

Multilevel integrated healthcare: The evaluation of Project ECHO® networks to integrate children's healthcare in Australia

C. Broccatelli ^{a,c,*}, P. Nixon ^b, P. Moss ^b, S. Baggio ^b, A. Young ^b, D. Newcomb ^{b,2}

^a Universitat Autònoma de Barcelona – GRAFO group, Department of Social and Cultural Anthropology, Spain

^b Children's Health Queensland Hospital and Health Service, Australia

^c The University of Queensland, Australia

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ABSTRACT

The present empirical study aims to explore medical knowledge sharing in the Australian healthcare context, aiming to broadly evaluate the potential impact of Project ECHO®, an online mentoring and networking health program. We focus on health-related knowledge sharing practices among the network of professionals through formal and informal channels, and across different health and non-health sectors and organisational systems. Studying knowledge transmission among professional networks is essential for optimizing healthcare delivery, promoting innovation, and providing insights on improvement of patient experiences within the healthcare system. We utilize a multilevel approach to shape our data collection strategy. Employing network measures and Multilevel Exponential Random Graph Models, we aim to explore how advice and knowledge sharing behaviours among healthcare professionals and their institutions are interdependently connected. Then, we incorporate network generated results within an evaluation framework for establishing some aspects of the efficiency of the ECHO program along four pillars: *Acceptability*, *Capability*, *Reachability*, and *Integration*. Our investigation found that among ECHO members, hierarchy is less pronounced compared to across levels and organizations, with certain individuals emerging as central in advice-sharing. The multilevel network perspective showed complex, informal patterns of knowledge and information sharing, including inter-organizational hierarchy, role and sector homophily, brokerage roles with popularity across health organizations, and connectivity through knowledge-sharing in cross-level small group clusters.

Introduction

It is widely acknowledged that fragmented care, such as the lack of collaboration and coordination in patient care between different healthcare providers and/or healthcare organizations, negatively impacts health outcomes and leads to treatment delays, interrupted relationships between patients and care providers, misdiagnosis, avoidable emergency department visits, hospital admissions, and longer hospital stays (Agha et al., 2019). The reasons for fragmentation vary across healthcare and local government jurisdictions, reflecting systemic contexts. This fragmentation is often attributed to health services operating in isolated silos, with specific administrative practices and management decision-making procedures (Peiris et al., 2024). Models of

integrated care have the potential to reduce health system fragmentation, bringing together health and non-health service providers to improve coordination and the care experience for patients (Goodwin, 2016). Depending on the health system context, multi-agency partnerships in integrated care might involve primary, secondary, and tertiary healthcare institutions as well as non-medical organisations, for example stakeholders in education (e.g., school-based nurse, school psychologist), housing (e.g., support worker), and social support sectors, both public and private (e.g. family wellbeing practitioner, youth worker).

In integrated care approaches, multi-agency providers become complementary and can work in more collaborative ways to understand health needs and provide services that include medical interventions as

* Correspondence to: UAB – Universitat Autònoma de Barcelona - Department of Social and Cultural Anthropology - Edifici B, Carrer de la Fortuna s/n, Campus UAB Bellaterra (Cerdanyola del Vallès), Barcelona, 08193, Spain.

E-mail address: chiara.broccatelli@uab.cat (C. Broccatelli).

¹ School of Music - The University of Queensland, Brisbane Qld 4072 Australia

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well as holistic wellbeing supports (World Health Organization, 2007). The improvements in quality of care are sustained by organic collaborations between providers from initial diagnosis through to the provision of treatments, including emotional and psychological supports in a way that overcomes traditional boundaries between services and disciplines (Valentijn et al., 2013; Lennox-Chhugani, 2023).

The estimated benefits of integrated care – the reduced fragmentation of the health system, coordination and collaboration among service providers, the better access to quality care by patients – are powerful and appealing, perhaps increasingly so in the current healthcare landscape where across the globe the cost of high-quality health care is on the rise. However, there is a need to improve understanding regarding how integrated care can be effectively implemented, and how health system programs can boost connectivity among inter-agency providers.

For instance, disseminating knowledge of applied technology for care practices among clinicians carries significant costs and risks. These costs may include maintaining stable and efficient relationships among practitioners across different institutions, necessitating a top-down transfer of skills and experience. Additionally, there are costs associated with bridging social clusters within different institutions. As for risks, a notable barrier is the competitive environment, where inter-organizational and personal linkages may be characterized by reluctance to collaborate. Physicians may be hesitant to share knowledge if mutual trust and incentives for collaboration are lacking, particularly in implementing new knowledge (Zeng et al., 2022). Integrated care continues to be a challenge in many countries (Barrenho et al., 2022; Spicer et al., 2020) and its tangible benefits are yet to be fully evaluated (van der Weert et al., 2022). Better utilisation of contemporary technologies such as virtual communities of practice to complement existing models of care are crucial for promoting quality and coordinated healthcare. The emphasis of the digital solutions is on providing networking opportunities among health professionals to facilitate exchanges of medical and critical knowledge to applied technology and reducing the distance among health professionals via better digital communication tools (Carrigan et al., 2023). However, the digitalization of healthcare processes and the improvement of IT infrastructure is only one key element that guarantees the efficiency of any healthcare management system (Uslu et al., 2020). To foster an integrated health care centred on the individuals' needs, equally important, if not essential, is the role of trust, cognitive and emotional proximity, and material/social support in fostering knowledge sharing and inter-institutional collegiality among medical doctors, clinicians, and any other holistic specialists (Zeng et al., 2022). Moreover, the mentioned authors emphasize that knowledge can vary in its level of explicitness, influenced by whether it's conveyed electronically or in person. In health technology, tacit knowledge can determine the successful adoption of innovations because it is supported by trust and cognitive proximity. Explicit knowledge, instead, often involves a more formal exchange of documents or digitally encoded data. As an example, we could consider that explicit knowledge might involve the formal exchange of patient records, while sharing informal care practices might tend to be more tacit and occurs in face-to-face interactions.

A long tradition of network studies in the organisational field has demonstrated the positive effects of collective problem-solving, dependent on who an individual is connected with, who they go to for advice, and their position in the knowledge transmission chain. Much of this work seeks to understand patterns of knowledge creation that support employees' skills (Cross et al., 2001) and performance (Cross and Cummings, 2004), across formal and informal relationships (Cross et al., 2001) and with different tie strengths (Byosiére et al., 2010). Moreover, implicit reasons for advice-seeking include gaining access to meta-knowledge, problem solving, and validation, each with the potential to create different paths of knowledge and information transmission (Cross et al., 2001). Other studies highlight the importance of advice-seeking interactions in boosting connectivity and regulating acquisition, transfer, and creation of new knowledge (Phelps et al.,

2012). This line of research focused on two collective knowledge outcomes: 1) network properties such as network position and structure, and 2) external factors including governance, geographical and technological characteristics, and competition dynamics.

We believe that studying knowledge-sharing might be more challenging in the context of complex inter-organisational healthcare environments compared with single organisational settings, due to the less tangible nature of health outcomes at a population level and the nested hierarchy of care providers, or structured levels of authority with different sets of responsibilities within the healthcare systems. For a deeper understanding of integrated healthcare, research should investigate inter-organizational knowledge sharing networks across various health and non-health care organizations such as hospitals, primary care clinics, and other facilities like education centres that provide coordinated care, as well as intra-organizational networks, for example, across diverse healthcare service providers within a hospital. This approach enables us to examine the advancement of integrated healthcare among diverse service providers, considering the varying levels of integration that can occur across both hierarchical and horizontal structures within and across institutions.

The compelling notion of fostering inter-organizational and intra-organizational relationships encompasses the vast array of potential synergies inherent in integrated-care initiatives. Yet, there are persistent challenges in understanding collaboration and knowledge sharing among healthcare professionals and organizations, due to the difficulties to navigate the complex web of multilevel (intra- and inter-) relational dynamics among a diverse array of stakeholders. Navigating through this complex scenario presupposes that there are still unanswered questions that require attention. For example, the first question that still needs to be answered is about the implications of health professional network structures for improving quality of care and patient outcomes (Cunningham et al., 2012). This calls for the use of a comprehensive evaluation framework of health networks that could include the dimensions of outputs (network characteristics and performances), outcomes (the immediate visible effects on healthcare), and impact (long-term changes). This framework might be a suitable theoretical tool to better assess health network governance topology and to understand whether the type of network governance can be considered a determinant of the effectiveness of the health sector and the sustainability of health policy (Cunningham et al., 2012). A second critical question for investigation is to establish which health professional network relational properties improve overall sharing of work-related knowledge, and which tie characteristics are more likely to sustain cross-sectoral collaborations. These synergies might allow the emerging of complex network advice-seeking behaviours that can boost the resilience of the whole healthcare system through informal interpersonal collaborations driven by patient needs (Bohnett et al., 2022), and at the level of management and governance (Nicaise et al., 2019).

