ASSESSING INTERDISCIPLINARITY IN HEALTH RESEARCH TEAMS

UNDERSTANDING AND ASSESSING INTERDISCIPLINARITY IN HEALTH RESEARCH TEAMS

By

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ABSTRACT

Increasingly over the last few decades, funders and academic institutions have promoted the idea of interdisciplinarity as a way of harnessing new knowledge and fostering innovation in science. This thesis sought to articulate how interdisciplinarity is experienced by health researchers involved in interdisciplinary research and to develop and implement a literature-based, researcher-informed framework for assessing interdisciplinarity.

The first paper describes a qualitative study where 19 researchers engaged in interdisciplinary health research took part in individual interviews. The primary theme "It's all about relationships" suggested that interdisciplinary teams tend to be formed based on who can contribute tangible skills needed for answering the research question, however interpersonal factors (e.g. previous positive working relationship) also drive how teams are formed.

Paper 2 involved the development of the Framework for Interdisciplinary Research Assessment (FIRA) that included: 1) a scoping review, and 2) key informant interviews. The literature revealed limited empirical work related to interdisciplinary evaluation, however, a detailed list of issues and possible metrics for evaluation was compiled. Participants identified characteristics common to the structure-process-outcome framework of quality as a possible way to

conceptualize interdisciplinary health research evaluation. The literature

examined was also concordant with the elements of this quality framework.

Paper 3 used a concurrent triangulation mixed methods design where 2

teams of researchers completed individual interviews as well as a survey, the

Partnership Self-Assessment Tool – Interdisciplinarity (PSAT-I). Results

indicated that guided discussion and the PSAT-I are feasible methods for

capturing elements of FIRA. Overall, there was a sense that skills, personality,

and knowledge were greater considerations than disciplinary affiliation.

Paper 4 involved the application of social network analysis in order to

understand knowledge sharing in an interdisciplinary health research team.

Results indicated that each person on the team was viewed as contributing new

knowledge to the team. This study also highlighted the important role of staff as

conduits of information.

The findings from these studies suggest that interdisciplinarity is valued

both in theory and practice, but is challenging to operationalize in practice.

Evaluation of interdisciplinarity is also conceptually seen as worthwhile however

conscious attention is needed to bridge the divide between intention and practice.

The Framework for Interdisciplinary Research Assessment can be applied to

health research teams and initial evaluation suggests that it can be a useful

structured method for teams to engage in formative and summative assessment of

interdisciplinarity.

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LIST OF ABBREVIATIONS

FIRA   Framework for Interdisciplinary Research Assessment

ID   Interdisciplinary / Interdisciplinarity

PSAT   Partnership Self-Assessment Tool

PSAT-I   Partnership Self-Assessment Tool – Interdisciplinarity

SNA   Social Network Analysis

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PREFACE

This thesis takes the format of a sandwich thesis, with four papers each comprising a separate chapter. There is a general introduction to this thesis which provides an overview of the topic of interdisciplinarity and evaluation in health research and sets the context for the subsequent 4 papers. Finally, there is a conclusion which offers overall implications of this combined work. Paper 1 has been published (August 2008) and the other 3 papers will be submitted for publication.

The principal investigator for all papers was Kalpana Nair. The supervisor (Lisa Dolovich) and committee members (Kevin Brazil, Parminder Raina) are co-investigators for all of the studies. Kalpana Nair and Lisa Dolovich conceived of the initial idea for this work. Kalpana implemented each of the studies, including data collection, analysis and interpretation, with guidance from Lisa Dolovich. Kevin Brazil and Parminder Raina contributed input as needed. All co-investigators are also co-authors for each of the papers and provided feedback on written drafts as each was submitted for publication.

The papers are presented in the following order:

1. *It's all about relationships: A qualitative study of health researchers' perspectives of conducting interdisciplinary health research*

2. *Towards evaluation of interdisciplinary health research: The development of the Framework for Interdisciplinary Research Assessment (FIRA)*

3. *Evaluating interdisciplinary health research: Implementing the Framework for Interdisciplinary Research Assessment (FIRA)*

4. *Using social network analysis to understand knowledge sharing in an interdisciplinary health research team*

INTRODUCTION

Thesis Objective

The objective of this thesis was to describe the experience of interdisciplinarity by health researchers and to articulate a framework that could be used for the evaluation of interdisciplinarity by health research teams. Academics and funders have increasingly supported the uptake of interdisciplinary (ID) teams to conduct health research, yet there is little evidence regarding the impacts of interdisciplinarity. This thesis work entailed the development, description, and implementation of a framework for interdisciplinary research evaluation that could be used by health researchers to assess whether and how interdisciplinarity is achieved in their work.

Why this is an important area of study

This is an important area of study as more and more researchers from many domains, including the health sciences, have been called upon by funders and their academic institutions to work in an interdisciplinary manner. While this goal seems laudable, limited empirical work has been conducted in the health sciences to provide substantiation that interdisciplinarity is a suitable archetype for researchers to employ. Despite this lack of evidence, funders and academic institutions have been persistent in their vision of the benefits that interdisciplinarity could achieve.[1;2] These benefits, such as knowledge sharing

between disciplines to better answer complex research questions,[3;4] intuitively make sense; but, it is not clear whether health researchers working in interdisciplinary teams actually elicit, value, and utilize the knowledge contributions of their team members from other disciplines.

Understanding what happens in actual research practice is a critical first step towards the development of an evaluation framework. This thesis involved a foundational qualitative study that examined the general experiences and perceptions of researchers engaged in interdisciplinary health research. This was followed by a review of the literature and the development and implementation of a framework for evaluating interdisciplinary health research. Finally, a social network analysis study was conducted to determine who was seen as contributing towards new knowledge within an interdisciplinary health research team. Ultimately this study will contribute practical information that will help enhance the options available for evaluation of interdisciplinarity in health research.

Overview of thesis papers

Paper 1 is a qualitative study that examined the experiences of health researchers who are currently engaged in interdisciplinary research in Canada. This study involved individual interviews to determine how interdisciplinary research was conceptualized and experienced from the academic health researcher's perspective and to understand how to foster success in

interdisciplinary health research. By talking directly with those currently engaged in interdisciplinary health research, we were able to provide a first person description of the motivators and challenges faced and what health researchers do to alleviate some of these challenges. The primary finding of this study, "It's all about relationships", suggests that it is important to consider interpersonal dynamics between research team members as this impacts how and when researchers work together.[5] There was a clear sense that disciplinary affiliation may not be a critical deciding factor when putting together a research team; rather, the known skills and past working relationships often took precedence when forming a research team.[5]

This paper provided a critical examination of how researchers currently conceptualize interdisciplinarity and the value placed on it. It reinforced the likely challenges with evaluating the concept of interdisciplinarity, when it is inextricably intertwined with interpersonal aspects of a working relationship. This work also echoed previous literature that highlighted the benefits and challenges of engaging in interdisciplinary scholarship. Paper 1 was published in BMC Health Services Research in August 2008 and has been well accessed and cited by a number of subsequent publications.[5]

Paper 2 focused on the development of a framework for evaluation of interdisciplinarity in health research teams. This framework was based on the

findings from the qualitative interviews that were used in Paper 1. During those interviews, participants were asked to also discuss their experiences with and ideas related to the evaluation of interdisciplinarity. Additionally, a detailed examination of the literature took place to yield citations regarding empirical work related to interdisciplinary assessment. Interestingly, there was no evidence of evaluation frameworks for health research that specifically sought to evaluate the interdisciplinary component of health research. The literature review and qualitative interviews suggested that components of existing frameworks, Payback Framework, and Research Impact Framework, as well as the Structure-Process-Outcome Quality Framework by Donabedian[6] could be extrapolated to create a framework for interdisciplinary evaluation.[7] As such, the Framework for Interdisciplinary Research Assessment (FIRA) was developed.[7] It was felt that this framework would offer concrete guidance for researchers and funders who may want to evaluate the value-added that interdisciplinarity brings to a health research team.

Paper 3 is a concurrent triangulation mixed methods study that provides a practical example of how one might implement the Framework for Interdisciplinary Research Assessment that was developed in Paper 2. Qualitative interviews were conducted and participants also completed the Partnership Self-Assessment Tool-Interdisciplinarity (PSAT-I). In this paper, findings from work with two research teams are presented. All aspects of the FIRA model were able

to be populated through the individual interviews. The PSAT-I results provided greater specificity related to benefits, drawbacks, and satisfaction from involvement in an ID team. All participants noted learning something new and expected a greater number of publications and presentations as a result of their involvement with the ID team they were on.

