 nurse manager Obstetrics – 29 contributors - 18 midwives; 3 community midwives; 2 incharge midwives; 4 midwifery managers
Berman Social workers Israel Two topic specific Lists (Berman 1996)	Email traffic - List 1 – 369 emails/37 days - List 2 - 194 emails/43 days	Discussion of issues: - List 1 43.4%; List 2 56.3% Information request only: - List 1 22.8%; List 2 10.9% Information transfer only: - List 1 10.7%; List 2 12.5%	List 1 168 posters 38 posters/ 58.8% of emails List 2 – 64 posters 8 participants / 51% of emails
Bowers Psychiatric nursing United Kingdom – International (Bowers 1997)	Email traffic – 16 months - Threads <3 emails = 130 - Threads > 3 emails = 45 (range 4-33)	Topics of importance: - Nursing models – 33 emails/ Advanced Practice – 27/ Lurking – 26/ Mental health laws – 23/ Labels (of patients) –	Not described

Study	Manifest Content	Latent Content	Posting behaviour
		22/ Violence - 22	
Thomas General practitioners United Kingdom (Thomas & James 1999)	May 1995 Traffic - 155 emails (daily average 5) January 1998 - 1160 (daily average 40)	13 Topics – humor 283, technical 232, clinical 226 - From survey Topics of greatest value: General discussion (75%); camaraderie (17%); clinical discussion (3%)	May 1995 - 59 posters; lurking 62% January 1998 - 182 posters; lurking 71% Range – 1 email/65 ;2-10 emails/392; 11-30 emails/12; >30/4, one person sent 14
Reutzel School nurses US-International Professional organisation US (Reutzel & Patel 2001)	Email traffic – 5 months 71 threads on medication management Emails per thread 1-27	Components of medication administration that present as problems - Administration 21%; Therapeutic appropriateness 19%; Use 17%; Storage 13%; Documentation 9%; Transfer 7.5%; Liability 7%; Information 2% - Sources of Authority - Practices 37 %; Opinions 28%; Policies 17%; Legalities 15%; guidelines 3%	Not evaluated
Cervantez Rehabilitation nurses US-International Professional organisation US (Cervantez Thompson 2002)	Email traffic – 18 months - 2053 emails - 551 initiations - 1678 responses - 178 both	- Administration -29% - Clinical procedures – 26% - Professional issues – 16% - Impairment/disability – 15% - Clinical documentation – 8% - Miscellaneous – 5%	- 67% (318/475) posted Range 1-91 (mean 6.4) - 27.8% - 1 post - 10 members - > 30 posts - 551 initiated postings
Smith Medical librarians United States (Smith 2004)	Email traffic - 1991 – 123 ; 1992 – 162; 2002 – 201 Singleton messages - 1991 – 22%; 1992 - 42.7%; 2002 – 68.2% - Thread length – mean(SD) - 1991 – 4.2 (1.6); 1992 – 2.8 (1);2002 - 2.1 (0.2)	- Discussion (exchange of opinion, practices, product evaluation) o 1991 – 58.5%; 1992 -35.2%; 2002 – 21.4% - Information exchange o 1991 – 13.5%; 1992 -22.2%; 2002 – 49.3% - Meta discussion (comments on List itself) o 1991 – 8.1%; 1992 -6.8%; 2002 – 0% - Noise	- Member contributions - 1991 – 6% (n=5) → 30.1% - 1992 – 12.1% (n=13) → 29.6% - 2002 – 15.5% (n=20) → 29.4%

Study	Manifest Content	Latent Content	Posting behaviour
		<ul style="list-style-type: none"> ○ 1991 – 8.9%; 1992 -11.7%; 2002 – 2% - Thanks <ul style="list-style-type: none"> ○ 1991 – 0.8%; 1992 -1.9%; 2002 – 16.9% - Miscellaneous <ul style="list-style-type: none"> ○ 1991 – 10.6% ; 1992 -22.2%; 2002 – 10.5% 	
(Hara & Hew 2007) Advanced practice critical care nursing United States	Email traffic – first two weeks of each month for 12 months - 1059 emails Query to response rate: 1.68-1	<p>Types of online activities - 1119 thematic units</p> <ul style="list-style-type: none"> - Sharing knowledge - 56.2%; Solicitation – 33.4 %; Job posting – 6.1 %; miscellaneous 3.3% <p>Types of knowledge shared</p> <ul style="list-style-type: none"> - Book knowledge – 8.7% - Practical knowledge – 92.3% : Institutional practice – 53.5%; Personal opinion – 24.7%; Personal suggestion – 13.2; Cultural knowledge - 0 	Not measured
Hew Advanced practice critical care nursing United States (Hew & Hara 2008)	Email traffic – 6 weeks (first two weeks of March 2003-2006)	<p>Types of knowledge shared</p> <ul style="list-style-type: none"> - Institutional practice 57.3% - Personal opinion - 26.3% - Personal suggestion 10.3% - Book knowledge 6.1% 	Not measured
Rodriguez-Recio Radiology professionals Spain Professional organisation (Rodriguez-Recio & Sendra-Portero 2007)	1998-2003 – 2700 emails Distribution - Monthly mean 44.3 (SD 26, range 0-107)	<p>Categories</p> <ul style="list-style-type: none"> - Scientific information 43.4% (n=1185) 130 subjects identified - Information request 24.7% (n=293) - Answer – 53.8% (n=638) - Information spreading 21.4 (n=254) 	No of messages - % of subscribers (n=) <ul style="list-style-type: none"> - >200 - 0.3 (1) - 41-50 - 1.3 (5) - 31-40 - 1.6 (6) - 21-30 - 2.4 (9) - 11-20 - 5.5 (21)