The current empirical study offers a unique opportunity to explore the theoretical concept of integrated care, examining inter-organizational social structures that enable collaborative practices and advice-seeking behaviours by employing a multilevel network analysis approach, enhancing analytical rigor in the mapping of relational mechanisms. To foster collaboration among health organizations operating in silos and to enhance connectivity, two relational mechanisms can be effective: encouraging the presence of individuals in brokerage positions and incentivizing the clustering of small teams for collaborative efforts.

This study focuses on understanding healthcare professionals' networks involved in an online mentoring and health-related knowledge-sharing program, aiming to identify key structural features of their advice-seeking behaviours, as a broader measure of their informal collaborations. This online program spans across diverse sectors, encompassing both health and non-health care service providers, as well as various organizational domains. The study is concentrated on network characteristics, tendencies, and outputs with a view to investigate if

Table 1
4PEF including RQs, Hypotheses and network measures.





Four Pillars Evaluation Framework (4PEF)				
<p>1) Acceptability</p>  <p>RESEARCH QUESTIONS</p> <p>1. Do ECHO members reach out to other ECHO participants for problem-solving advice?</p>	<p>Engagement of health professionals in knowledge sharing behaviours.</p> <p>Dimension: <u>Level of engagement of ECHO health professionals</u></p>	<p>HYPOTHESES</p> <ul style="list-style-type: none"> - ECHO members and other professionals actively connect beyond ECHO videoconference sessions to exchange valuable information and offer advice. - We expect slightly more connections within Network 2 (Disability) due to its longevity. 	<p>RATIONALE</p> <p>There is a tendency to reach-out for advice, independently to hierarchical constraints.</p>	<p>NETWORK MEASURES</p> <ul style="list-style-type: none"> - Network descriptive statistics of ECHO networks (i.e., density, clustering coefficient). - MERGM baseline density effect.
<p>2) Capability</p>  <p>RESEARCH QUESTIONS</p> <p>1. What strengths, capabilities, roles, and sector characteristics do ECHO members and their nominees exhibit? 2. Are there any differences based on strengths, capabilities, roles, and sectors for the two networks? 4. Are knowledge-sharing patterns occurring across organisational boundaries (i.e., distinction by sectors and roles)?</p>	<p>Individual characteristics enable health professionals to become well-connected within the network and encourage knowledge exchanges.</p> <p>Dimension: <u>Individual and personal features</u></p>	<p>HYPOTHESES</p> <ul style="list-style-type: none"> - We do not expect many differences in terms of strengths. - Roles and sectors of ECHO members and their nominees reflect the different focus on child-care of the programs. - Knowledge-sharing relationships are incentivised by shared roles and sectors. 	<p>RATIONALE</p> <p>- Homophily is a key mechanism that sustains sharing of information and knowledge. Homophily tendencies are more likely to occur among individuals with similar characteristics (McPherson et al., 2001).</p>	<p>NETWORK MEASURES</p> <ul style="list-style-type: none"> - Descriptive statistics for respondents and nominees. - Network visualisations depicting linkages among individuals distinguished by individual roles and sectors (one-mode networks) - MERGMs Homophily/Heterophily tendencies (Homophily level A, Heterophily & activity level X parameters).
<p>3) Reachability</p>  <p>RESEARCH QUESTIONS</p> <p>1. How many steps are necessary for the information to move from one professional to another through</p>	<p>Ability to reach out to different clusters and groups of health professionals, including different healthcare organisations.</p> <p>Dimension: <u>Inter-organisational clustering and segregation</u></p>	<p>HYPOTHESES</p> <ul style="list-style-type: none"> - ECHO members and other professionals are only a few steps away from each other through 	<p>RATIONALE</p> <p>- A common tendency among health professionals is to seek advice from the</p>	<p>NETWORK MEASURES</p> <ul style="list-style-type: none"> - Optimal paths (i.e. distance measures) - Network visualisations for

Table 1 (continued)

Four Pillars Evaluation Framework (4PEF)				
<p>their connections? 2. Are professionals willing to share knowledge in small groups of individuals belonging to different institutions?</p>	<p>their connections.</p> <ul style="list-style-type: none"> - Health professionals share knowledge with many individuals in different health care providers. - Individuals tend to create high-level closure, with multiple knowledge cycling inter-organisational routes. 	<p>advisors someone's else advisors (Fronzetti Colladon et al., 2022).</p> <ul style="list-style-type: none"> - Individuals tend to share advisors at higher or lower level to seek advice to each other (Fujimoto et al., 2021). 	<p>organisations (two-mode networks).</p> <ul style="list-style-type: none"> - MERGMs Activity spread and cycle tendencies (Activity Spread level A parameter, Transitivity/Closure level A, Activity Spread for node type A and B level X, Transitivity/Closure for node type A and B level X) 	
<p>4) Integration</p>  <p>RESEARCH QUESTIONS</p> <p>1. Are well-connected individuals and prominent advisors playing a crucial role in facilitating inter-organizational knowledge flow routes?</p>	<p>Relational tendencies that explain how linkages of shared knowledge and expertise arise across and within overlapping networks.</p> <p>Dimension: <u>Brokerage and activity at system-level</u></p>	<p>HYPOTHESES</p> <ul style="list-style-type: none"> - Patterns of interactions between broker individuals and organizations imply that brokers are well-connected to access inter-organizational resources and opportunities through multiple channels. 	<p>RATIONALE</p> <ul style="list-style-type: none"> - Key diffusors are strategic individuals acting as brokers that direct information from one person to another, that can also be highly connected and mobilise resources (Cunningham et al. 2012, Fujimoto et al., 2021). - Well-connected brokers incorporate clinical and cultural knowledge, enabling the necessary coordination for effective care integration (Nixon et al., 2024) 	<p>NETWORK MEASURES</p> <ul style="list-style-type: none"> - MERGMs brokering tendencies (Brokerage and activity parameter, Activity Spread for node type A and for node type B).

participation in the program is associated with the emergence of integrated information exchange structures and networking, as defined in Table 1. Before we introduce the current study, we provide a brief overview of the current literature on social network research in the healthcare context, with a view to set the ground of the multilevel approach that informs our investigation.

Multilevel social network research in health

Social networks theories and methods have been extensively applied in the public health and healthcare fields. Luke and Harris (2007)

proposed a 3-dimensional classification to group this varied research agenda. Firstly, they distinguished studies focusing on understanding relational mechanisms that sustain the flows of knowledge transmission (see the landmark studies on the diffusion of innovation: Coleman, Katz and Menzel, 1957; Rogers, 1962); and of disease transmission in the epidemiological tradition (Rothenberg et al., 1998; Shelley et al., 1995). Research on health care professional networks that look specifically at communication flows and medical knowledge exchange are few and tend to be limited to a specific group (i.e., nurses; physicians), or within hospital settings (see, for example, Cunningham et al., 2012; Fronzetti Colladon et al., 2022). Secondly, they grouped studies on peer influence and risky behaviours (Campbell et al., 2008), and social support and well-being (Lin et al., 1999). Thirdly, the authors considered research on health social network interventions (see the recent review by Hunter et al., 2019) and organisational networks. This last group includes research on networks of health service providers. Here there is a shift in the research objective focus because rather than mapping individual relationships, the analysis refers to linkages among organisations and agencies. The authors pointed out that this new emerging line of research is the result of the new paradigm of system thinking introduced in 2006. At its core, this idea comprises a multidisciplinary range of theories, principles, conceptual and analytical tools that intend to explain the multitude of interactions at different levels, for example biological and political, between different components that hold on together for the common purpose of generating change (Leischow and Milstein, 2006). System thinking is a complex and multidisciplinary paradigm that implies a wide variety of theoretical and analytical tools, as highlighted by Peters (2014). Flow charts, participatory impact pathways analysis, agent-based models, scenario plannings, causal loop diagrams, can all be applied to conduct research and interpret the results of the interplay of different components. Social network theories and methods also fit here, opening several possibilities for further analyses of network and process mapping, allowing the researchers to study the linkages within and across individuals and organisations and resulting in a proliferation of studies that apply social network approach for understanding some sort of social aspects of a whole system.

In contemporary literature, scholars have progressed and refined the system thinking idea by suggesting that healthcare networks have a multilevel nature. As explained by van der Weert et al., (2022) in their recent review on interorganizational multilevel healthcare networks, linkages in healthcare span across different levels. Teamwork among health professionals in a given setting occurs at a clinical level; health professionals communicating with their patients and families denotes a community level; health professionals from different service providers collaborating toward a common goal, notwithstanding their potential different culture and managerial experience, maps to the organisational level. In addition, there is also the policy level, that considers the influence health practitioners might have on policy implementation by providing inputs and ideas. All these relationships are interdependent, linked to each other simultaneously to produce multiple effects on the quality of the provision of care and the degree of fragmentation of the healthcare systems. These multilevel relationships generate complex governance structures such as shared governance versus hierarchy. Therefore, to fully understand barriers and factors that limit collective goals it becomes crucial to adopt a multilevel theoretical and analytical network approach. However, the research is limited and usually addresses only one level without consideration of interdependence. With some exceptions, multilevel network studies in public health have been rather limited in conducting analysis at the level of data on individuals or on organisations or both, individuals and organisations, but without studying the linkages across levels, thus omitting the joint effects deriving from the interplay of these relationships.³

³ See the review by van der Weert et al., (2022) for a detailed description of the 22 (out of 184) studies they found that adopted a multilevel perspective.