In Paper 4, social network analysis was employed with one of the teams from the mixed methods study in Paper 3. This study sought to understand knowledge sharing in an interdisciplinary health research team. Team members were asked to indicate who contributed new knowledge and who contributed the greatest amount of new knowledge. Finally, participants were asked who they would want to work with again in the future if given the opportunity. Results showed that each person on the team was nominated at least once as contributing new knowledge to the team as well as wanting to be worked with again. Centrality measures highlighted the principal investigator (PI), 2 co-investigators, and 2 staff people as central to network activity. The PI and one co-investigator, who were from a different discipline than most, were found to have contributed the greatest amount of new knowledge to the team. This study highlighted the important role of staff as conduits of information as evidenced by their centrality scores, a finding which could have implications for other ID health research teams.

Putting interdisciplinarity in context – an overview of the literature

Interdisciplinary research in the health sciences

Interdisciplinary research has been explored in the arts and social sciences for almost 4 decades and it is only within the last 10-15 years that the health sciences have considered this area in any depth.[8] Distinctions have been made in the literature regarding the differences between multidisciplinary, interdisciplinary, and transdisciplinary research.[2;9;10] Multidisciplinarity refers to different disciplines working on a study with each researcher functioning relatively independently and their contribution reflecting their disciplinary affiliation. Interdisciplinarity implies a more collaborative approach, whereby disciplinary borders are softened and there is an expected contribution of each discipline to all parts of the study process (i.e. design, implementation, dissemination, publication). In interdisciplinarity there is borrowing of methods and approaches from various disciplines. Transdisciplinarity reflects the construction of new knowledge that does not have disciplinary boundaries, and often relates to the emergence of new domains (e.g. biochemistry).[11] Of note, is the lack of uniformity in how these terms are described in the literature and how they are operationalized in practice.

There have been 2 predominant foci regarding interdisciplinarity in the health sciences: 1) inter-disciplinary or inter-professional clinical care teams, and 2) inter-professional education. Both of these areas have highlighted the

importance of collaboration, respect for differences, and role clarification, and offer a similar model of practice to interdisciplinary health research with varying disciplines working together on a predetermined goal. Beyond this similarity, the focus of research activity is fundamentally different from clinical care or education, thus, necessitating its own evaluative framework.

Finally, there is a broad literature base related to team formation and partnerships that also informs how interdisciplinary health research teams work together.

Benefits and challenges of interdisciplinary research

There has been considerable literature documenting the benefits and challenges of interdisciplinary research in general, and more recently within the health sciences. The main benefits of interdisciplinary research include greater creativity, greater applicability of study findings, exploration and application of different methods and theories, and emergence of new ways of thinking.[2;12-14] Interdisciplinary contributions are also lauded with increased capacity for problem solving and innovation.

The benefits of interdisciplinarity also come at a cost and challenges of ID can occur at different levels, including institutional barriers and within team challenges. The main institutional barriers relate to the lack of value placed on

interdisciplinary research, especially when tenure and promotion is being

evaluated.[2;14] This has implications for the types of knowledge that are ultimately

shared between disciplines.

For researchers working within an interdisciplinary team, lack of respect,

increased time to acclimatize new disciplines to one's theories and methods,

disciplinary rigidity, and the threat of becoming adisciplinary have also been

discussed.[14-16] Despite these documented challenges, ID health research continues

to be encouraged by primary funding bodies worldwide, reinforcing the need to

minimize potential negative consequences and to understand its impacts.

Evaluation of interdisciplinarity

Evaluation of interdisciplinarity has been increasingly discussed in the

literature, at the funder level, and within academic circles.[1] There have been a

variety of methods proposed for the evaluation of interdisciplinarity. On one end

of the spectrum, researchers have taken a reflective approach and have

qualitatively described their experiences with conducting interdisciplinary

research by offering an anecdotal account of whether they feel they have achieved

interdisciplinarity.[12;14;17] Bibliometric methods are the other common

methodology used for ascertaining the degree of interdisciplinarity achieved.[3;18;19]

Most often this involves examining the breadth of publishing generated by a

particular research centre, research group, or project, with citation indices used to

track the number and types of disciplines, and where articles have been published, with publishing outside of one's own discipline cited as evidence of interdisciplinarity. While both types of evaluation can be useful, each is limited in scope and does not fully articulate the impact of interdisciplinarity; commentaries are often too subjective and bibliometric methods are not feasible until at least 5-10 years after a study has been published. Social network analysis is useful for capturing relational aspects of knowledge sharing and communication and offers promise for health researchers to better understand "who is talking with/working with whom".[20] However, there is skill required in performing social network analysis and this too may limit its uptake by health researchers.

Work completed to date has also highlighted some methodologic considerations with regards to evaluation. First, how interdisciplinarity is defined varies and it can be uncertain whether a study is truly interdisciplinary. For example, a study may be framed as an interdisciplinary study, yet in practice may operate more like a multidisciplinary research team. Also, there may be differences among research team members' perceptions with regards to whether a team is interdisciplinary, multidisciplinary, or transdisciplinary. Funders themselves further add to this confusion. The Canadian Institutes of Health Research (CIHR) have initiated a number of funding opportunities aimed at fostering interdisciplinarity, such as the Interdisciplinary Capacity Enhancement (ICE) Team Grants. Literature on the CIHR website indicates that one of the

objectives of this grant is "forging multidisciplinary teams".[21] This lack of consistency in terminology is confusing and problematic.

How a discipline is defined is not a straightforward endeavor as we found when asking researchers to tell us their discipline.[5] Many researchers considered themselves to be affiliated with a number of disciplines and depending on where they were publishing or speaking would adjust their alignment with these disciplines accordingly. This also relates to the issue of disciplinary shift whereby researchers acquire knowledge and skills through their academic career and thereby develop new affiliations.[5;14] This raises the issue of whether discipline per se is an appropriate metric for interdisciplinary assessment and what other factors should be considered.

Expected contribution of overall thesis

Context is an important facet to consider when conducting any type of evaluation exercise and one of the strengths of this research is that it has taken this into account by focussing specifically on health research conducted in Canada. This will therefore contribute information that will be readily accessible to decision makers and researchers operating in Canada.

The present research also offers the explication of a possible model of interdisciplinary assessment that has the potential to offer researchers an efficient

and practical way to assess the value added that ID brings to their research. Given the limitations of the existing published work, it becomes all the more clear that a broad framework for assessment of interdisciplinarity, consisting of multiple factors for evaluation, would contribute immensely to this gap in knowledge and practice.

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Research article

It's all about relationships: A qualitative study of health researchers' perspectives of conducting interdisciplinary health research

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Abstract

Background: Interdisciplinary research has been promoted as an optimal research paradigm in the health sciences, yet little is known about how researchers experience interdisciplinarity in practice. This study sought to determine how interdisciplinary research was conceptualized and operationalized from the researcher's perspective and to better understand how best to facilitate interdisciplinary research success.

Methods: Key informant interviews were conducted with health researchers with expertise or experience in conducting interdisciplinary research. Interviews were completed either in person or over the telephone using a semi-structured interview guide. Data collection occurred simultaneously with data analysis so that emerging themes could be explored in subsequent interviews. A content analysis approach was used.

Results: Nineteen researchers took part in this study. Interdisciplinary research was conceptualized disparately between participants, and there was modest attention towards operationalization of interdisciplinary research. There was one overriding theme, "It's all about relationships", that emerged from the data. Within this theme, there were four related subthemes: 1) Involvement in interdisciplinary research; 2) Why do I do interdisciplinary research?; 3) Managing and fostering interdisciplinary relationships; and 4) The prickly side to interdisciplinary research. Together, these themes suggest that the choice to conduct interdisciplinary research, though often driven by the research question, is highly influenced by interpersonal and relationship-related factors. In addition, researchers preferred to engage in interdisciplinary research with those that they had already established relationships and where their role in the research process was clearly articulated. A focus on relationship building was seen as a strong facilitator of interdisciplinary success.

Conclusion: Many health researchers experienced mixed reactions towards their involvement in interdisciplinary research. A well thought-out rationale for interdisciplinary research, and strategies to utilize the contribution of each researcher involved were seen as facilitators towards maximizing the benefits that could be derived from interdisciplinary research.