Study	Manifest Content	Latent Content	Posting behaviour
		<ul style="list-style-type: none"> - Discussion – 21.7 (n=592) - Announcement – 15.7% (n= 436) - Noise – 13.5% (n=368) - Clinical case – 5.4% (n=148) 	<ul style="list-style-type: none"> - 5-10 - 8.5 (32) - 2-4 - 20.6 (78) - 1 only - 13.5 (51) - None - 46.5 (175)
<p>Macdonald Travel medicine Multi-disciplinary International Professional organisation (Macdonald, MacPherson & Gushulak 2009)</p>	<p>Email traffic</p> <ul style="list-style-type: none"> - 1710 messages over 8 months - Primary – 26% (n=389) - Response – 74% (n=1120) - Mode – 1 (Range 1-51) 	<p>Message types</p> <ul style="list-style-type: none"> - Administration – 12% (n=204) - Educational – 88% (n=1506) <p>Topics - 27</p> <ul style="list-style-type: none"> - Vaccine preventable diseases – 37% - Vector-borne diseases – 22% - General – 16% - Pre-travel – 12% - Miscellaneous - 13% 	<p>369 users (41% of List members)</p> <ul style="list-style-type: none"> - Doctors - 68% (n=252) – 68% posts - Nurses – 22% (n=80) – 27% posts - Location: US & Canada – 65%; Europe – 18%; Oceania – 6%; Asia – 5%; Africa – 2% <p>Users</p> <ul style="list-style-type: none"> - 20 most frequent users – 43% total posts - 10 most frequent users – 30% total posts
<p>Morken Occupational health (OH) Multidisciplinary Norway Professional organisation (Morken, Bull & Moen 2009)</p>	<p>Email traffic</p> <ul style="list-style-type: none"> - 1997-2006 -5269 emails – - Messages per year:1997-417; 2000-746; 2006 -315 	<ul style="list-style-type: none"> - Chemical hazards – 19% (n=1001) - Organisation of OH services – 17% (n= 890) - Methods in health, safety and environment – 10% (n=554) - Ergonomics – 8% (n=436) - Noise and radiation – 5% (n=5) - August-October 2006 activity - 46 subjects: 28 posed as questions; 13 as pure information; 5 irrelevant - Of questions: 64% (n=18) were answered satisfactorily; 32% (n=9) partially answered; 18% (n=5) were not answered 	<p>Messages per list member: 1997-2.1; 2004-0.6</p> <ul style="list-style-type: none"> - Contributors (n=132): occupational hygienists (27%); doctors (14%); physiotherapists (13%); nurses (13%) - Mean messages per contributor: 2.4 (range 1-20) - 2% (11/467 list members) contributed 26% (n=83) messages
<p>Long Paediatric occupational therapists Australia Healthcare organisation (Long et al. 2009)</p>	<p>Email traffic – 12 months</p> <ul style="list-style-type: none"> - 2104 posts [843 initial posts] - Mean reciprocity – 2.5 (SD 2.8) 	<ul style="list-style-type: none"> - Practice and organisational – 26.69% (n=225) - Performance component– 21.12% (n=178) - Performance area – 17.91% (n=15) - Health conditions – 6.76%(n=57) 	<p>430 of possible 600 posted</p> <ul style="list-style-type: none"> - Low level (< 4) – n=239 contributed 20.48% of total posts - Medium level (4-20) – n=179 contributed 62.32% of total posts - High level (19-59) – n=12 contributed 17.2% of total posts

Study	Manifest Content	Latent Content	Posting behaviour
Cook-Craig social workers Israel Public Health organisation (Cook-Craig & Sabah 2009)	<ul style="list-style-type: none"> - Jan 07 - 10 discussion forums with 1750 hits - Jan 08 – across 16 discussion forums with 6800 hits - May 08 – across 18 discussion forums with 7000 	Not evaluated	<ul style="list-style-type: none"> Jan 07 - 200 users/1000 members - 8.75 hits/user Jan 08 - 1200 users/3000 members - 5.66 hits/user May 08 – 1500 users/4200 members - 4.66 hits/user
Franko Twitter Orthopedic (Franko 2011)	-	<ul style="list-style-type: none"> - Last 10 tweets - 64 - News - 71.8% - Personal - 56.2% - Professional - 37.5 - Opinions - 12.5% - Product/promotion - 6.3 - Other - 9.4 	<ul style="list-style-type: none"> - 1 tweet % n=69 - Within 1 week - 34.7% - Within 1 month - 46.3 Within last year - 71%
Foong India Plastic surgeons Discussion forum (Foong & McGrouther 2010)	2217 emails in a calendar year 330 discussion threads (average 6.7 emails per)	Categories - 4 <ol style="list-style-type: none"> 1. Advice on treatment – 40% 2. Education (meetings; courses; fellowships) – 25% 3. Case reports – 25% 4. Introduction of new members – 4% Topics <ol style="list-style-type: none"> 1. Training & courses – 26.7% 2. Cleft – 15.4% 3. Aesthetics – 13.1% 4. Trauma – 12.5% 5. Head & Neck – 8.4% 6. Cutaneous – 6.4% 7. Perineal/genital – 6.1% 8. Scar – 4.7% 9. Other – 6.7% 	Not evaluated
Abrahamson International discussion	294 discussion threads – over one month	25 categories	Not evaluated