There are three possible reasons accounting for the lack of studies analysing interdependent ties at several levels. First, there are the burdens associated with collecting data in the healthcare context including access to potential interviewees due to competing clinical demands, a high turnover of professional staff, and the blurred network boundaries of a group within a specific setting (Pomare et al., 2022). Second, the low uptake of multilevel network analytical and statistical tools that are currently available reduce the diffusion of multilevel studies. Interested researchers can find useful readings in Brass and Borgatti (2019) that promote multilevel research presenting a theoretical guide on how to use multilevel “lens” when conducting network research. Additionally, Wang et al., (2016a), (2016b) offer a practical guide on the specification of the statistical model and graph statistics. Some examples of applications in healthcare can also be found (McGlashan et al., 2019; Broccatelli et al., 2021). Third, another limiting factor that restricts the growth of multilevel studies might also be due to the ambiguity in translating evidence-based network results within a comprehensive framework for evaluating multilevel network outcomes at each level and within levels. Although some attempts in incorporating interpersonal, intergroup, and interorganizational measures to analyse short-term, medium-term, and long-term relational outcomes have started to circulate in public health (Cunningham et al., 2012) and social networks (Bohnett et al., 2022), a lot of work still needs to be done on how to quantify the effectiveness of a network structure using traditional network measures that could be universally applied for evaluating health-system outcomes.

This study attempts to progress in these three directions. First, a multilevel lens is applied to inform the data collection strategy, as per the methods section. Second, multilevel statistical tools, the so-called Multilevel Exponential Random Graph Models, were utilised to understand the interdependence of advice-knowledge sharing behaviours between and across health professionals and their agencies as per the results and discussion sections. Lastly, referring to the research questions and hypothesis and discussion sections, we incorporated network generated results within an evaluation framework for establishing the efficiency of the implemented network health program.

The current study: project ECHO® Networks at Children’s Health Queensland Hospital and Health Service

To address the challenges of fragmentation impacting on the quality of care for children and youth across the state of Queensland (Australia), Children’s Health Queensland Hospital and Health Service (CHQHHS) adopted an Integrated Care Strategy (2018) to improve child and youth health outcomes by building inter-professional and cross-sector collaboration and synergy. Specifically, Project ECHO® Networks have been implemented at CHQHHS to foster the knowledge sharing and collaborative partnerships required for effective service integration across different primary, secondary, and tertiary healthcare services providing care in Queensland (e.g., hospitals, general practice physicians) and with non-medical institutions (e.g., disability support services, schools). Attendees join from CHQHHS and other government departments, private institutions, community-based organisations. In an ECHO Network, professionals convene regularly via videoconference to share experiences and gain advice and support related to de-identified patient cases (aged 0–16). Group members contribute their knowledge and experience in response to the cases and questions of others, offering tailored recommendations. The ECHO facilitator and expert panel members further enrich discussions with additional best practice advice and guidance. As relationships are formed, professionals also connect spontaneously for advice and support. (For a detailed explanation of the ECHO program refer to Moss et al., 2023). Project ECHO was first developed at the University of New Mexico, utilising technology to optimize sharing of best practices among health and non-health professionals (Arora et al., 2007; Moss et al., 2020). The programs help building collective knowledge, facilitating new connections and inter-professional collegiality, and improving coordinated actions among

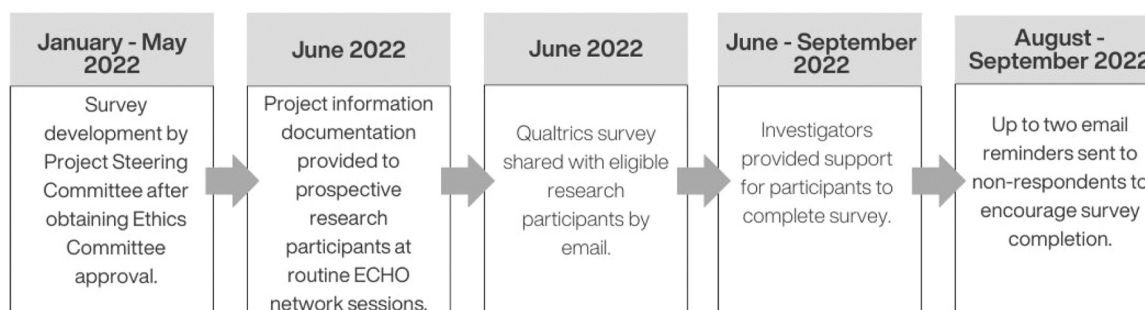


Fig. 1. Data collection flow chart.

service providers, including in remote and rural areas. Since Project ECHO is a networking program that aims to boost connectivity, there is a need to investigate the level of connectivity between institutions. Social network research is uniquely suited to answer questions related to the interconnectedness generated by ECHO, and to reveal network structure characteristics. To date, rigorous social network research has not occurred in the analysis of Project ECHO.

This research has focused on two cross-sectional ECHO Networks: Network 1) Aboriginal and Torres Strait Islander Kids ECHO, and Network 2) Navigating Paediatric Disability ECHO. Network 1 was implemented in alignment with the health equity strategy at CHQHHS. Historically, Australia's Aboriginal and Torres Strait Islander peoples have experienced intergenerational trauma, racial discrimination, and absent and culturally inappropriate health services. The inequitable health outcomes for Aboriginal and Torres Strait Islander peoples compared to their non-Indigenous counterparts (Commonwealth of Australia 2020, AIHW Australian Institute of Health and Welfare, 2023) are compounded by the challenges of services and systems fragmentation. The ECHO network was launched in 2021 with the objective of improving care for Aboriginal and Torres Strait Islander children and families through increased cross-sector workforce capability for culturally responsive care. Network 2, launched in 2020, aims to support children with disabilities and their families. The former was selected for its relevance in promoting improved access to care for Aboriginal and Torres Strait Islander people, the latter was selected for comparison reasons. Specifically, by being active for longer, we anticipated the characteristics of its network structure would have likely mirrored the active participation and stronger collaborations among participants.

Research questions and hypotheses

Creating an online space for information exchange among health and non-health professionals generates new collaborations and a cascade of benefits, including better care for patients. The current analysis focuses on defining the networking characteristics of ECHO participants and mapping these collaborations with a view to evaluate the level of networking and integration of service providers. Specifically, we intend to answer the overarching research question: *Are ECHO networks able to promote broader collaboration through knowledge sharing within and across different levels of the healthcare system (outside the routine ECHO online meetings)?* Using social networks analytical and conceptual tools we aim to assess ECHO Networks within the broader integrated care health system along four pillars – 1) *Accessibility*, 2) *Capability*, 3) *Reachability*, 4) *Integration* – each corresponding to a different dimension. The Four Pillars Evaluation Framework (4PEF) is used to inform an evaluation framework that includes the multilevel perspective to assess some aspects of the efficiency of the networking program in promoting circulation of health knowledge and integration of inter-organisational healthcare services. We also intend to find out whether our investigation can reveal the key role of some specific health workers as connectors and brokers (i.e., cultural brokers that act as cultural mediators). [Table 1](#)

presents our 4PEF in relation to RQs, Hypotheses and network measures in a schematic way.

Settings, data, and method

Participant engagement and data collection process

Data were collected from two ECHO Networks. For Networks 1 and 2 we conducted a separate investigation. [Table 2](#) indicates the data collection steps and timeline. ECHO Network members considered eligible were invited to complete the online survey during a routine ECHO session and were followed up by email with study information and re-assurance of confidentiality. To reiterate the scope of our research, a short video message from ECHO Network facilitators was embedded within the online survey. ECHO facilitators also provided reminders at each ECHO session during the data collection period (June-September 2022), and invited respondents to attend online ad-hoc drop-in sessions via Zoom for advice, support, and information from the research team. Each respondent completed one survey since our study adopts a cross-sectional design.

Network boundaries

Our network boundaries were defined using four criteria: 1) geographical, 2) relationship-based, 3) role-based, and 4) place-based. For the first criterion, ECHO members considered eligible for our survey were Queensland residents and attended at least one ECHO Network session in the period January-May 2022. For the second, we asked respondents to focus on the sharing of work-related knowledge, guidance, and advice. Third, we were only interested in the advice-seeking behaviours among health and other professionals only working for child and youth health and wellbeing (i.e., no adults). Fourth, we asked ECHO participants to consider who else they reached out to outside ECHO, by considering other professionals within their institution or the institutions of other ECHO participants. Institutions in Queensland that did not have any representative in the ECHO network, were excluded.