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Background

Interdisciplinarity in health research has become a common research paradigm. Globally, central research agencies such as the National Institutes of Health (NIH) in the United States, the Seventh Research Framework Programme (FP7) in the European Union, and organizations such as the World Health Organization (WHO) have all focused efforts towards increasing interdisciplinary research. In Canada, the Canadian Institutes of Health Research (CIHR) has been at the forefront of promoting interdisciplinarity within health research with many funding opportunities geared specifically towards the development of interdisciplinary teams [1]. This shift in how research is funded, along with changes in academia (e.g. joint appointments; interdisciplinary programs and faculties), has further reinforced the value placed by funders and academic institutions on the conduct of interdisciplinary research. Despite this emphasis on interdisciplinarity, relatively little has been documented about how researchers experience interdisciplinary health research in practice.

Although interdisciplinarity is touted as a valuable aspect of health research, it is only recently that there have been attempts to define and operationalize it, with varying definitions in existence. Interdisciplinarity within health sciences research usually involves researchers from multiple disciplines working *together* to tackle complex, multifaceted research questions. In 2005, the Canadian Academy of Health Sciences defined interdisciplinary research as "a team of researchers, solidly grounded in their respective disciplines, that come together around an important and challenging health issue, the research question for which is determined by a shared understanding in an interactive and iterative process" (p.764) [1]. A systematic review in 2007 saw interdisciplinary research explicated as: "any study or group of studies undertaken by scholars from two or more distinct scientific disciplines. The research is based upon a conceptual model that links or integrates theoretical frameworks from those disciplines, uses study design and methodology that is not limited to any one field, and requires the use of perspectives and skills of the involved disciplines throughout multiple phases of the research process" (p.341) [2]. Thus, the presence of at least two disciplines, a shared delineation of the research question, and involvement from each discipline throughout the research process have been noted as key elements of interdisciplinary research. Related types of research, multidisciplinary and transdisciplinary share similar features. Multidisciplinary research typically involves disciplines working more independently on a research study, and transdisciplinary research purports to utilize the methods and perspective of various disciplines to generate new knowledge and approaches. Therefore, each type of research is characterized by different levels of involvement by researchers and has varying impacts on knowledge generation. It is interdisciplinary research, however, that has been the focus of much attention within the last few years regarding its definition.

Scholars such as Julie Thompson Klein [3-5] have been writing about interdisciplinarity since the early 1990s, but it is only in the last five-to-ten years that there has been a marked increase in the nature and frequency of attention devoted to interdisciplinary research. A number of commentaries and articles have described some of the challenges of interdisciplinary research in health and science [1,6-9]. In Canada, government, industry, and academia have both supported and hindered the uptake of interdisciplinary health research [1]. For example, despite many funding initiatives focused on interdisciplinary health research, academic institutions are still primarily organized through disciplinary-based boundaries (and faculty rewarded for contribution to these disciplines), thereby thwarting incentives for moving beyond these boundaries. Others have also cited the tenure system as a major impediment to interdisciplinary research, and as a result some researchers may avoid opportunities for participation in interdisciplinary research [6,8,9]. The push for involvement in interdisciplinary research has left some researchers feeling compelled to undertake interdisciplinary research, concerned about becoming adisciplinary, and feeling frustrated with continually re-educating new disciplines about one's own discipline [8]. As well, within an international research milieu, context is important in shaping research questions and their findings, and there can be difficulties in navigating differences in terminology and culture [10]. These papers have been instrumental in laying the foundation for documenting the nature and realities of interdisciplinary research in health and science. The logical next step is an examination of the experience of researchers currently conducting interdisciplinary health research within academia. Accordingly, this study sought to determine how interdisciplinary research was conceptualized and experienced from the academic health researcher's perspective and to understand how to foster success in interdisciplinary health research. This study was the first phase of a larger study examining evaluation of the interdisciplinary component of health research, and it was felt that researchers' in-vivo experiences and perceptions would be a suitable platform from which to build an evaluation framework for interdisciplinary research.

Methods
Design
This was a descriptive study utilizing qualitative interviews to explore the experiences and perceptions of academic health researchers. Although focus groups were a possible data collection method, focus groups would not

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have allowed for an in-depth examination of individual experiences. The study setting was the university environment as we were interested in understanding the perspective of health researchers working within academia.

Sampling and data collection

A purposeful approach to sampling was used [11]. Researchers, or key informants, with known experience of or expertise in interdisciplinary health research were invited to participate in this study as we wanted to learn from those who had already engaged in the conduct of interdisciplinary health research. This use of specific inclusion criteria is common when conducting key informant interviews [12]. Often studies that involve key informants start with the investigators drawing up a list of potential participants [12]. In this study, two of the study investigators (LD and KN) generated a small list of possible participants based on their knowledge of the type of research that they did (e.g. researchers completing interdisciplinary health research or having published findings from interdisciplinary research). Researchers who had worked together were not specifically sought however there were participants in this sample who indicated in their interview that they had worked with other participants. Three specific types of purposeful sampling strategies were used in this study, and it is not uncommon for qualitative studies to involve more than one type of sampling strategy [11]. Critical case sampling was utilized to elicit participants who exemplified key characteristics [11]. For example, we explicitly sought to include researchers with backgrounds in statistics and in health policy as it was recognized that these disciplines were inherently interdisciplinary within the health field and that these key informants could therefore provide this unique perspective. Snowball sampling was also used to determine other suitable participants, as we were aware that there were likely key informants that were not known to us at the onset of the study [11]. Finally, maximum variation sampling (seeking a range of participants) was utilized to ensure that data reflected a diversity of experiences. For example, it was evident half way through the interviews that more participants who were earlier in their careers were needed (e.g. junior faculty), and participants reflecting this characteristic were specifically sought.

Potential participants were initially contacted via email by the principal investigator (KN) and provided a copy of the study information sheet and study consent form. Participants were asked to respond to the request for an interview via a return email. If the participants agreed to complete the interview, arrangements were made to either complete the interview in person or over the telephone, depending on the preference of the participant. Those who did not respond to the initial email request were sent another email within a couple of weeks. If after three email attempts, no response was received, no further contact was initiated. All participants were asked to complete one interview.

A semi-structured interview guide was used to explore participants' perceptions and experiences of conducting interdisciplinary health research, potential barriers and facilitators, and knowledge of literature about interdisciplinary research. Detailed questions on evaluation were also asked and will be reported as part of the wider study. All interviews were digitally recorded and transcribed with the participant's consent. Participants were mailed a $25 gift certificate as a token of appreciation after completion of the interview.

Saturation was the main determinant of how many interviews were completed, and data collection stopped when no new information was gained for each of the main themes generated [13]. Personally identifying information was deleted from transcripts during the transcription and data cleaning process, and a coded number identified each participant.

Data analysis

Data analysis took place concurrently with data collection to ensure that new themes were sufficiently explored. A content analysis approach was used to extract recurrent themes across interviews [14]. All transcripts were coded by the principal investigator [13]. Coding involved reading each transcript and putting like elements of text into broad groupings. Each of these groupings was then read and re-read to establish key themes. Following the delineation of key themes, all interviews were examined for the presence of each theme and for a range of responses within each theme [13]. This coding process allowed for understanding of the breadth and variation in responses that were present in the interviews. A provisional codebook was developed after the first couple of interviews and refined as the analysis progressed. Quotes reflective of emerging themes were extracted as the analysis was conducted and further examined as the paper was written to ensure that these best reflected the interpreted experience of participants. Illustrative quotes are included within findings.

QSR NVivo (version 2), a software program designed for qualitative research, was used to help organize the data.

Study rigour

This study proceeded once ethics approval has been obtained from the St. Joseph's Healthcare Hamilton Research Ethics Board (#06-2689) in Hamilton, Ontario, Canada. Study rigour was maintained in a number of ways. An audit trail was kept to document reasons for

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changes to the interview guide, codebook, and themes. All interview transcripts were cleaned prior to coding to ensure accuracy. The principal investigator documented personal perceptions, biases, and beliefs about interdisciplinary research at the onset of the study and periodically examined these as data collection and analysis were taking place in an effort to minimize undue influence of these on the interpretation of the data.

All participants were invited to a presentation of the study findings and given the opportunity to provide feedback about the key themes generated. Any comments provided were incorporated into the final analytic picture. This step (member checking) was completed to ensure that the interpretation of findings reflected participants' experiences and resonated with their perceptions [15].