Study	Manifest Content	Latent Content	Posting behaviour
forum for nurses Themed forums (Abrahamson, Fox & Anderson 2013)	-	<ol style="list-style-type: none"> 1. Technical or Clinical – 17% 2. Non-clinical – 83% - 24 categories <ol style="list-style-type: none"> a. Career advice – 26% (75) b. Education advice – 8% (24) c. Perception of unjust treatment by management – 7% (21) d. Shift work – 5% (14) e. Handling job related emotions – 4% (13) f. Sharing stories – 4% (13) g. Nursing management – 4%(12)other 	
Dieleman United kingdom Forensic occupational therapist (Dieleman & Duncan 2013)	2494 posts over 8 years (monthly median 303 IQR 227-424)	<p>Themes:</p> <ol style="list-style-type: none"> 1. Seeking & giving advice - 40.5% (n=1010) 2. Requesting and sharing material resources - 19.4% (n=485) 3. Networking - 27.3% (n=680) 4. Defining the OT role – 8% (n=199) 5. Student posts - 5.2% (n=129) 	<p>Post origin Location</p> <ul style="list-style-type: none"> ▪ UK – 60% (n = 1485) ▪ Unknown – 32% (n=810) ▪ 20 other countries – 8% (n=199)
(Stewart & Abidi 2012) Paediatric pain forum Multidisciplinary	<p>568 posts over 115 threads</p> <p>Average thread length 4.94 (range 1-25)</p> <ul style="list-style-type: none"> • 		<p>46 unique members</p> <p>31 posters</p> <p>Posters</p> <p>12 ≥ 10 posts</p> <p>Nurses - 77% posts</p> <p>Reading</p> <p>26 < 25 reads</p> <p>8 – 25-44 reads</p> <p>12 – 45-94 reads</p>

Study	Manifest Content	Latent Content	Posting behaviour
			<ul style="list-style-type: none"> Nurses - 67%
Whitaker Pharmacy Listserv United Kingdom (Whitaker, Cox & Alexander 2003)	One month 386 covering 429 topics	Topics 1. Patient problems/clinical problems 20% (n=87) 2. Pharmacy politics 18% (n=77) 3. Non-pharmacy chat 14% (n=60) 4. Legal issues 9% (n=37) 5. Drug Tariff 7% (n=30) 6. Government policy 5% (n=21) 7. Business/finance 5% (n=22) 8. Risk management 4% (n=17) 9. Supportive 3% (n=14) 10. Non-pharmacy IT 2% (n=7) 11. Pharmacy IT 1% (n=4) 12. Other 12% (n=53)	
Desai 2012 North America Multi-disciplinary nephrology Twitter (Desai et al. 2012)	993 tweets Informative 29% Uninformative 38%	Sentiment score Mean 0.094 (SD 0.476; range -1.70-2.67)	993 tweets by 172 (1.4% of participants)
Hajar 2014 Twitter USA (Hajar, Clauson & Jacobs 2014)		Exclusively social 57% (n=115) Predominantly social 33% (n=68) Predominantly professional 9% (n=18) Exclusively professional 1% (n=3)	Daily tweets mean (SD) – 3 ± 7 Reach mean (SD) – 399 ± 1163
Kim 2014 Korea Facebook	Cat 1 – Asking for clinical advice on a difficult case to aid decision making – 26.7% (74/277) – 667 comments; median		277 index posts

Study	Manifest Content	Latent Content	Posting behaviour
Emergency physicians (Kim et al. 2014)	<p>6(IQR 3-10); difficult ECGs 54% and acute coronary syndrome 32.4%)</p> <p>Cat 2 posts discussing interesting cases 50.5% (140/277)</p> <p>Cat 3 Educational (informative knowledge, sharing references or informative websites - 15.9 % (44/277)</p> <p>Cat 4 - announcements - 6.9% (19/277)</p>		<p>Posts per member not quantified</p> <p>Identified 14 major respondents however did not quantify</p>
Moorley 2014 Twitter Nurses (Moorley & Chinn 2014)			<p>Tweet chats</p> <p>Dignity – 75 participants</p> <p>The new vision for nursing – the vision and 6Cs – 89 participants (1700 website pages visits)</p> <p>The new vision for nursing – obstacles and solutions – 72 participants (1610 website pages visits)</p> <p>Inpatient use of social media – 140 participants (2930 website pages visits)</p> <p>Defining sage staff levels – 95 participants (1403 website pages visits)</p> <p>The Francis report – 93 participants (1322website pages visits)</p>
Ferguson 2014 Australia and New Zealand Twitter Cardiac professionals (Ferguson et al. 2014)			<p>Origin of tweets</p> <p>Australia - 68.9% (514/779)</p> <p>USA – 28.4% (212/779)</p> <p>UK – 1.6% (12/779)</p> <p>5 other countries – (8/779)</p> <p>Top ten tweets (range) – 14-83</p>