The survey was administrated online through Qualtrics. For the network survey, a roster name generator including all eligible ECHO participants was used. We asked respondents: *“Please select all the people inside the ECHO Network with whom you tend to reach out and connect, for example, for general advice and guidance, for cultural advice, to share ideas...”*. We followed up with another roster, populated based on the organisations of all eligible ECHO participants, asking respondents to select the organisations in which they know someone working for children and their families with whom they have a similar relationship and share knowledge and advice. For each selected organisation, we followed up with an open question for respondents to report up to 6 names of people they tend to reach out to and connect. These questions generated another list of people outside the ECHO network, limited to those affiliated with the institutions of ECHO participants. We used this list to generate another roster of names and requested respondents to

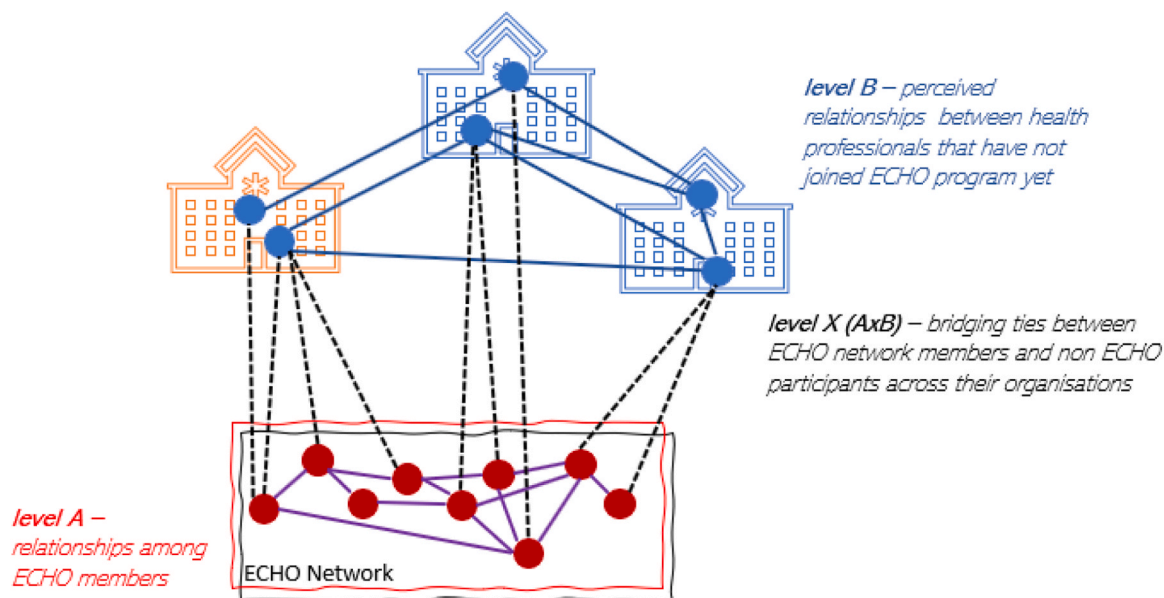


Fig. 2. Interdependent network levels visually represented.

indicate, to the best of their knowledge, the presence of knowledge-sharing communications (i.e., alter-alter ties) among all the further nominees they provided. Fig. 1 presents a schematic of our boundaries considering a multilevel perspective. This perspective is applied to both Network 1 and Network 2, resulting in two distinct multilevel networks.

As shown in Fig. 2, level A comprises the knowledge-sharing ties among ECHO participants; cross-level X (AxB) represents the bridging ties between ECHO members and health professionals in different institutions; and level B only includes the relationships between the nominated health professionals that are not enrolled in ECHO and that are working in other organisations. Information exchange between ECHO participants (level A) were documented with the first name generator roster. Information sharing tendencies with professionals outside ECHO (level X or AxB) was obtained with up to 6 external nominations in each listed institution. Lastly, the knowledge exchanges among nominees outside ECHO (alter-alter ties, level B) we collected by asking respondents to report, to the best of their knowledge, any information exchanges occurring between all their nominees.

Participant characteristics, capabilities, and roles

Additional information was also requested from respondents. We asked them to indicate the area of residence for the majority of people they helped (i.e., city, major region, rural, remote), and to indicate the strengths they were likely to bring to ECHO by choosing one or more of the following knowledge types: cultural, clinical, social and welfare, justice, foster care, education, disability, advocacy, policy and project or other.

To facilitate the analysis, ECHO Network coordinators (co-authors 2 and 4) systematised the individual's reported information on their job title and organisation for ECHO members and their nominees into two categorisations: roles and sectors. Individuals were assigned one of the following roles: allied health, child safety, community elder, cultural brokers (i.e., Aboriginal and Torres Strait Islander Health Workers, cultural officer, Indigenous Health and education liaison officers), director/program lead, disability, education, medical, nursing, partnerships, project officer, youth worker, or other/unknown. The sector categorisation, based on respondent organisation's primary alignment, distinguished: primary health/community care, secondary/tertiary health, child safety/youth justice, disability, education, or other/unknown.

Multilevel ERG models specification

Exponential Random Graph Models for Multilevel networks (MERGMs) were applied to investigate advice-seeking behaviours and how knowledge exchange “pipes” or channels among health professionals were sustained within and across healthcare organisations. ERG Models assume that the presence of one (type of) relationship might depend on the presence of another (type of) relationship. Since there might be overlapping reasons why ties occur (or not), there are different dependence assumptions that reflect diverse scenarios, or relational mechanisms, tendencies or social processes (See Robins and Pattison, 2005 for a clear explanation of the dependence assumption). For each assumption, there is a corresponding statistical parametrization that can be modelled to reveal what is the likelihood that linkages appear, considering their combination. Multilevel ERGMs do that assuming the combination of relational tendencies within and across levels (Peng et al., 2016). Overall, the presence or absence of relational tendencies is used to examine the level of segregation, clustering, integration, and connectivity, as well as governance and efficiency, in any given network.

To specify parameters in our model, we refer to past research. Healthcare network on communication flows highlighted the presence of recurring relational tendencies or common scenarios. The baseline tendency to seek advice from others (*Density, Level A*) can be affected by hierarchical differences, thus knowledge sharing does not always go both ways between two people. *Transitivity Closure*, the tendency to seek advice from the advisors of my advisors is quite common in the healthcare context and applies also to the sharing of new ideas (Fronzetti Colladon et al., 2022). This process reveals the tendency to reinforce local closure where someone is likely to be involved in giving/receiving advice patterns with a pair of two individuals that also exchange information. This tendency might be also likely to underline the presence of hierarchical constraints (Brennecke & Rank 2017). Cross-level *Transitivity Closure for node type A and B* are additional tendencies for individuals with shared advisors at higher or lower level to seek advice to each other (Fujimoto et al., 2021). Closure is often analysed together with brokerage, another relational mechanism that is the tendency for strategic individuals to act as brokers and directing information from one person to another. The more people in brokerage roles in a network, the more fragmented and less cohesive the network structure becomes, since individuals tend not to share connections unless they are already connected (Lusher et al., 2013). Brokers are key diffusors of information

Table 2
MERGMs parameter estimates for Network 1.



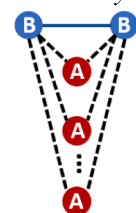
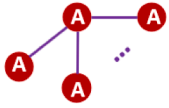
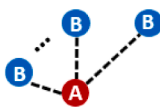
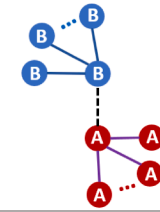
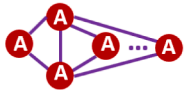
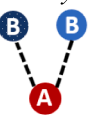
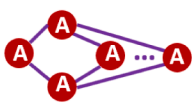
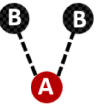




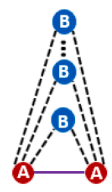
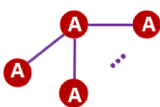
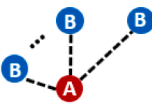
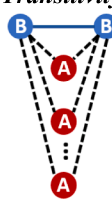
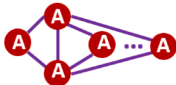
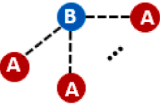
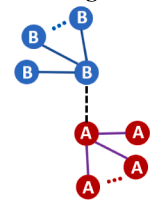
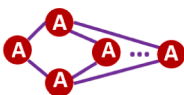
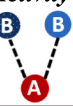

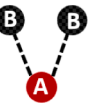

1) – Aboriginal and Torres Strait Islander Kids ECHO Network					
Level A		Level X (AxB)		Level A, B and X (A&B&X)	
<i>Density</i>		<i>Density</i>		<i>Transitivity Closure for node type B</i>	
					
Parameter	SE	Parameter	SE	Parameter	SE
-3.714	0.758*	-5.515	0.209*	0.064	0.199
<i>Activity Spread</i>		<i>Activity Spread for node type A</i>		<i>Brokerage & Activity Spread</i>	
					
Parameter	SE	Parameter	SE	Parameter	SE
-0.120	0.291	0.586	0.098*	0.013	0.005*
<i>Transitivity Closure</i>		<i>Heterophily (Different Role) & Activity</i>			
					
Parameter	SE	Parameter	SE		
0.695	0.162*	0.013	0.024		
<i>Alternating 2-paths A</i>		<i>Homophily (Same Sector) & Activity</i>			
					
Parameter	SE	Parameter	SE		
-0.022	0.069	0.045	0.024		
<i>Homophily (Same Role)</i>					
					
Parameter	SE				
1.199	0.238*				
<i>Homophily (Same Sector)</i>					
					
Parameter	SE				
1.053	0.215*				

Table 3
MERGMs parameter estimates for Network 2.