Results

Of the 20 people invited to participate, 19 agreed and one declined due to scheduling conflicts. Seventeen interviews were conducted in person, and two were completed over the telephone. Interviews ranged from 17 to 66 minutes. Eleven participants (58%) were female, and 12 (63%) had worked in research for over 15 years. Fourteen participants (74%) had worked on more than 20 studies that they considered interdisciplinary. Twelve participants (63%) were in a leadership position in academia (e.g. Director, Associate Director). A range of disciplines (as identified by participants) were represented in this sample and are noted in Table 1.

Conceptualizing interdisciplinary health research

Participants were involved in a variety of interdisciplinary health research studies that included clinical trials, health services research, health policy analysis, environmental health, and patient and clinician-related interventions. However, despite all participants engaging in interdisciplinary research, there were variations in how researchers defined and conceptualized interdisciplinary research. All participants generally agreed that at least two different disciplines were needed for the conduct of interdisciplinary research, although a small minority felt that having a minimum of three or four different disciplines present was a more ideal scenario. Interdisciplinary research was typically conceptualized in very general terms (bringing multiple disciplines together to answer a research question) and there was little use for the distinctions between multidisciplinary, interdisciplinary, and transdisciplinary research. There were two participants, however, who felt that these distinctions were useful and needed. Both of these researchers were among the few interviewed who were more familiar with the literature about interdisciplinary research. Participants typically added investigators with particular skills as a study progressed versus having a complete complement of all disciplines present at the onset of the study. Three participants had conducted and published articles in academic journals about their experiences or perceptions of doing interdisciplinary research.

Conducting interdisciplinary research

There was one overriding theme that emerged from the data, "It's all about relationships". Research conducted where there was an existing positive relationship was seen as facilitative of knowledge generation and transfer. One

Table 1: Participant Characteristics

Self-Identified Primary Discipline (Participant ID #)	Leadership position	Number of ID studies	Number of years in research
Clinical Pharmacology (1)	Yes	21–25	15
Economics (14)	No	11–15	20
Environmental Health (8)	No	40+	35
Family Medicine (6)	Yes	40+	22
Health Policy (3)	No	6–10	8
Marketing (4)	No	16–20	30
Medicine (specialist) (13)	Yes	40+	25
Medicine (specialist) (19)	Yes	40+	30
Nursing (12)	Yes	26–30	29
Pharmacy (2)	Yes	21–25	9
Philosophy (15)	No	11–15	16
Philosophy (17)	Yes	11–15	27
Political Science (7)	Yes	31–35	9
Social Work (9)	Yes	26–30	15
Sociology (10)	No	26–30	15
Sociology (11)	Yes	40+	20
Sociology (16)	No	6–10	8
Sociology (18)	Yes	40+	36
Statistics (5)	Yes	40+	10

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of the most commonly cited incentives for doing interdisciplinary research (or continuing to do interdisciplinary research), related to engagement with others where there was a mutual respect, comfort, and in many cases, a past history of working together.

> *...it [interdisciplinary research] appears not to be thought about consciously, certainly on my part, and I think the more I've done this, the less conscious it becomes, more gets taken for granted in an interdisciplinary context as it would in a disciplinary one. ...I think certainly as you move through and I'm sure you're going to be talking with people at their difference stages of their interdisciplinary careers you'll find that there's people that you can work with well and others that you will never work with again because it wasn't a great experience. [Int8-Environmental Health]*

This response was echoed through all of the interviews. It appeared that prior experience with different disciplines working together mitigated the potential for disciplinary division within the research team. One researcher nicely captured this sentiment of balancing the difficulties with the possible benefits that could be derived:

> *[What is] underappreciated is that relationships develop over time and there's a huge transition cost of establishing one ... I think it has to do with relationships, it has to do with rapport. It has to do too with really creative thinking;, maybe it's too strenuous for me, maybe a smarter person wouldn't have a problem, but I think it is strenuous communicating and getting someone else to understand. Getting a whole room full of people to understand is difficult. But I can say a couple of colleagues with whom I've just hit it off intellectually, we've done, even when there's been a group, we've tended to pull the project along. And I think it's been wonderful and even quite a stretch across totally different methods, totally different backgrounds, so that kind of friendship almost based engagement. I don't know which comes first, the collaboration I guess and then friendship in most cases. [Int10-Sociology]*

Researchers valued the ability to build upon existing relationships and some felt that this focus contributed most towards new knowledge development. Working in large teams (more than five or six people) was not seen as a productive mode of research; often working closely with one to three people was seen as the ideal as a smaller group would better allow for focused attention and integration regarding what each discipline could contribute to the study.

Within this primary theme, there were four related subthemes: 1) Involvement in interdisciplinary health research; 2) Why do I do interdisciplinary research?; 3) Managing and fostering interdisciplinary relationships;

and 4) The prickly side to interdisciplinary research. Taken together, they offer a picture of how interdisciplinary research was experienced by the interviewees as a group, why some researchers chose to involve themselves in interdisciplinary health research, and how some of the challenges they experienced were managed.

1. Involvement in interdisciplinary health research

For many, forming an interdisciplinary team of researchers was not a conscious decision but was inherent to the type of research questions they studied. Those with interdisciplinary backgrounds also tended to find themselves working predominantly with interdisciplinary teams:

> *I think that because I don't easily fall into one particular discipline, I've always just been at the interface of a bunch of different domains, and certainly the teams I work in are typically like that. ... I do think that our work is so fundamentally at the juncture of so many domains, it's just how we do it [research] and I think it's [interdisciplinary research] just second nature to us individually and as groups. [Int7-Political Science]*

Importantly, a number of participants commented on the necessity of recognizing that not all research questions require an interdisciplinary approach, with many questions being appropriate for single disciplines to investigate:

> *And not all questions need to have a multidisciplinary or interdisciplinary team working on a project. Some questions don't need that; some questions can be very well answered within disciplines. We can't loose sight of that either. [Int2-Pharmacy]*

There were also researchers who discussed the appropriateness of when and who should engage in interdisciplinary research. There was a widespread recognition that interdisciplinary research could be disadvantageous to more junior researchers, and that some seniority was needed in order to effectively negotiate the complexities of interdisciplinary work:

> *When you go into interdisciplinary work ... you have to be very good at boundary setting...and you have to be prepared to do the political balancing act to what you say yes to and what you don't. I don't think you can do it as a junior scholar. I really believe that you do that at your peril. You have to have some seniority and some political clout to move into it [interdisciplinary research]. [Int9-Social Work]*

Many senior investigators commented that interdisciplinary research was not valued equally when tenure and promotion was being considered and that junior faculty may not be in a position to negotiate otherwise. A revisit-

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ing of tenure and promotion criteria in some departments was felt necessary to truly foster an academic milieu of open interdisciplinary research. For example, one researcher described a scenario whereby a colleague opted not to join an interdisciplinary research team, as his department did not recognize the contribution of multi-authored papers in the tenure and promotion process.

2. Why do I do interdisciplinary research?

Participants were asked to talk about what motivates them to conduct or continue to be involved in interdisciplinary research. There were four factors consistently noted by participants as contributing towards this pursuit: 1) the nature of the research question, 2) opportunities for funding, 3) opportunity to learn about something new/see problem in a new light, and 4) the ability to have a stronger impact on knowledge transfer and uptake.

The central driver for engaging in interdisciplinary research was the need for different knowledge sectors to contribute towards understanding a complex health research area; this sample was predominantly comprised of a seasoned group of researchers who recognized that many health questions could not be answered effectively within a single discipline.

On a more pragmatic note, most researchers took advantage of funding opportunities that arose within an environment of shrinking research dollars; being opportunistic was a necessity for survival within academia. Experienced researchers expressed frustration at the almost forced interdisciplinarity that funding agencies imposed, and how this focus often led to inefficient and less productive research. Some reflected that multidisciplinary research would have been more effective as this type of research would have allowed each discipline to bring their expertise to the study in a more focused manner. Ultimately, having a strong, well-defined rationale for interdisciplinary research was seen as a key facilitator towards research success.

The opportunity for exposure to new methods or theories was cited by some participants. In most cases, this experience was simply an antecedent bonus to doing interdisciplinary work, as it was generally not practical to develop a research proposal solely around an area that one was interested in learning more about.