Study	Manifest Content	Latent Content	Posting behaviour
			Top ten username mentioned – (range) 30-151 Top ten impressions (range) – 9034 - 979100
Mishori 2014 USA 4 medical professional societies One general (AMA), three specialty (AAFP, AAP and ACP)			High dissemination potential (AMA 122 066 397; AAP 14 496 559; ACP 11 228 160; AAFP – 6 959 092) Low actual dissemination
Anderson 2014 Australia Public health Twitter (Anderson et al. 2014)	748 tweets 13 broad themes 1. Statement from keynote & plenary session - 37.3% (282) 2. Concurrent sessions – 14.2% (107) 3. What is happening next and looking forward to – 12.2% (92) 4. Personal comments, likes and dislikes – 8.2% (62) 5. Pre-conference workshop (aboriginal and Torres strait islander – 6.7% (51) 6. AHPA and Croakey - 6.6% (50) 7. Workshops - 4% (30) 8. General appreciative remarks – 3.6% (27) 9. Health information not from conference – 2.5% (19) 10. Statistical facts - 2.2 (17) 11. Conference oration - 1.3% (10) 12. Not categorized – 0.7 (5)		12.8% of attendees (96 tweeters/466? = 20%) Range 1-129 75% < 6 9% >20 (129, 82, 50, 36)

Study	Manifest Content	Latent Content	Posting behaviour
	13.Posters – 0.5 (4)		
Mishori 2014 USA Physicians Twitter(Mishori, Levy & Donvan 2014)	1818 by 181 user accounts Tweet types <ul style="list-style-type: none"> • Original – 61% (1103) • Modified – 9% (159) • Re-Tweet – 31% (556) Original tweet content <ul style="list-style-type: none"> • Session related 69.7% • Social – 14.2% • Logistics – 6.9% • Other – 7.6% Advertisement - 1.6%		13% of attendees (181 /1370) Top tweeter – 15.4% of all tweets Top 10 <ul style="list-style-type: none"> – 56% of data – Range – 61-280
Hawkins 2014 International Radiology professionals Twitter (Hawkins, Duszak & Rawson 2014)	Tweets – 2011 4061; 2012 5630 Characteristics <ul style="list-style-type: none"> • Meeting related with links – 201150% (n=1630); 2012 55% (n=2443) • Original tweets – 2011 62% (n=2015) ; 2012 63% (n=2816) 		N tweeting – 2011_755; 2012-1116 Tweets per participant: mean 4.9 both years <ul style="list-style-type: none"> • 2011 range 1-156; SD 12.4; • 2012 range 1-235; SD 15.1 • > 5 tweets 2011-135; 2012-179 • Top 100 2011 mean 22(range 6-156); 2012 mean 29 (range 8-235) ; + 31.8% User origin <ul style="list-style-type: none"> • 2011: USA 67%; Europe 17%; Asia 5%; South America 3%; Australia 0.6%; Africa 0.4% • 2012: USA 65%; Europe 18%; Asia 5%; South America 2%; Australia 2%; Africa 0.4%
Matta 2014 North America Physicians Twitter(Matta, Doiron & Leveridge 2014)	Tweets #uro12 n=756; (Retweets 17.8% , Informative 21.8% , uninformative 60.4%) #aia13 – 3956 (Retweets 24.9%, Informative 29.4%, uninformative 45.3%) #cua2012 – 635 (Retweets 19%,		N tweeting <ul style="list-style-type: none"> • 2012-134 • 2013-540

Study	Manifest Content	Latent Content	Posting behaviour
	Informative 44.8% , uninformative 36.2%) #cua2013 – 5402 (Retweets 27.2%, Informative 38.6% , uninformative 34.2%		
Canvasser 2015 North America Physicians Twitter (Canvasser et al. 2015)	335 tweets (217 primary; 118 retweets) Informative 56.7% (n=190; 39.5%) Uninformative 44.3%	Tweet sentiment – mean 0.13 (range -0.90- 1.80); 57% neutral	N tweeting – 68 (42 at meeting); 4.9 per (range 1-55) Tweets for top ten tweeters <ul style="list-style-type: none"> • Range 2-55 • Responsible for 64% tweets (87% primary; 35% retweets) Tweeting conference faculty 3.3% (10/302) Tweet reach 38 141
Context: healthcare professional type; country; initiating organisation;	Φ Knowledge work- posts with critical reflection Ψ Information work – posts without critical reflection	Personal opinion – individual opinion (I believe ...) Person suggestion – personal solution for problem or issue (whenever I teach a topic I...) Institutional practice – knowledge related to an institution (our hospital ..) Book knowledge individual's awareness of knowledge about mere facts such as statutes, policies, and standards.	AMA – American medical association ACP – American college of physicians AAP – American Academy of Pediatrics AAFP – American Academy of Family Practice

Appendix H UTS HREC 2010-226N

18 June 2010

Professor Doug Elliott
Nursing, Midwifery and Health
CB10.07.213
UNIVERSITY OF TECHNOLOGY, SYDNEY

Dear Doug,

UTS HREC 2010-226 – ELLIOTT, Professor Doug – “Evolution of an intensive care listserv”

Thank you for submitting a Low Risk/Negligible Risk Impact Research Declaration Form.

We have considered your Declaration and agree your research does not require further review from the UTS Human Research Ethics Committee. Please keep a copy of your Declaration form on file to show you have considered risk.

For tracking purposes, you have been provided with an ethics application number, which is UTS HREC 2010-226N.

I also refer you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

If you or anyone connected with this research have any queries please do not hesitate to contact either myself, or the Research Ethics Officer, Ms Racheal Laugery on 02 9514 9772.