2) – Navigating Paediatric Disability ECHO Network					
Level A		Level X (AxB)		Level A, B and X (A&B&X)	
<i>Density</i>		<i>Density</i>		<i>Transitivity Closure for node type A</i>	
					
Parameter	SE	Parameter	SE	Parameter	SE
-3.546	0.674*	-5.722	0.238*	1.329	0.140*
<i>Activity Spread</i>		<i>Activity Spread for node type A</i>		<i>Transitivity Closure for node type B</i>	
					
Parameter	SE	Parameter	SE	Parameter	SE
-0.453	0.231	1.071	0.154*	1.514	0.107*
<i>Transitivity Closure</i>		<i>Activity Spread for node type B</i>		<i>Brokerage & Activity Spread</i>	
					
Parameter	SE	Parameter	SE	Parameter	SE
0.682	0.179*	-0.203	0.125	-0.010	0.005*
<i>Alternating 2-paths A</i>		<i>Heterophily (Different Role) & Activity</i>			
					
Parameter	SE	Parameter	SE		
0.087	0.012*	-0.171	0.051*		
<i>Homophily (Same Role)</i>		<i>Homophily (Same Sector) & Activity</i>			
					
Parameter	Parameter	Parameter	SE		
0.812	0.177*	-0.098	0.043*		
<i>Homophily (Same Sector)</i>					
					
Parameter	SE				
0.966	0.200*				

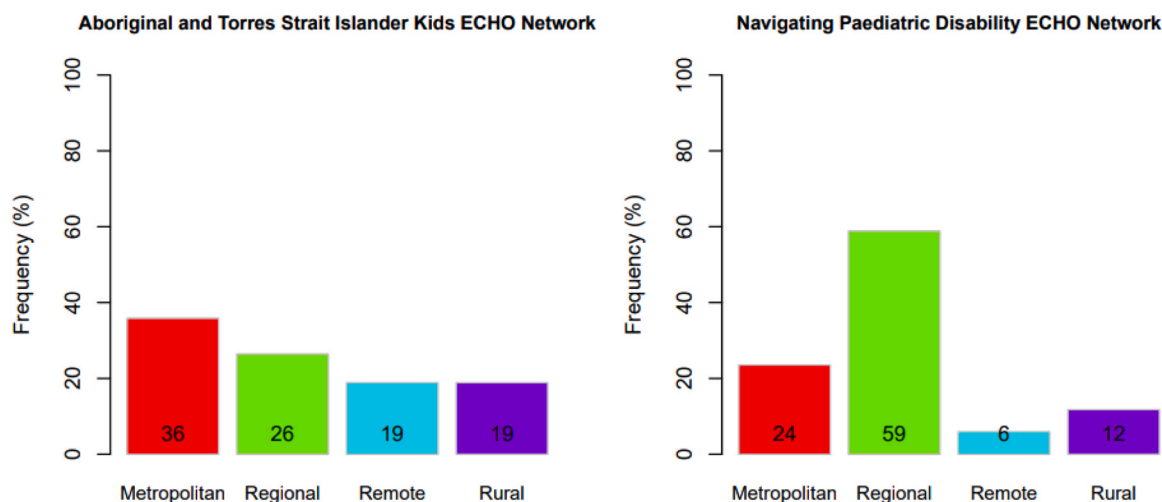


Fig. 3. ECHO respondents' areas of intervention for both networks. Numbers express percentage values.

in the healthcare context (Cunningham et al., 2012), and can be even more powerful if all individuals within the network are loosely connected and organised around clusters (Everett and Valente, 2016). Across linguistic groups and ethnic communities, brokers have access to valuable knowledge that they are more willing to share in the context of scarce competition (Matous and Wang, 2019). If considering the multilevel aspect, brokering tendencies can be expressed by the brokerage-centrality conjugates idea (Fujimoto et al., 2021) (*Brokerage & Activity parameters*). This emphasises the interactions between broker individuals and organisations by contemplating that individuals in a brokering role might also be the most connected ones. This can generate several advantages such as better access to resources and opportunities via multiple people. *Activity Spread* parameters represent the tendency to reach out for advice consistently and repeatedly. Individuals that are extremely active tend to be more central. These people could be widely considered trustworthy mentors or leaders and thus are likely to act more frequently as advisors (Lazega et al., 2012). Across-level, similar parameters (*Activity Spread for node type A* and *Activity Spread for node type B*) take into account degree centrality for ECHO participants at higher level and represent the professional tendencies of bridging multiple individuals in different healthcare providers. Additional parameters included in our model consider how individual-level attributes might explain social selection processes. Channels of information flow tend to appear more often between individuals with similar knowledge and background (*Homophily*), than between people different to themselves (*Heterophily*). In our models we consider homophily/heterophily by roles and sectors, at different levels. Finally, we also included in our model the *Alternating 2-paths A* parameter to control for the tendency to share advice with multiple ECHO participants and to help fit the long-tailed degree distributions. To help with convergence, we also controlled for the tendency to form closure by creating two-mode cycles (*Alternating cycle with 2-paths AB*).

Two more points are important to note. We considered seeking advice from a colleague as the most appropriate relationship to capture the formal and informal interactions among health professionals in different sectors and with different roles, to avoid the ambiguous nature of other types of relationship definitions such as collaboration (Pomare et al., 2022). We provided clear advice to participants regarding identification of advice-seeking relationships and offered examples during the drop-in sessions and in survey material emailed to participants. Also, we suggested respondents consider both formal and informal relationships that were of value in the general provision of care for children and families. Albeit advice-seeking behaviours might not always be reciprocal, we considered them bijective, assuming that the linkages through which knowledge and information are “attached” are open channels that

go in both directions between any two individuals. Thus, our network ties are considered undirected for this analysis. This decision was also necessary to take considering the low uptake of the survey and the high number of non-respondents that were considered deemed eligible. By doing that we believed our network mapping better represented the real information exchanges among health professionals, also aligning with the narrative shared by participants during the drop-in session data collection.

Results

The survey was completed by 37 out of 53 (69.8 %) eligible participants of the Aboriginal and Torres Strait Islander Kids ECHO Network, and 31 out of 66 (46.9 %) eligible participants of the Navigating Paediatric Disability ECHO Network. Among the respondents, 12 individuals (17.6 %) were Aboriginal and/or Torres Strait Islander people. There were 8 respondents who participated in both Networks.

Network 1 at level A, including ECHO participants and their nominated co-participants, comprised N=44 individuals and N=96 ties. At level B there were N=179 individuals and N=229, corresponding to nominees outside ECHO network and their relationships. For Network 2, there were N=56 individuals and N=118 ties at level A, and N=119 individuals and N=178 ties at level B. N=239 were the bridging ties across level A and B (X) for Network 1, and N=183 the AxB (X) ties for Network 2.

Tables 2 and 3 report the MERGMs results for Networks 1 and 2, including the visual representations of included parameters. Positive significant parameters (*) are more likely to happen than what would have been found by chance. Negative significant parameters (*) are less likely to happen than what would have been found by chance. To achieve convergence of parameter estimates, we fixed network density at level B for both Network 1 and 2, therefore assuming the number of ties for networks at level B are given and do not change. For Network 1, Goodness-of-fit (GOF) t-ratios were less than 0.1 for fitted parameter effects and less than 2 for unfitted ones, suggesting a highly adequate fit. Network 2 was more difficult to model, but it is still acceptable. Some GOF statistics were higher than 2 (but less than 4) suggesting few difficulties in reproducing dense cliques. Models were fitted using the MPNet Software.

Four pillars evaluation framework

Findings relevant to the 4PEF (refer to Table 1) are presented below.