Finally, for many researchers there was also a strong belief that different knowledge bases would be able to contribute towards the creation of stronger solutions and answers, thus leading to more meaningful and useful results. Interdisciplinary research was seen as something that could foster uptake of research findings:

… and the [research] product was different due to team composition, and the product was better and by the time that research was done… that project went forward to the government and has been implemented, where it could have just sat being critiqued… [Int12-Nursing]

3. Managing and fostering interdisciplinary relationships

The importance of cultivating interdisciplinary relationships was raised by many participants, and leadership and role clarification were cited as drivers that could foster this development. Without a strong leader to guide the interdisciplinary research process, the potential contributions of researchers from other disciplines could not be effectively realized.

But it also takes a lot of leadership to make that [interdisciplinarity] possible. You could have an interdisciplinary group that is completely dysfunctional because there's nobody to actually give it a sense of direction. Anytime you have a group, I mean even a group of well-qualified individuals, they often sometimes need direction. So having someone who is good in directing people or at least providing some sense of direction really helps. [Int5-Statistics]

Involvement in a team that fostered the input of all team members was an expectation of most participants and this focus was seen as the responsibility of the principal investigator.

The role that each researcher assumed varied based on how the team was initially constructed. Involving all researchers in most aspects of the study was seen as a way to keep team members engaged and participating. For example, one researcher described a study where some of the team members had never been involved with empirical research and the principal investigator had all researchers take part in the data analysis:

I actually insisted on [everyone taking part in data collection & analysis]. Because I thought in order to have a meaningful discussion about the material…everyone should be involved in at least two interviews and one level of analysis of part of the dataset. [Int3-Health Policy]

Other participants discussed the importance of clarifying the role of each team member. This elucidation was seen as critical for research success as it helped to ensure that everyone on the team was aware of what each other was contributing to the team.

I think one of the things is to fairly early on have a discussion about what each team member brings and even more importantly why they were asked to join the team. [Int12-Nursing]

Participants also articulated how interdisciplinary research itself influenced the researcher-team relationship and how one participated in the team. One participant noted that interdisciplinary research involved a high level of confidence to be able to acknowledge gaps in one's knowledge:

> One has to be reasonably comfortable with oneself and to the point where you say, " I don't know anything about this. I'm a learner in this part of this study and I can't even challenge, apart from being a naive listener saying, well, from my perspective I hear this". So it takes a lot of maturity and self-confidence when you're doing that kind of work to even enter into it because it [interdisciplinary research] is going to take longer, it is going to cause you to be uncomfortable frequently with what you don't know. [Int3-Health Policy]

4. The prickly side to interdisciplinary research

There were mixed feelings expressed about involvement in interdisciplinary research. Most barriers related to the large time investment needed to effectively coordinate and work with a team of disparate disciplines. A few people noted the challenges of working across distances when doing interdisciplinary research and it was typically recommended to work with people where face-to-face meeting was possible.

A general theme that proliferated the interviews was the notion that interdisciplinary research simply involved an understanding of interpersonal dynamics and how to deal with differing personalities, irrespective of the discipline that they come from. In many interviews, researchers highlighted how challenging personal dynamics could be:

> And the other thing is the personalities, anytime you're dealing with different people, there's always issues of differences in culture. And our educational backgrounds are cultures, so personalities also sometimes make it difficult in an interdisciplinary environment. [Int5-Statistics]

Taking time to build interdisciplinary relationships was cited as a key factor that could enhance the conduct of interdisciplinary research. Time to build relationships was seen as both a necessity but also as a frustration as sometimes the short time frame of grants did not allow for this development. Time was needed to learn about the perspective of others, assess the value of what they are contributing, and finally, to assimilate this new knowledge into one's own knowledge base. For some, the length of the relationship-building process obscured the possibility of more informed solutions and learning that could be gained from interdisciplinary work. Overall, participants were attuned to the practicalities of conducting interdisciplinary health research, versus taking time to reflect on their experience of it.

Marginalization within an interdisciplinary team was also an ongoing concern, and this typically resulted from roles and expectations not being clearly delineated. Some people recognized that power imbalances could exist and made a conscious effort to articulate when this occurred, while others felt limited in their ability to openly address this marginalization. Dealing with these dynamics was seen as a disincentive towards being involved with interdisciplinary teams.

> The other part of interdisciplinarity that doesn't feel talked about much is power...sometimes it feels like we have just one discipline [present] with all of these smaller voices on the edge. [Int16-Sociology]

Interdisciplinary Success

Participants in this study offered possible solutions to three key challenges of interdisciplinary health research that were consistently raised during the interviews: 1) not understanding what interdisciplinarity research is really about; 2) varying personalities and viewpoints; and 3) marginality and power dynamics. Ideas for maximizing the potential benefits of interdisciplinary research emerged from the interview discussions and are summarized in Table 2. In general, an explicitness about the role and contribution of each discipline was seen as critical for facilitating a smooth research process. Strong leadership by the principal investigator throughout the research study could also keep all disciplines engaged and could minimize the power differentials between the various disciplines involved.

Discussion

This study examined how interdisciplinary research was conceptualized and experienced by researchers involved in health research. Researchers valued interdisciplinary research as a mechanism for more completely answering complex health questions and they appreciated the potential advances in how knowledge was generated and the possible impacts of this new knowledge. However, many researchers described mixed reactions towards participation in interdisciplinary research. The challenges of managing different personalities, working with large numbers of people, and the time needed for effective relationship building were seen as disincentives to interdisciplinary research. Nevertheless, a well thought-out rationale for interdisciplinary research, strong leadership, an attention to power imbalances, and strategies in place to maximize the contribution of each researcher involved were seen as facilitators towards taking advantage of the benefits that could be derived from interdisciplinary research. Importantly, researchers consistently talked about the critical role of relationships in fostering interdisciplinary success.

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Table 2: Maximizing the benefits of interdisciplinary health research

Challenge	Description	Possible solutions for addressing challenge
Not understanding what interdisciplinary research is really about	▪Researchers come to the table without fully appreciating the intent of interdisciplinary research study	▪The research team together establishes how they define and view interdisciplinarity for their study
		▪A plan to assess whether the research team is meeting their goals regarding interdisciplinarity is in place
		▪Regular assessment/refinement of progress is conducted
Varying personalities and viewpoints	▪The focus of the research study is derailed by those with their own agenda/perspective	▪Active leadership by principal investigator to keep all disciplines engaged and contributing
		▪Regular interaction/communication by team members
Marginality and power dynamics	▪Some research team members minimize and exclude the contribution of other disciplines in the research team	▪Explicitness re: each person's role & contribution to the study is established at the onset of the study
		▪Regular assessment of each discipline's contribution is built into the study plan

Participants in this study cited many benefits (opportunity for greater impact; new knowledge generated; learning new methods) and challenges (managing different personalities; tenure criteria; time investment) of interdisciplinary research that have been previously described in the literature [8,9,16-19]. Of particular note was the recurrent sentiment that interdisciplinary research could be detrimental to the careers of junior faculty due to the lack of recognition that it has in some tenure and promotion criteria. This concordance with previous findings helps to consolidate knowledge about the main drivers for academic health researchers towards engagement in interdisciplinary research. Participants generally agreed on the value of conducting interdisciplinary research. However, most researchers conceded that new disciplines are often brought into teams when particular skills are needed, and not necessarily at the proposal development stage. These researchers did not view this deviation as indication that their research was perhaps more accurately multidisciplinary [20] in nature; they felt that engagement with new disciplines at specific junctures in a study could still lead to new learnings and directions in the research.

Interdisciplinary research was unconsciously undertaken by some participants and was seen as intrinsically part of their research scope. Interdisciplinary research conduct as "second nature" has also been described by those who have undertaken interdisciplinary graduate programs [21]. These researchers highlight their ability to bridge the divide between disciplines given their knowledge and exposure to a variety of methods and approaches [21]. It may be that there is an emerging breed of researchers who may be better equipped to manage the challenges of interdisciplinarity in health research due to their early exposure of working in an interdisciplinary manner.

Much of the scholarly writing about interdisciplinarity is situated within a discourse of how knowledge is constructed [3,5,20,22,23]. The researchers interviewed focused primarily on the practicalities of conducting interdisciplinary research (e.g., managing group dynamics). In addition, all researchers were asked to share information about literature regarding interdisciplinarity and interdisciplinary research, and few were aware of the vast compilation of literature related to interdisciplinarity. This gap in knowledge highlights the focus of this sample on 'getting the research done" with few having time to deeply ponder epistemological debates. This lack of explicit attention towards epistemology and knowledge construction may also be reflective of this sample's focus on one type of research, health research, which may have more fluid disciplinary boundaries and foundations.