Yours sincerely,

Mr Peter Trebilco
Deputy Chairperson

Appendix I UTS HREC REF NO. 2010-364A

21 October 2010

Professor Doug Elliott
Nursing, Midwifery and Health
CB10.07.209
UNIVERSITY OF TECHNOLOGY, SYDNEY

Dear Doug,

UTS HREC 2010-364 – ELLIOT, Professor Doug, DAVIS, Associate Professor Deborah, FOUREUR, Professor Maralyn (for ROLLS, Ms Kaye, PhD student) – “Content analysis of emails exchanged on a professional listserv”

At its meeting held on Tuesday 12 October 2010, the UTS Human Research Ethics Committee reviewed your application, noting that the research was well planned and clearly thought through. I am pleased to inform you that ethics clearance is now granted.

Your clearance number is UTS HREC REF NO. 2010-364A

Please note that the ethical conduct of research is an on-going process. The *National Statement on Ethical Conduct in Research Involving Humans* requires us to obtain a report about the progress of the research, and in particular about any changes to the research which may have ethical implications. This report form must be completed at least annually, and at the end of the project (if it takes more than a year). The Ethics Secretariat will contact you when it is time to complete your first report.

I also refer you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

If you have any queries about your ethics clearance, or require any amendments to your research in the future, please do not hesitate to contact the Ethics Secretariat at the Research and Innovation Office, on 02 9514 9772.

Yours sincerely,

Associate Professor Marion Haas

Chairperson
UTS Human Research Ethics Committee

Appendix J UTS HREC 2014000378

Please note that the HREC changed processes to an email notification

UTS HREC Approval

Research.Ethics@uts.edu.au [Research.Ethics@uts.edu.au]

Sent: Wednesday, August 06, 2014 1:49 PM

To: Kaye Roll; Doug Elliott; Research Ethics

Dear Applicant

The UTS Human Research Ethics Committee reviewed your application titled, "Why healthcare professionals belong to a virtual professional community", and agreed that the application meets the requirements of the NHMRC National Statement on Ethical Conduct in Human Research (2007). I am pleased to inform you that ethics approval is now granted.

Your approval number is UTS HREC REF NO. 2014000378

Your approval is valid five years from the date of this email.

Please note that the ethical conduct of research is an on-going process. The National Statement on Ethical Conduct in Research Involving Humans requires us to obtain a report about the progress of the research, and in particular about any changes to the research which may have ethical implications. This report form must be completed at least annually from the date of approval, and at the end of the project (if it takes more than a year). The Ethics Secretariat will contact you when it is time to complete your first report.

I also refer you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

You should consider this your official letter of approval. If you require a hardcopy please contact Research.Ethics@uts.edu.au.

To access this application, please follow the URLs below:

* if accessing within the UTS network:

<http://rmprod.itd.uts.edu.au/RMNet/RM0001N.aspx>

* if accessing outside of UTS network: <https://remote.uts.edu.au>, and click on "RMNet - ResearchMaster Enterprise" after logging in.

We value your feedback on the online ethics process. If you would like to provide feedback please go to: <http://surveys.uts.edu.au/surveys/onlineethics/index.cfm>

If you have any queries about your ethics approval, or require any amendments to your research in the future, please do not hesitate to contact Research.Ethics@uts.edu.au.

Yours sincerely,

Professor Marion Haas

Chairperson

UTS Human Research Ethics Committee

C/- Research & Innovation Office

University of Technology, Sydney

T: (02) 9514 9645

F: (02) 9514 1244

E: Research.Ethics@uts.edu.au

I: <http://www.research.uts.edu.au/policies/restricted/ethics.html>

P: PO Box 123, BROADWAY NSW 2007

[Level 14, Building 1, Broadway Campus]

CB01.14.08.04

Appendix K UTS HREC 2014000683**UTS HREC 2014000683****HREC Approval Granted**

Research.Ethics@uts.edu.au [Research.Ethics@uts.edu.au]

Sent: Monday, December 15, 2014 3:03 PM

To: Doug Elliott; Kaye Rolis; Research Ethics

Dear Applicant

UTS HREC REF NO. 2014000683

The UTS Human Research Ethics Expedited Review Committee reviewed your amendment application for your project titled, "Why healthcare professionals belong to a virtual professional community - Amendment", and agreed that the amendments meet the requirements of the NHMRC National Statement on Ethical Conduct In Human Research (2007). I am pleased to inform you that the Committee has approved your request to amend the protocol by incorporating key informant interviews as a data collection method.

You should consider this your official letter of approval. If you require a hardcopy please contact the Research Ethics Officer (Research.Ethics@uts.edu.au).

To access this application, please follow the URLs below:

* if accessing within the UTS network: <http://reprod.itd.uts.edu.au/RMENet/HOMEBIN.aspx>

* if accessing outside of UTS network: <https://remote.uts.edu.au> , and click on "RMENet - ResearchMaster Enterprise" after logging in.

We value your feedback on the online ethics process. If you would like to provide feedback please go to: <http://surveys.uts.edu.au/surveys/onlineethics/index.cfm>

If you wish to make any further changes to your research, please contact the Research Ethics Officer in the Research and Innovation Office, Ms Racheal Laugery on 02 9514 9772.

In the meantime I take this opportunity to wish you well with the remainder of your research.