- 1) Acceptability: level of engagement of ECHO health professionals

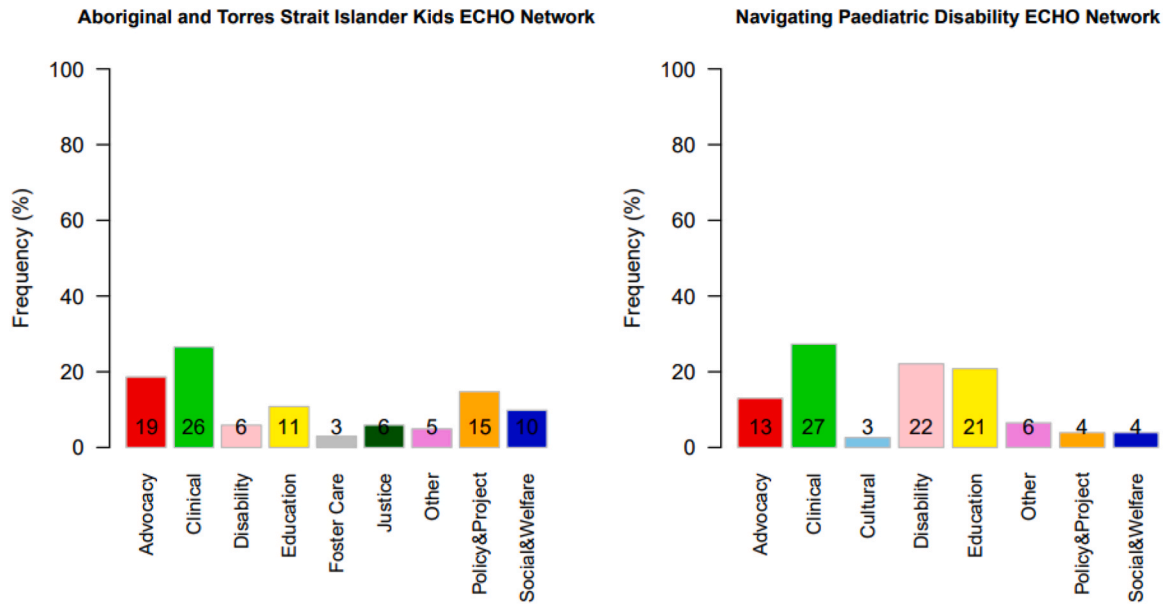


Fig. 4. ECHO respondents' strengths for both networks. Numbers express percentage values.

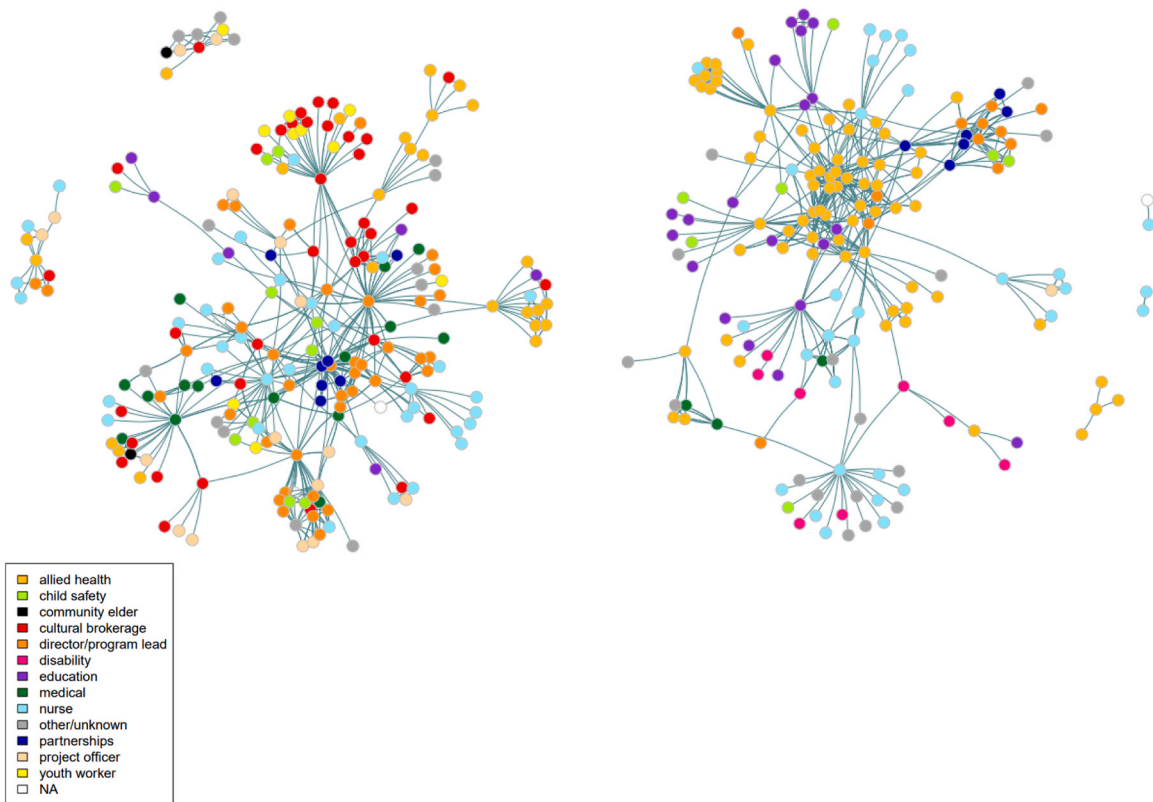


Fig. 5. Networks of ECHO members and their nominees by roles.



This pillar considers the engagement in advice-seeking

behaviours of health and non-health professionals that joined ECHO. We expected ECHO members to reach out to one another outside the ECHO videoconference sessions and hypothesised a slightly higher density for Network 2 due to its longevity. Network 1 (Aboriginal and Torres Strait

Islander Kids) at level A had an overall network density of 10 % and an average degree of 2.2 (SD = 7.3; min = 0, max = 26). Network 2 (Disability) at level A presented an overall network density of 7.6 % and an average degree of 2.1 (SD = 8.8; min = 0, max = 48). The clustering coefficient, a basic cohesion measure of the overall network tendency to cluster or clump together in dense areas that form distinct groups or clusters, is 0.35 for Network 1 (level A) and 0.29 for Network 2 (level A). This reveals that ECHO member engagement in knowledge sharing behaviours showed no remarkable differences across the networks.

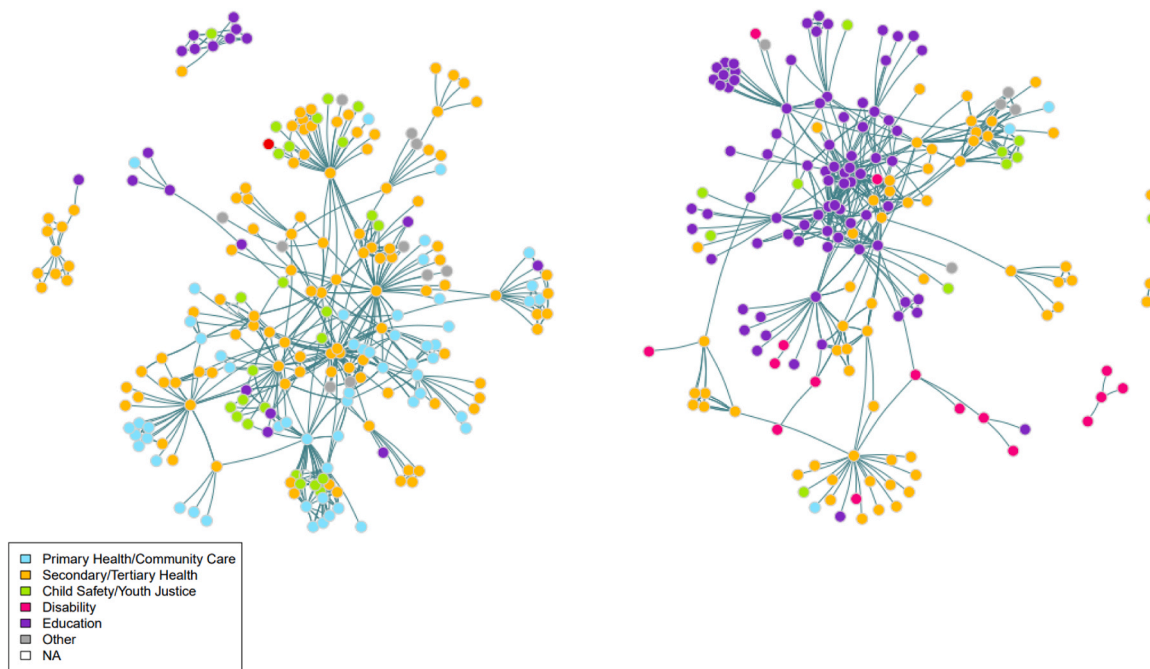


Fig. 6. Networks of ECHO members and their nominees by sectors.

2) *Capability: individual and personal features.*



This pillar focuses on the individual characteristics of re-

spondents and their nominees, looking at how these characteristics might generate linkages that facilitate knowledge sharing flow. Fig. 3 indicates network respondent characteristics in relation to predominant location of patients served, and Fig. 4 depicts individuals' perceived strengths. Most ECHO respondents supported children and/or youth in metropolitan and regional areas and to lesser extent in remote and rural areas. The distribution of strengths reveals the predominance of clinical expertise as well as a variety of other knowledge types.

In Fig. 5, we depict the networks of ECHO members and their nominees. Individuals are represented as nodes and colours indicate their different roles. Network 1 (Aboriginal and Torres Strait Islander

Kids ECHO) includes directors/program leads (18 %), cultural brokers (17 %), nurses (16 %), allied health professionals (11 %), project officers (7 %), medical professionals (7 %), youth workers (5 %), partnership-oriented roles (3 %), and others (7 %). Network 2 (Navigating Paediatric Disability ECHO) comprises allied health professionals (40 %), nurses (18 %), education professionals (11 %), directors/program leads (7 %), disability workers (5 %), child safety workers (4 %), partnership roles (3 %), medical professionals (2 %), project officers (0.6 %), and others (9 %).