These findings are important as they offer insight into the motivations of health researchers towards conducting interdisciplinary research. Although all participants were health researchers, there were 15 distinct disciplines represented within the sample. The general uniformity of experiences and perceptions across these disciplines implies a universality of factors that could be delineated for successful interdisciplinary research. For example, many researchers found that they favored working with those with whom they had pre-established relationships. This preference suggests that when forming an interdisciplinary health research team, starting with a core group of researchers who have already worked together and then adding a minimum of new researchers could help to ameliorate typical interdisciplinary "growing pains". Strong leadership and clearly delineating each person's role on the research team can also help to minimize difficult group dynamics.

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This study is not without its limitations. Some participants had difficulty separating their experiences within interdisciplinary research teams from non-interdisciplinary research teams. Despite efforts to re-orient participants back to an interdisciplinary focus, it is possible that some comments will have been more general in nature than expected. The study findings emphasize the challenges of disentangling general group dynamics from interdisciplinary group dynamics. Also, some interviews were shorter than expected and in one case it was evident that the interview was 'fit in' between other commitments. Although the findings generated from these shorter interviews were useful, the difficulties of engaging busy health academics (and in some cases clinicians) in a qualitative study were affirmed. This study sample was also comprised of researchers more seasoned in the conduct of interdisciplinary health research, despite efforts to recruit junior investigators. As a result, the transferability of findings may be limited. Furthermore, this study's exclusive focus on the perspective of researchers involved in interdisciplinary health research may also impact the transferability of findings to other types of researchers and those working outside of academia. Future research examining the views and experiences of researchers from a broad spectrum of environments and foci would be of interest. Finally, few participants engaged in the member checking exercise and greater participation would have provided stronger assurance that the findings accurately reflected their perceptions.

Conclusion

The current pressure to be involved in interdisciplinary research has created a scenario where interdisciplinarity is viewed with mixed emotions. Dalke et al [23] remind us that "interdisciplinarity is not a place to be reached" but evolves as process of working where one is open towards seeing the world in different ways. They see interdisciplinarity as a "freeing" process that liberates one from feeling that one "must know it all" [23]. Unfortunately, the pressured funding climate and sometimes one-dimensional approach towards promotion in academia, has created an atmosphere that has made involvement in interdisciplinary research less desirable, particularly early in one's career. By documenting actual struggles and possible remedies, this study provides a place from which the development of an organizing framework for the successful conduct of interdisciplinary health research is possible. A focus on relationship building is one path that can facilitate a positive interdisciplinary experience.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

KMN and LD conceived of the study. KMN collected the data. All authors provided input into the data collection and analysis stages of the study. KMN drafted the manuscript and all authors read and approved the final manuscript.

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Towards Evaluation of Interdisciplinary Health Research: The Development of the

Framework for Interdisciplinary Research Assessment (FIRA)

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ABSTRACT

Health research conducted by an interdisciplinary team has become a prevalent model of

research activity. Despite this, few research teams or funders articulate how the

interdisciplinary component of a research study could be evaluated. The purpose of this

study was to develop an assessment framework that could be used to evaluate

interdisciplinary health research. This study involved two components: 1) a scoping

review of literature related to interdisciplinary evaluation, and 2) key informant

interviews with health researchers to determine their experience with and perception of

how interdisciplinarity could be measured. Findings from each study component were

brought together to develop the Framework for Interdisciplinary Research Assessment

(FIRA). The literature revealed limited empirical work related to interdisciplinary

evaluation; however, a detailed list of issues and possible metrics for evaluation was

compiled. Nineteen researchers were interviewed for the qualitative component. None

had formally evaluated the interdisciplinary aspect of their research, although three had

completed reflexive exercises related to their experience of being involved in

interdisciplinary health research. Participants identified characteristics common to the

structure-process-outcome framework of quality as a possible way to conceptualize

interdisciplinary health research evaluation. The literature examined was also concordant

with the elements of this quality framework, and elements from 2 general research impact

frameworks were integrated with the quality framework to form the FIRA. This

framework holds promise for moving the discourse of evaluation forward as it offers a

comprehensive overview of the types of factors and elements that require assessment and

monitoring to determine if interdisciplinarity has been achieved.

INTRODUCTION

Interdisciplinary research has become a predominant research model within the health sciences and is viewed as a foundation for innovation and problem solving. Interdisciplinary research involves multiple, distinct disciplines working collaboratively on a shared research question. In the health sciences, this characteristically entails complex, multi-faceted research questions that single disciplines have not been able to adequately answer on their own. Funding agencies such as the Canadian Institutes of Health Research (CIHR),[1] the National Institutes of Health (NIH),[2] and others[3] have documented interdisciplinarity as an important research agenda. Recently, evaluation of this paradigm has generated interest and debate as it is unclear what constitutes successful interdisciplinary research and how to measure and evaluate its impact.[1;4]

In 2006, a special issue of *Research Evaluation* was devoted to the assessment of interdisciplinary research.[4] Interestingly, a large part of current knowledge about evaluation of interdisciplinarity has come from research involving grant review panelists and attempts to understand their decision-making processes and criteria used for evaluation of grants.[5-7] A 2006 meeting of the American Association for the Advancement of Sciences focused on "what constitutes quality interdisciplinary work" and "what assessment processes are most appropriate to discern the quality of interdisciplinary work".[7] This meeting highlighted the need to acknowledge individual disciplinary standards, the establishment of conditions for "good work", and the need for

processes that effectively synthesize knowledge from the contributing disciplines.[7] Social network analysis (SNA) was suggested as a promising methodology to examine "conditions for quality interdisciplinary work".[7] A more recent issue of the American Journal of Preventive Medicine in August 2008 focused on the "*science of team science*" and a number of articles sought to delineate appropriate outcome measures. Unfortunately, most of the literature to date lacks empirical evidence, is not based on a cohesive framework, and is largely descriptive in nature.[8]

The momentum for documenting evaluation criteria and impacts related to interdisciplinarity has led to much discussion about the inherent challenges associated with evaluation. This includes the lack of definitive standards regarding what constitutes a discipline, varying evaluative standards for each discipline, and challenges of clearly articulating what reflects new knowledge development and use.[9;10] However, despite these anticipated difficulties, the push for interdisciplinary research by funders, as well as the ever-increasing acceptance by health researchers of this paradigm, suggests that there is urgent need for metrics for evaluating interdisciplinary health research.

The primary aim of this study was to develop a framework that could be used to guide the evaluation of interdisciplinary health research. As this was a new area of inquiry multiple methods were employed to elicit this information: a) a scoping review of the literature was conducted, and b) qualitative interviews were held with researchers

engaged in interdisciplinary health research. Both sources of information were used to

inform the development of the framework. Given the complexity of conducting

interdisciplinary research, the resultant framework will be useful for advancing our

knowledge of the merits of interdisciplinarity.

METHODS

Study Design

This study involved two components: 1) a scoping review; and 2) a qualitative study to explore the views of health researchers towards evaluation of interdisciplinary (ID) research. The methods for the qualitative component have been described elsewhere but will be summarized briefly below.[9] Once each study component was completed, the results were integrated to develop the Framework for Interdisciplinary Research Assessment (FIRA). This study received ethics approval from the St. Joseph's Healthcare Hamilton Research Ethics Board in Hamilton, Ontario, Canada (#06-2689).

Literature Review

The following key words were used to search both bibliographic databases (MEDLINE, CINAHL, EMBASE, Social Science Citation Index; Science Citation Index; ABI Inform, ERIC, PsychInfo, Inspec, and Library and Information Science; Library, Information Science, and Technology Abstracts) and grey literature: interdisciplinary; interdisciplinarity; evaluation; assessment; framework; impact; measure; outcome. The terms multidisciplinary, multidisciplinarity, transdisciplinary, and transdisciplinarity were also included in the search strategies as it was recognized that there might be relevant literature from these related areas. Personal files of the investigator team were also reviewed for potential articles. A health services research librarian was consulted to help

refine the search strategy and search terms. The primary inclusion criterion was that the citation had to involve evaluation of inter/multi/trans disciplinary research. Only English language articles were included. All steps of the review were completed by the principal investigator.

Qualitative Component

Sampling

Participants came from varied disciplinary backgrounds though all were involved in health research in some capacity and each had an academic appointment at a university.