Yours sincerely,

Professor Marion Haas

Chairperson

UTS Human Research Ethics Committee

C/- Research & Innovation Office

University of Technology, Sydney

T: (02) 9514 9772

F: (02) 9514 1244

E: Research.Ethics@uts.edu.au

I: <http://www.research.uts.edu.au/policies/restricted/ethics.html>

P: PO Box 123, BROADWAY NSW 2007

[Level 14, Building 1, Broadway Campus]

CB01.14.08.04

Ref: E13

Appendix L Data Dictionary

Subject-topic taxonomy			
Subject major The specific area identified within <i>the</i> parent tweet	Subject minor	Primary topic Primary area of concern within the post	Minor topics Minor topic/s introduced during a post or DT
Clinical governance Is the systematic approach to maintaining and improving the quality of patient care within a health system	Education & training		
	Risk Management		
	Clinical audit		
	clinical effectiveness		
	Information management		
	Research & development		
	Clinical audit		
Staffing			
Equipment any equipment DT except where the poster is concerned with infection prevention			
Clinical practices	Infection prevention		
	Procedures		
	Patient assessment & Monitoring		
	Ventilation circuit		
	Respiratory support		

Appendix L Data Dictionary

Knowledge type taxonomy – knowledge requested - experiential		example	
Institutional practice experience	Where poster asks for how a unit manages a particular clinical practice	<ul style="list-style-type: none"> • Just wondering what people are using for ETCO2 monitoring for out-patient cardioversions done in wards/ CCU. • I'm interested to know what the general consensus on ventilator circuit changes are. 	
Personal experience	Where the poster asks for personal clinical experience or clinical practice tips	<ul style="list-style-type: none"> • Quick and dirty survey - how many ICU nurses out there have had ventilated trachy patients eating and drinking? • What are peoples views with ventilated tracheostomy patients ... inner cannula or no inner cannula? 	
Clinical treatment advice	Where poster asks for specific treatment advice for a patient	<ul style="list-style-type: none"> • 	
Product service	Experiential - Institutional product experience	Where the posters ask for how a unit has experienced a product (includes equipment & disposables)	<ul style="list-style-type: none"> • I would like to know what masks others are using for "non-invasive" Ventilation currently. • Can anyone tell me how successful the NIV is with the Servo??
	Explicit Product information	Where the poster asks for product, equipment or service information	<ul style="list-style-type: none"> • We are seeking some information regarding long term ventilation for patients who no longer require Intensive care, but due to their disease state, for example, motor neuron disease, require ventilatory assistance long term/ 24hrs a day. Can anyone provide us with information regarding which company would be best able to supply equipment, education and backup for home ventilation? • What devices are out there? What are other ICU's using. I know RPH and a few other ICU's in the West, use Clapper Board set up.
	Product – service	Where poster asks for both explicit & experiential knowledge on a product	<ul style="list-style-type: none"> • I was wondering about the different hospitals preferences with the use of the Portex Tracheostomy vs. the Shiley Tracheostomy and the reasons why?

Appendix L Data Dictionary

Knowledge type taxonomy – knowledge requested - Explicit		example
Codified institutional practice	Where the poster asks for explicit or codified institutional practice including education programs	<ul style="list-style-type: none"> • but can people give me an idea when they change the ventilator circuits and what current evidence you use to justify this procedure. • At XXX Hospital, we have had problems with pressure areas from endotracheal tube tapes. We use white tracheostomy tapes and reston foam, change them prn. Recently we have been changing them every shift. Does anyone have a protocol on ETT tapes and how to secure a tracheostomy. I have attended to an audit re securing/changing ETT tapes
Scientific knowledge	Where the poster asks for research evidence	<ul style="list-style-type: none"> • Does anyone 'out there' have any good evidence re patients with tracheostomies having ice to suck. • Please could you elaborate on the references you quote - there is not enough information for me to find what "studies have shown". Even better, if you have copies, they could be sent to the list so we can all read them

Appendix L Data Dictionary

Knowledge type taxonomy – knowledge supplied - Experiential			example
Beliefs, opinions or advice	Where the poster provides their opinion or beliefs or offers advice	Use of I or my personal preference	<ul style="list-style-type: none"> Unfortunately M-34 is right. The statement "we will not guarantee the integrity of xxx after yy days" is all to do with marketing and nothing to do with science. Why would a company do research that might show it doesn't need to sell as many widgets?
Personal experience	Where the poster provides personal practice experience		<ul style="list-style-type: none"> I would ensure patient is awake and wants the ice to suck - give a little - observe and if there are problems - stop! Ask for SP involvement until successful decannulation.
Institutional experience	With practice –	where the poster provides unit experience with a practice but doesn't include descriptors indicating these are codified practices	<ul style="list-style-type: none"> We currently change our circuits weekly and the closed suction daily. For short term ventilation, we use an HME for 48hrs (which is changed daily), then move to a humidified circuit if further ventilation is required.
	With product or service	where the poster provides unit experience with a product (includes equipment & consumables)	<ul style="list-style-type: none"> Let me add my voice of support for the full face masks - they have dramatically changed the way we use NIV as they patients actually like them!!!