Fig. 6 distinguishes individuals based on their sector. In Network 1, most individuals were from Secondary/Tertiary Health (50 %) and Primary Health/Community Care (25 %) sectors. Smaller groups were in Child Safety and Youth Justice (11 %), Education (7 %), and Other (5 %). In Network 2, the majority were in Education (46 %) and Secondary/Tertiary Health (34 %) sectors. Others were in Disability (9 %), Child Safety and Youth Justice (6 %), Primary Health/Community Care (2 %), and Other (3 %).

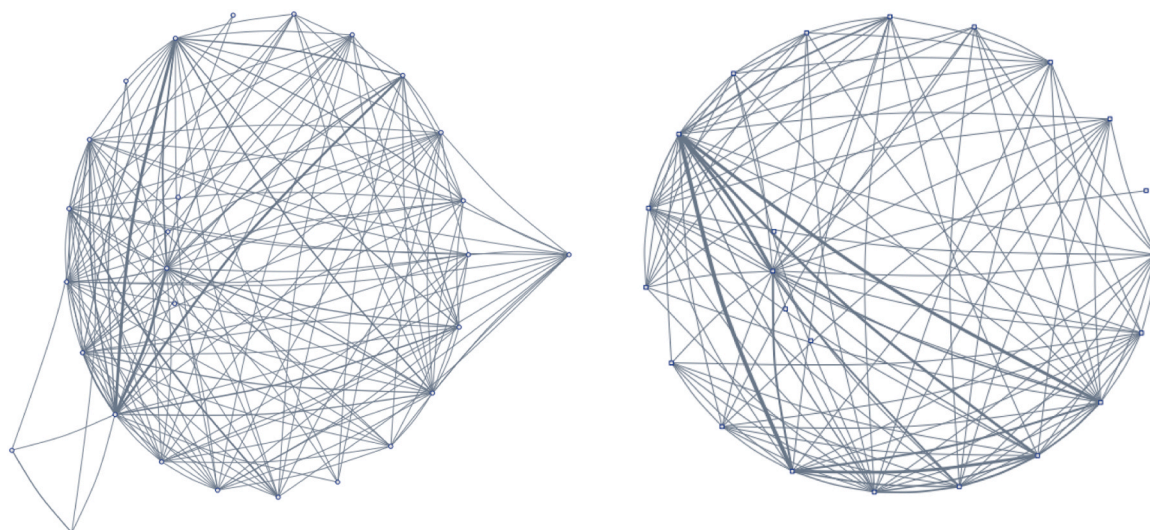


Fig. 7. Networks of two-mode projections.

The MERGMs parameters controlling for Homophily/Heterophily effects indicate that knowledge sharing is encouraged by shared roles and sectors. In both networks at level A, there are tendencies to share knowledge with individuals in similar disciplines and sectors. Seeking advice among those in similar roles (*Positive Homophily [Same Role], level A parameter*) and within the same sector (*Positive Homophily [Same sector], level A parameter*) is common among ECHO members.

Slightly different tendencies were noted for bridging networks at level X (AxB). In the Aboriginal and Torres Strait Islander Kids ECHO Network, tendencies toward both homophily and heterophily outside of ECHO members were not significantly more common than expected by chance (non-significant parameters). In the Disability ECHO Network, members were less likely to connect with individuals in other institutions working in different roles (*Negative Heterophily (Different Role) & Activity, level X parameter*) and to exchange information with professionals from the same sector (*Negative Homophily (Same Sector) & Activity, level X parameter*).

3) *Reachability: Interorganisational clustering and segregation.*



This pillar analyses the steps away between health and non-health workers, as well as health and relevant non-health organizations, to explore the extent of segregation among different organizations and sectors.

The average distance between nodes in Network 1 (Aboriginal and Torres Strait Islander peoples) is 3.7. This means that, on average, anyone can be reached in less than 4 steps. Network 2 (Disability) present similar result with 3.6 average path distance. Both networks have diameter 7.

Fig. 7 shows one-mode projections of organizations based on the two-mode network data collected, where respondents indicated both their organizational affiliation and that of their nominees. Square nodes represent organizations, with ties between them indicating the level of collaboration among health professionals across institutions. Thicker lines signify greater integration across institutions, indicating that their respective health workers share advice more extensively. In Network 1, there were 28 organizations, with a network density of 4 % and an average degree of 11 (SD = 7; min = 0; max = 21). Network 2 consisted of 23 health institutions, with a network density of 5 % and an average degree of 10 (SD = 6; min = 0; max = 19).

MERGM parameters relative to degree distribution and network closure within and across levels fit in this pillar. There is not a huge propensity to reach out to other ECHO members, as shown by the non-significant activity effects for level A (*Activity Spread, level A parameter*) that control for degree distribution. This result suggests that ECHO members may not seek advice within the ECHO program, but to evaluate it accurately, we must also consider the positive and significant clustering tendency (*Positive Transitivity/Closure, level A parameter*). The positive *Closure* parameter in both networks suggests that ECHO members tend to form triangular group-like patterns of knowledge exchange and within ECHO, members are likely to share information with the advisors of others' advisors. Thus, knowledge flow is integrated in patterns of advice relationships that involve close triangles. We also found some alternative routes. Professionals were not always willing to share expertise and advice in small groups of individuals belonging to different institutions, preferring instead to seek advice from multiple colleagues at level B. (*Positive Activity Spread for node type B, level X parameter*). The positive estimate for the effect of *Transitivity Closure for node type A and node type B* in Network 2 indicates a tendency to form multiple cliques and high-level closures, facilitated by higher-level health professionals linking two connected ECHO members. This effect only applies to Network 2 (in Network 1 cross-level *Transitivity Closure for node type B* is not significant), highlighting that knowledge sharing is

sustained by inter-organizational clustering dynamics, where multiple knowledge cycling routes among ECHO professionals share a common higher-level linkage.

4) *Integration: brokerage and activity at system-level*



The final pillar evaluates the level of integration of professionals at a systems level. Cross-level knowledge flow routes might involve the presence of intermediaries acting as well-connected brokers. In Network 1, prominent and active advisors at their own level potentially activate cross-level bridging ties, aligning advice-sharing partnerships through intermediate linkages at the higher level outside ECHO (positive and significant parameter for *Brokerage and Activity, level A, B and X*). Multiple brokers in the same network position facilitate these partnerships, indicating high-level brokers have high degree centrality, meaning they are also the most active and well-connected individuals within levels. In Network 1, ECHO members at level A tend to turn to preferred colleagues at level B, who act as key knowledge brokers across levels and groups. On the contrary, in Network 2, health professionals share multiple advisors and circulate knowledge in small triangular groups, rather than through direct liaisons (positive and significant *Transitivity Closure* and negative and significant *Brokerage and Activity, level A, B and X*).

Discussion

The application of MERGMs opens new avenues for future data analysis, particularly since multilevel network studies in healthcare are still rare (van der Weert et al., 2022). In this work, the multilevel approach, using participation in the program and organizational affiliation to distinguish between interorganizational levels, provided greater insights on the social structures that sustain collaborative practices and advice-seeking behaviours. Participants' institutional affiliation was a key in building bridging networks and evaluating interorganisational clustering and knowledge sharing patterns.

The network-generated results for our two case-studies can inform an evaluation of some aspects of the efficiency of the ECHO Networks along four pillars.

- 1) **Acceptability.** In ECHO Networks, we found opportunities for members to connect with health and non-health professionals across different organizations and geographies. This highlights the program's potential to encourage inter-organizational knowledge-sharing behaviours, thereby enhancing conditions for integrating service and system-level collaborations.
- 2) **Capability.** Role and sector similarity was not always a driver of advice sharing. Heterophily tendencies might indicate not-so-obvious competition versus coordination tendencies, which could also lead to reduced system fragmentation. Different roles working together might indicate the tendency toward completing each other's knowledge and bridging different backgrounds to coordinate activities. Informal knowledge sharing practices between role-like professionals might suggest a collaborative predisposition in promoting system-level integration within the Children's Hospital.
- 3) **Reachability.** Information sharing in triangular group-like structures might suggest the presence of horizontal knowledge sharing patterns at the grassroots level of the healthcare system in Australia. Health workers and their cross-sector colleagues are likely to share advice in small groups rather than solely with hierarchical leaders. At cross-level perspective, this exchange might be supported by strong inter-organisational clustering dynamics, enforcing system-level collective action and shared goals to mitigate fragmentation. Notably, these patterns were observed specifically in Network 2.

4) **Integration.** In Network 1, brokers with high popularity were found to occupy central positions within the network, likely overseeing the dissemination of information across local clusters. These brokers are individuals actively engaged in multiple knowledge exchange routes, assuming various roles. Acting as multifaceted liaisons, these people control the flows of knowledge sharing and reduce the overall network fragmentation. This, in turn, can promote system-level integration because it improves flows of communication across institutional levels.