Data Collection and Analysis

One investigator (KN) completed all interviews using a semi-structured interview guide that was modified throughout the data collection process to accommodate emerging themes. This investigator was a PhD student who had had extensive experience working with ID research teams. She engaged in a process of assumption checking to minimize personal perceptions from impacting the analysis process. The interviews included questions related to experiences in conducting interdisciplinary research,[9] as well as thoughts and perceptions regarding evaluation of interdisciplinarity, with this latter focus contributing to the present paper. Data collection continued until emerging themes

reached saturation and a repetition of information was evident.[11] Participants received a $25 gift certificate for taking part in the interview.

Analysis took place as soon as data collection began, using a content analysis approach.[12] An initial process of immersion/crystallization occurred that involved prolonged engagement with each transcript.[13] Crabtree sees immersion/crystallization as an approach to identify patterns in the data. [13] Key statements and quotes were highlighted and grouped together in an attempt to document patterns and gaps in the analytic picture. Finally, like statements were coded together to form themes. The data were organized using QSR NVivo (version 2).

RESULTS

LITERATURE REVIEW FINDINGS

The literature review yielded 1544 citations from the bibliographic databases. After reviewing these titles, 210 abstracts were included for review. Eighty-four full articles were retrieved and reviewed. Of these, 32 were included in the review. The grey literature was accessed and personal files were searched to find relevant information about general health research evaluation tools and frameworks, and this resulted in an additional 15 citations. The total number of included articles was 47. Tables summarizing study characteristics of included articles and the reasons for exclusion are available from the authors upon request.

An assessment of study quality was not undertaken given the disparity in types of articles found (i.e. many were descriptive in nature and therefore not amenable to application of existing quality tools).

The majority of articles did not focus predominantly on interdisciplinary evaluation. Most citations described possible evaluative measures but did not provide any empirical evidence of use of these measures. As such, it was evident that a descriptive summary of the key considerations when evaluating ID research, as well as a summary of the main types of evaluative measures, was a more reasonable focus for this review. The

results that follow focus on the evaluation issues raised and possible evaluation measures that were described in the literature.

Evaluation of interdisciplinarity: What is success and how do we measure this?

There were no formal evaluation frameworks in the health sciences that exclusively evaluated interdisciplinary success. However, the literature provided a list of key evaluation considerations that should inform any evaluation activity: 1) meaning of quality; 2) coaching and reflection; 3) examination of communication and interaction patterns; and 4) knowledge integration and synthesis (see Table 1). Together, these 4 issues suggest possible areas of evaluation when considering ID in a research study. Figure 1 is a visual schematic that depicts the connectedness of the 4 issues found in the literature and has been termed the interdisciplinarity evaluation triangle.

The literature also highlighted the need for a comprehensive evaluation approach given the intersection of multiple disciplines tackling a complex scientific problem.[14;15] Gordon[16] postulated 3 criteria for evaluation of integrative scholarship: 1) are new questions raised that challenge status quo?; 2) is the problem examined in a broad manner that addresses its complexity?; and 3) does the work make connections across diverse fields. Porter et al[17] have suggested factors necessary for successful interdisciplinary research: 1) intellectual, 2) infrastructure, and 3) research process factors. Their work reinforces the idea that both broad contextual factors (such as funding and institutional

support), as well as interpersonal and epistemological factors (e.g. leadership, team size, range of knowledge to be integrated, etc) must be considered when evaluating interdisciplinary research success.[17] Overall, there were 4 types of evaluative measures described in the literature: A) descriptive measures; B) survey; C) bibliometrics; and D) social network analysis (SNA).

A. Using descriptive methods to document interdisciplinary success

One common method for documenting interdisciplinary success was through descriptive and qualitative research studies. Slatin et al[18] described lessons learned from an ongoing interdisciplinary study focused on understanding occupational health disparities of workers in health care. They pointed out the need for establishing conflict resolution measures and communication systems that will meet the team's needs.[18] They also noted the importance of publications as a metric for assessing interdisciplinarity, and held meetings with their complete research team to develop study protocols, including authorship guidelines. In Baker et al's work,[19] they suggest that evaluation should involve both proximal and ultimate outcomes. This emphasizes the idea that evaluation of ID should be multifaceted to account for the complexity in ID research. The literature was also instrumental in documenting the institutional barriers to interdisciplinarity and the need for a clear delineation of roles,[7;10] expected contribution,[7] and authorship guidelines[18] at the onset of the study.

B. Surveys and other quantitative approaches

A few studies employed the use of surveys to assess outcomes related to the formation of interdisciplinary research teams. Typically, these studies related to educational coursework and both process[20] and outcome[21-23] variables were evaluated. In one study of students engaged in a year-long interdisciplinary project, synergistic knowledge development (SKD) was assessed through a pre-post survey designed for the study.[23] Results indicated a significant increase in SKD.[23] Other studies found a positive impact on knowledge and attitudes towards ID work,[22] and an increase in knowledge gains from other disciplines compared with their own.[21]

Braimoh and Craswell[24] utilized multidimensional scaling to assess water science programs and found low levels of integration between disciplinary clusters, suggesting that strong disciplinary roots can negatively impact the uptake of ID.

C. Bibliometric Methods

The most frequently cited form of evaluation for interdisciplinarity relied on bibliometric methods, with a focus on impacts related to knowledge transfer between disciplines. Bibliometry allows one to see the influence of a particular paper, journal, researcher, or institution on other disciplines, most commonly through citation analysis. Research by Rinia et al[25] has advanced understanding of the levels and types of measurement items best suited towards evaluation of interdisciplinarity in the sciences.

The work of van Raan and colleagues has sought to assess the scientific basis for interdisciplinarity using bibliometric methods.[26] They are strong proponents that advanced bibliometrics combined with peer review is the most formidable way to assess research performance.

Degree of interdisciplinarity has also been examined within the context of specific disciplines.[27-29] In one study, researchers used co-classification analysis to quantitatively assess level and strength of interdisciplinary relationships between fields.[28] In another study, degree of interdisciplinarity was determined and a typology of disciplines and research areas was delineated within science.[30] Others have examined "how interdisciplinary" a researcher is and have noted 2 measures, integration and specialization, that have impacted degree of interdisciplinarity.[31] Carayol and Thuc Uyen[32] completed a study that assessed factors that affect engagement in ID by a cohort of over 900 researchers at one university. They found that factors associated with the researcher's laboratory (size, age, affiliations) were related to more ID work.[32] Qin et al found that collaboration was highly correlated with interdisciplinarity.[33]

There was a large number of articles related to bibliometrics or citation analysis that focused on the multi- or interdisciplinarity of various journals[34-36] or how interdisciplinarity could be measured across or within particular disciplines or fields of research[28;29;35;37-40] as a means of understanding the presence of interdisciplinarity.

Citation analysis has been used to study communication flows between journals as a means for understanding knowledge diffusion.[41]

D. Social Network Analysis

Another method for evaluating interdisciplinarity described in the literature was social network analysis. Social network analysis (SNA) has its roots in sociology, business, and mathematics and has become used more frequently in health research during the last decade.[42;43] SNA is a quantitative data analysis strategy that seeks to map and measure relationships between people, groups, organizations, or other entities.[44;45]

There has been some promising research about interdisciplinarity using SNA. In 2003, Rhoten of the Hybrid Vigor Institute examined the social and technical conditions for interdisciplinary collaboration in research centres funded by the National Science Foundation by employing social network analysis and ethnographic techniques.[46] They found diversity in how interdisciplinary was manifested, and that researchers were initiating and creating opportunities for interdisciplinary work both within and outside of their research centers.[46] Haythornthwaite[47] examined knowledge exchange in ID collaborations and found that learning from one another is a key aspect of what fuels ID relationships.

Malin & Carley[48] looked at how editorial boards integrate researchers from different backgrounds, with a specific focus on the intersection between bioinformatics and medical informatics groups. They found an increase in information exposure over time between each of the fields.[48] SNA research has also studied communication patterns in primary care practices and results showed distinct differences between practices.[49] SNA has been used to examine the structure of multidisciplinary long-term care teams and findings indicate that decision-making by allied health care professionals was increasing but that this was limited to specific groups.[50] Finally, SNA is also being utilized to assist in forming collaborative teams in organizations,[51] and could be used similarly in interdisciplinary research team formation.