Appendix L Data Dictionary

Knowledge type taxonomy – knowledge supplied - Explicit			example
Guideline/standard	Institutional (ICU or LHD specific)	Where the poster provides explicit or codified institutional practice including education programs	<ul style="list-style-type: none"> H-2 ICU has a difficult airway drill (guideline) with 5 flow diagrams to suit different scenarios – these are used as a learning tool for mock drills.
	State/national	Where the poster provides explicit or codified practice at either a state or national level	<ul style="list-style-type: none"> However if you look at the revised policy of the College of Anaesthetists PS18 (attached) it says "A monitor of carbon dioxide level in inhaled and exhaled gases must be in use for every patient under general anaesthesia."
Products	Company recommendations	Where poster describes/discusses specific company recommendations	<ul style="list-style-type: none"> The last time communication from a company regarding the frequency of ventilator circuit changes was when there was a reported risk of fire from a circuit was used for more than 7days.
	Product availability	Where poster describes/discusses product availability	<ul style="list-style-type: none"> ETCO2 monitors are available that monitor CO2 on non intubated patients via sampling cannulas that look much the same as nasal prongs
	Product function	Where poster describes/discusses product functions/ality	<ul style="list-style-type: none"> BiPAP Vision is not TGA registered for invasive ventilation except via a trachy. It cannot be used for normal ETT ventilation as its primarily a Non-invasive Pressure Support / CPAP device via masks. It does have a timed breath backup feature but was included as an emergency if the patient has become Apnoeic and buys time to setup for intubation and invasively ventilate.
Scientific knowledge	Specific study/ies	Where poster provides Scientific information +/- unpacks research to apply to situation	You probably need to search American respiratory therapists and SCCM however a quick scholar google search found (see attached) a SHEA guideline which outlines what M-34 spoke about
	Appropriate research method	Where poster discusses/describes how to research a topic	<ul style="list-style-type: none"> To do an effective trial would require thousands of participants given an accidental extubation rate of around 2.5%, and not all of these could be attributed to having a full length tube insitu. So it comes down to a consensus view informed by risks and benefits.

Knowledge supplied - Know – how

- know-how knowledge includes an articulation of the problem, solution and rationales for a specific situation.

We use leukoplast tapes too, and change once daily/prn as required. (*what is done*) ..

We have found they secure the ETT well, and provided they are applied to clean dry skin, they adhere well. (*rationale*)

For patients at risk of removing their own ETT (*problem*)

, we may also use x1 trache tape over the leukoplast (*solution*)

to ensure it is more secure. (*rationale*)

For the people with a moustache/beard (*problem*) , we use x2 trache tapes, sometimes we "twist the tapes", clearing it from the mouth and preventing (*rationale*) it dragging across a patient's mouth/aggravating the corners (*problem*)

. We also use gauze behind the ears (*solution*) to prevent damage there. (*problem*)

Knowledge supplied - Know-why

- Know-why is embodied by an understanding of the problem, working through alternative solutions, rationales and application of scientific evidence to a specific situation.

<http://rc.rcjournal.com/content/early/2013/06/18/respcare.02168.short>

For the time poor - look at Table 5 in the full text pdf (Page 19) (*explicit or scientific knowledge*)

and note - many, many sites in Australia use suction pressures well over 150mmHg, the suction level used in the experiment, however the suction pressure at the wall does not always equal the suction pressure at the end of the suction catheter as discussed. Many of us use outlets that routinely deliver 40kPa of suction (40kPa below atmospheric) or roughly 300mmHg - double that used in the experiment. (*problem*)

The numbers in the table cannot be doubled however, but this paper is still a useful indicator of the airway pressure drops that may be experienced by patients using various suction catheter/ETT dimension combinations. (*rationale/s*,)

One of the questions this paper raises is: "what is the biggest pressure drop we should tolerate in the airway during suctioning?" probably depends on duration, what the patient is doing (breathing in or out), and a whole lot of other factors... tough to study too... I suspect anything more negative than 10cm

H₂O would probably be concerning but have absolutely no evidence to back up this statement. (reflection)

Bear in mind that with a high quality ICU ventilator the suction offset is from PEEP, so on a PEEP of 15cmH₂O, a suction drop of 20cmH₂O results in an airway drop to 5cmH₂O below atmospheric. (rationale/s,)

Take home message from this paper - watch your ETT:suction catheter dimension ratio! (solution,)

In H-17, I am pretty sure we use 14Fr suction systems in ETT down to 7.0mm - maybe we should drop to a 12Fr system in any ETT smaller than 8.0... Hopefully no adults are getting size 6.0 tubes or smaller :-) (specific situational application)

Appendix M Focus groups - Online recruitment -demographic and group rules

Page 1 of 2

<p>1. What is your IC-VC email address This will be used to identify how many times you have posted in the last two years (Sept 1 2012-August 312014). This will be used to place you into one of three focus groups</p> <ul style="list-style-type: none"> • Focus group 1 – posted > 5 times • Focus group 2 – posted ≤ 5 times • Focus group 3 – have not posted 	
<p>2. Please select the healthcare professional?</p>	<ul style="list-style-type: none"> ○ Nurse (go to 2) ○ Doctor ○ Physiotherapist ○ Pharmacist ○ Dietitian ○ Occupational therapist ○ Healthcare manager ○ other
<p>3. For nurses only – please indicate what best describes your primary professional role</p>	<ul style="list-style-type: none"> ○ Clinical care of patients within a designated unit ○ Clinical care of patients across the hospital ○ Education of staff within a unit or hospital ○ Tertiary education ○ A combination of research, practice development or education ○ Management of a designated clinical unit/s ○ Management across a healthcare facility ○ Not a nurse
<p>4. How long have you been a healthcare professional?</p>	
<p>5. Please indicate the best description of your primary workplace</p>	<ul style="list-style-type: none"> ○ Adult ICU(includes sub specialities) ○ Paediatric ICU ○ Emergency department ○ Coronary care ○ Not critical care – please describe
<p>6. How long have you been working in critical care? If not in critical care please move onto question 6</p>	
<p>7. What is your primary place of employment</p>	<ul style="list-style-type: none"> ○ Public hospital ○ Private Hospital ○ Health department unit ○ Healthcare industry ○ Tertiary education facility ○ Other (please indicate where)