Our finding, consistent with past studies (Cunningham et al., 2012), emphasise complex patterns of advice relationships that reveal the interconnectedness of individuals and providers across the entire system. Using MERGMs adds a novel aspect by demonstrating a mix of collaborations at different levels within the health system. While homophily likely facilitates information sharing among health professionals of similar disciplines joining ECHO programmes, homophily across different levels may indicate challenges in communicating with institutions in other sectors. Competitive dynamics could also influence these social structures, affecting the sharing of information among professionals working in similar roles but at different organizations.

Previous studies on healthcare delivery networks found that network structures are influenced by the presence of brokers, usually well-connected senior leaders/coordinators who act as mentors and leaders with better access to resources to govern the whole network more efficiently (van der Weert et al., 2022). Brokers, also defined as “brokerage-conjugates” (Fujimoto et al., 2021), coordinate the spread of information across local clusters and have multiple functions. They drive multiple collaborations assuming the key role of multifaceted liaisons that control the channels of knowledge sharing. This, in turn, can improve cohesion and reduce health system fragmentation. Moreover, well-connected brokers might indicate that at grass roots level there is a diffused predisposition to build stronger and collaborative relationships between professional clusters, to break down the healthcare silos. This aligns well with previous research that highlighted how densely connected networks are more efficient in boosting connectivity to support overall communication flows and synergy partnerships (Long et al., 2013). In the context of our research, the stronger presence of brokerage-conjugates within the Aboriginal and Torres Strait Islander Kids ECHO Network may result from the significant role of “cultural brokers” – health professionals who provide holistic care and culturally safe services for Aboriginal and Torres Strait Islander people, integrating clinical and cultural knowledge. Being a cultural broker is often expected of Aboriginal and Torres Strait Islander staff members, even though it is not typically included in job descriptions or remunerated. Our investigation suggests that brokering between distinct groups could enhance coordination and support professional engagement across traditional boundaries. In a separate manuscript we are specifically addressing the presence of cultural brokers within the ECHO context using the same data analysed here. Interested readers are encouraged to refer to this for further information (Nixon et al., 2024).

In essence, our network investigation revealed that less hierarchy exists among ECHO members when compared to across levels and organizations, as certain individuals emerged as central figures in advice-sharing relationships. Adopting a multilevel network perspective demonstrated that knowledge and information sharing are embedded in complex informal patterns. These patterns involve some degree of inter-organizational hierarchy, not-so-spread homophily by roles and sectors, brokerage coordinators blended with popularity within and across multiple health organizations, and connectivity sustained by knowledge sharing triangulation in cross-level small group clusters.

All these considerations prompt curiosity regarding which visible network patterns would be more suitable to sustain system-level connectivity and integration. Would a network characterised by many popular individuals in brokering roles be more integrated and resilient and, thus, at a lesser risk of fragmentation than a network with high

transitivity closure? Could these lead to the same network outcomes? Albeit at the theoretical level, the idea of healthcare system-level integration is increasingly sustained and sought after as an absolute necessity. Operationally the concept is often poorly defined, sometimes resulting in misuse of resources. For example, it might not be obvious which network abilities (i.e., brokerage versus transitivity) might be more efficient to optimise inter-level connectivity and system resilience. The difficulties of effectively promoting collaborations and networking by the executive might be due to a diffuse perceived sense of network ineffectiveness. Some network members may collaborate due to institutional pressures to network, driving them towards collaborative behaviours but without effectively contributing to solutions for healthcare challenges (Peeters et al., 2023). A systematic analysis of healthcare systems using a multilevel lens can be discussed with executive stakeholders to leverage existing informal networks, to effectively improve collaboration. Such matters might be considered as a starting point for future investigations.

Summary and conclusion

This study applied social network theories and methods to explore medical knowledge sharing in the Australian healthcare context, aiming to broadly evaluate the potential impact of Project ECHO, an online mentoring and networking program. Network analysis results were integrated into an evaluation framework to assess ECHO’s potential impact within the healthcare system in Queensland, Australia. Our analysis used a multilevel approach to guide data collection and analyse network data relative to knowledge-sharing structures across individuals at different inter-organizational levels, providing innovative insights into organic collaborations within and between health professionals and service providers that support healthcare system integration.

Limitations and future research

We found several limitations in our work. First, in-person restrictions due to the COVID-19 pandemic shaped our data collection design since we were required to collect data only online. This affected survey completion rate, resulting in missed network respondents and a low response rate. For health professionals with competing clinical demands, it was difficult to find the time to complete an online survey, even though it was offered during the regular network session and accessible in their own time. Potential overbookings, obligations, and competing responsibilities can be considered as possible explanations for survey non-completion. Second, we regret that we couldn’t involve over 80 % of member institutions, potentially leading to some bias in the network social structures we discovered.

Despite these limitations in our study, there is an intrinsic value in this acknowledgement. It is important to recognise that conducting research in the healthcare sector might require additional efforts from researchers to improve survey participation. Moreover, where possible, face-to-face private sessions might help with motivation and engagement, providing a dedicated time for health professionals to be interviewed. Second, respondents would have benefited from having the researcher reiterating the type of relationships we were interested in knowing using additional examples than what was reported in the survey. Having the opportunity to discuss this with the respondents may have resulted in more reported linkages. As such, network analysis tools that control for missingness would also be appropriate here. Third, mapping ECHO over the years could clarify the consistency of the network tendencies over time. This study establishes a baseline from which to continue to map these and other ECHO Networks into the future.

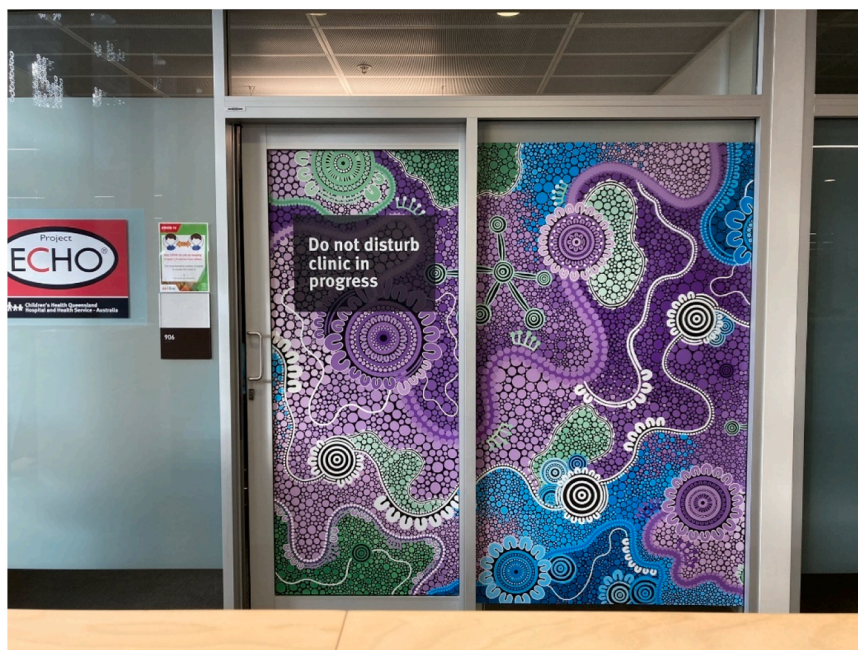


Fig. 8. Current use of the artwork generated by our research.

Reporting results to respondents

We recognise the importance and ethical responsibility in sharing the main findings of our analysis with stakeholders, respondents, and the community (Tubaro, 2021). The research grant that funded this research was part of a newly established fund at the University of Queensland (Australia) to support Early Career Researchers build relationships with industry partners and end-users based on mutual sharing and translation of knowledge, to improve research impact. With this grant, we secured a portion of our research budget for research impact purposes at larger scale. We were able to hire an Aboriginal and Torres Strait Islander artist to produce a visual artwork, using our main findings to inspire their creative process. This beautiful artwork visualises our health networks in a culturally engaging way, using the Aboriginal and Torres Strait Islander traditional iconography and symbolism. The artwork was included in a digital booklet summarising our main results in plain language, with the intention of engagement with a non-academic audience. This became a key communication tool that we shared with respondents, other ECHO participants and stakeholders. The booklet also provided several practical suggestions on the directions that ECHO members could take to improve their individual networking and connectivity. For example, suggesting to link-up with discipline-like colleagues inside and outside ECHO and promoting brokering initiatives such as inviting for a coffee two colleagues that might not know each other, with a view to increase connectivity at a broader level. We believe that reporting results to respondents can promote the culture of collaboration that, in the long run, might open new opportunities for innovation and shared best practices, leading to continuous improvement in healthcare delivery. CHQHHS installed the artwork in two rooms devoted to hosting the regular online ECHO network meetings. This promotes ongoing discussion regarding the impact of this research, to continually grow and evolve CHQHHS integrated care work.(Fig. 8).

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CRedit authorship contribution statement

Dana Newcomb: Writing – review & editing, Validation, Conceptualization. **Angela Young:** Writing – review & editing, Validation, Conceptualization. **Sarah Baggio:** Writing – review & editing, Validation, Project administration, Conceptualization. **Perrin Moss:** Writing – review & editing, Validation, Conceptualization. **Phil Nixon:** Writing – review & editing, Resources, Project administration, Conceptualization. **Chiara Broccatelli:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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