Appendix M Focus groups - Online recruitment -demographic and group rules (page 2 of 2)

<p>8. What is the location of your primary place of employment</p>	<ul style="list-style-type: none"> <input type="radio"/> NSW <input type="radio"/> Victoria <input type="radio"/> Queensland <input type="radio"/> Western Australia <input type="radio"/> South Australia <input type="radio"/> Tasmania <input type="radio"/> Northern Territory <input type="radio"/> Outside Australia (please indicate which country)
<p>9. Please review the Focus group ground rules and identify whether you agree or disagree.</p> <ul style="list-style-type: none"> i. I will keep my comments focused on the specific question and use professional language and spelling. However I will use emoticons, capitals or punctuation where I wish to add emphasis to my posts. ii. I will not make personal derogatory comments about the content of other focus group participants' posts iii. Where I discuss the online behaviour of ICUConnect members I will use professional language and not be personally derogatory about any individual iv. I will not discuss the content of any focus group discussions with other colleagues v. I will not disclose the participation of other focus group members to colleagues 	
<p>10. Are there any other ground rules you believe are important? Additional rules will be discussed at the beginning of the focus group.</p>	

Appendix N Notification to ICUConnect members

4/3/2009

Dear Members

I would like to start a conversation on ICUConnect regarding research and the listserv. The main reason, although not the only, for doing so is that I am enrolled in a Doctor of Nursing and I am proposing using ICUConnect as the study site. There is very little research on the Use of listservs and like media by health professionals and there is a lack of ethical guidelines, specifically around the use of retrospective data (past emails). I believe there is a wealth of information contained within ICUConnect and research will reveal much about how intensive Care is practised in Australia. While some researchers have not addressed this issue others have raised it on-list and those lists concerned have had no problems. As we dont currently have any items regarding research on ICUConnect netiquette I would like to review these to reflect the current memberships' views on research and the listserv. Therefore I would like to propose the following additions to our listserv netiquette (wording to be reviewed in light of discussion). I have already discussed these issues with the chair of a university ethics committee.

Database

1. The ICUConnect database includes the following details of members: Name, position description, unit, hospital/facility, Area health service, state, country, email address, subscription date, and subscription status.
2. The ICUConnect member database will be kept behind an institutional firewall within a department specific drive.
3. ICCMU undertakes that this database is PRIVATE and WILL NOT forward the database onto a third party.

ICUConnect Discussions

1. ICUConnect discussions will be compiled and posted at the ICCMU website
2. When compiling ICUConnect discussions ICCMU will identify posters by position, type of hospital/unit and country
3. Copyright of ICUConnect discussions belongs to the ICUConnect community with ICCMU able to compile discussions.

ICUConnect and Research

1. Any research project that is conducted on ICUConnect discussions or involving ICUConnect members will

- a. have been approved by an institutional ethics board b - refer to members using pseudonyms and/or by demographic description
 - b. when requesting members to participate in research the researcher will contact members twice only
 - c. satisfy the usual procedures for maintaining data integrity, privacy and confidentiality
2. Members of ICUConnect agree that they can be contacted via email for the purposes of research that satisfies the above conditions
 3. NO LURKING or covert monitoring of ICUConnect, for the purposes of research, will be allowed.

Kaye Rolls CNC

Single response

4/36/2006

Just pointing out that despite anonymity in point 2 and 3; the ICU discussion postings using just position and unit/hospital will make it very apparent who contributors are from many facilities in Oz. Perhaps for true anonymity - the role and type of unit is displayed with a name that the person has chosen to be known by aka a 'call sign'. (Not sure of net ID name)

Appendix O Results of recruitment

Type of member	Focus group 1 – Frequent posters (> 5)	Focus group 2 – Low posters (1-5)	Focus group 3 – Non posters	Total
Clinical nurse-internal ^a		4	2	6
Clinical nurse-external ^b		1	1	2
Knowledge Broker nurse ^c	3	4	2	9
Clinical unit manager ^d	1	2	1	4
Academic Nurse ^e		4	1	5
Physiotherapist			1	1
Physician		1		1
Healthcare manager ^{6f}			1	1
Total	4	16	9	29
Post range	6-19	1-4 (Mode 1; median 1)		

Notes:

^aClinical nurse-internal - provides clinical services within a clinical unit

^bClinical nurse-external - provides clinical services across multiple clinical unit

^cKnowledge Broker - job role could include advanced practice, education, research or practice development

^d Clinical unit manager – manages a defined ward or clinical area

^e Nurse academic– employed by a tertiary education institution

^f Healthcare manager - employed in a non-clinical or managerial role in health service

Appendix P Member type intensive care and professional experience

Member type	Intensive care experience	Professional experience
	Mean (SD; range)	Mean (SD; range)
Clinical nurse-external (n=2)	23 (4.23; 20-26)	32 (2.82; 30-34)
Knowledge broker (n=7)	22.88 (5.817; 16-34)	28 (6.00; 20-34)
Academic (n=5)	21.8 (2.49; 20-25)	26.8 (5.35; 20-32)
NUM (n=5)	20.4 (8.47; 7-27)	27.8 (8.55; 14-36)
Physician (n=2)	20(0; 20)	24.5 (0.70; 24-25)
Clinical nurse-internal (n=3)	10.33 (3.215; 8-14)	18.67 (9.80; 12-30)
Bureaucrat (n=1)	13	15
Allied health (n=1)	12	16
Total (n=27)	19.85 (6.44; 7-34)	25.81 (7.26; 12-36)