Assessing the impacts of interdisciplinarity – Drawing from general health research evaluation

The grey literature was examined for general health research evaluation frameworks to better understand the types of criteria and frameworks currently being used by funders and evaluators. Three frameworks were found: 1) Research Impact Framework; 2) Payback Framework; and 3) Donabedian's Quality Framework. The *Research Impact Framework* includes 4 areas of impact: 1) research-related, 2) policy, 3) service (health and sectoral), and 4) societal impacts and was developed from a literature review and analysis of projects funded at the London School of Hygiene and Tropical Medicine.[52] Use of this framework suggests that it can be used to prompt researchers to talk about key areas of impact.[53]

The *Payback Framework* also provides a multi-dimensional categorization of potential benefits of health research. This model includes 5 categories for evaluation: 1) knowledge production; 2) research targeting and capacity building; 3) informing policy and product development; 4) health and health sector benefits; and 5) broader economic benefits.[54] A comprehensive modified version of this framework was used in a multiple case study of 16 research studies from the funding initiative, the Arthritis Research Campaign.[55] This study found a wide range of outputs and outcomes beyond publications, and that short project grants were good value for money.[55]

Donabedian's *Structure, Process, Outcome (SPO) model* was originally developed to assess healthcare quality;[56] however, it can be modified to examine interdisciplinarity. Structure refers to the *attributes of the system* in which research occurs. Process indicators reflect *what is done* in conducting interdisciplinary research. Outcomes represent *the impact of interdisciplinary research on researchers* as well as the *impacts of their research on health and health policy.*[56] In later work, Donabedian discusses the contextual and operational factors that influence effectiveness, and leadership was noted as a key contextual factor to consider.[57] This model shares some features suggested by Porter et al[17] for interdisciplinary success; that structural and process factors are important to consider.

Qualitative Component: During the qualitative data analysis process, it became evident that the types of evaluative properties that participants were describing mapped well onto the SPO framework and the definitions developed by Donabedian[56] for evaluating quality of health care were modified to reflect evaluation of interdisciplinary research (as noted above).

QUALITATIVE INTERVIEW RESULTS

Experience with evaluating interdisciplinary health research

None of the participants interviewed had formally evaluated interdisciplinarity in a research team that they had participated on, although everyone indicated that there could be value in this activity. Three participants had written about and published reflexive accounts related to the conduct of interdisciplinary research.

Structure-Process-Outcome as an organizing framework for interdisciplinary evaluation

The Structure-Process-Outcome (SPO) framework[57] reflected the various layers of evaluation and measurement that participants felt would be necessary for comprehensively evaluating interdisciplinary health research. Table 2 summarizes the key evaluative areas of interdisciplinary health research raised in the interviews.

Structure: Structure can serve as a gauge of how well an organization or institution is set up to foster interdisciplinary research. Assessing structural factors can provide important

contextual information about the influences of interdisciplinary success. There were 3 main attributes of structure described: 1) institutional culture; 2) funding; and 3) communication infrastructure.

Process: By far, this was the area that most participants were able to offer concrete input, as they felt that these indicators were measurable and attainable. These process indicators typically related to how the research team was organized and how roles were delineated: 1) team formation; 2) leadership; and 3) knowledge sharing.

Outcomes: In many ways, participants felt that if the process indicators (i.e. team dynamics component) were attended to, this naturally could lead to a positive influence on outcomes of interest (publications, policy changes, etc). Interdisciplinary health research outcomes were conceptualized in 2 ways: 1) impact on researchers, and 2) impact on health and health policy.

Framework for Interdisciplinary Research Assessment (FIRA)

The main purpose of this study was to articulate a framework that could be used to guide the evaluation of interdisciplinary health research. The qualitative component of this study examined health researchers' experiences and views of evaluation of ID health research and responses were classified into three categories: structure, process, and outcome. This work, coupled with extant literature about different methods for evaluating

interdisciplinarity, has resulted in the Framework for Interdisciplinary Research

Assessment (FIRA). We have used the literature to support the analytic framework that

emerged from the interviews. Both the Payback Model and Research Impact Framework

contained elements that were described in the literature review and in the interviews. In

looking at the Payback Model, knowledge production was noted in our literature review,

and knowledge production, informing policy, and health and health sector benefits were

seen in the qualitative interviews. From the Research Impact Framework, research-related

impacts were key elements described both in the literature and in the interviews, and

policy impacts were raised by interview participants.

In developing our Framework for Interdisciplinary Research Assessment, we have

conceptualized Structure, Process, and Outcome as 3 layers of possible evaluation and

within each of these layers have denoted indicators related to "Research Conduct" and

"Knowledge Production". Research conduct reflects the opportunity for and development

of interdisciplinarity and includes factors such as team formation; communication; and

role clarification.[53] Knowledge production examines whether new knowledge was

generated and includes number of publications and citations, and research methods

used.[55]

As described in Table 3, each category contains descriptions of factors associated

with interdisciplinary research success. We expect that the FIRA could be used by

research teams to assess if and how well interdisciplinarity is achieved. This framework presumes that evaluation activities will take various forms and will take place from study inception to publication. Although a number of the factors within this framework could be used by single disciplinary teams, the literature used as a basis for this framework has been rooted in ID work affirming its use by these types of research teams.

DISCUSSION

This study sought to develop a literature-informed, researcher-based framework for evaluation of interdisciplinary health research. The literature review produced findings convergent with the qualitative study whereby research conduct and knowledge production were commonly described as important evaluative areas for interdisciplinary research. The literature also highlighted the merits of reflexivity[58;59] and bibliometrics[25;41;60] as data collection methods for use in the evaluation of interdisciplinarity. The evaluation markers suggested by study participants were categorized into the structure-process-outcome framework proposed by Donabedian a number of decades ago.[56] Although Donabedian's framework was originally developed to examine the quality of health care delivery, it aligned nicely as a framework for assessing the quality of interdisciplinary research.

The Framework for Interdisciplinary Research Assessment provides a well grounded overview of the indicators and areas for assessment in an interdisciplinary team. Previous work has acknowledged the complexity of interdisciplinary evaluation and has suggested that multiple methods and levels need to be examined.[2;61] It is clear that FIRA provides some needed direction in this realm; however, greater specificity in terms of particular tools and evaluative measures would be helpful. It is acknowledged that teams will need to tailor the foci of evaluation to their individual teams and choose

measures accordingly, but a reasonable next step would be the articulation of a menu of measures and tools.

What to evaluate and how best to evaluate complex, multifaceted groups, has been debated within circles such as community-based health care networks,[62] policy research networks,[63] and partnerships.[49;64] Dowling et al.[64] examined the literature related to partnerships and categorized success of partnerships on two dimensions: 1) processes and, 2) outcomes. They also found that role clarity and leadership were important processes for consideration, and they too distinguished between outcomes that impact health and health service delivery.[64] Their review found that few studies had focused on outcome measurement. This literature highlights that organizational (or macro) level factors must also be considered along with intra-team factors such as team composition, satisfaction and knowledge sharing. Overall, it is promising that the criteria generated in the present study have been delineated, albeit piecemeal, in other studies.[14;64-66]

Our findings are important as they contribute towards filling a gap in the literature for an area of research that is growing in interest. We are at a juncture where both funders and researchers want evidence that interdisciplinary research works. This study has suggested that it is possible to develop an evaluation framework and that researchers themselves are amenable to some type of evaluation. It is clear that for such a framework to be used in practice, it must be straightforward in its operationalization of components

and in its data collection methods. It is our hope that future work within our group and by others will provide tangible data related to the uptake and application of this framework in practice.

Limitations

First, as many participants had not thought about evaluation of interdisciplinarity, the majority of suggestions provided were hypothetical in nature and it is difficult to know whether busy academics would actually engage in the range of evaluation indicators discussed. As well, although participants were provided with initial findings, they were not given the final proposed evaluation framework to review. Feedback regarding the FIRA from on-the-ground researchers would be an important next step. We recommend the implementation of this framework by health researchers as a means of validation and moving the discourse of interdisciplinary evaluation forward.

Conclusions

The Framework for Interdisciplinary Assessment holds promise as it offers a comprehensive overview of the types of factors and elements that require assessment and monitoring to determine if interdisciplinarity has actually been achieved. This framework is grounded both in interdisciplinary literature and within the perceptions and experiences of current interdisciplinary health researchers, and this reinforces the potential utility of this model.

Table 1: Evaluation issues derived from the literature

Evaluation Issues Raised	Elaboration of Issue (applied to ID research)	Possible Evaluation Methods
Meaning of quality	▪ Successful ID research may be a relative concept that requires a flexible evaluation approach [10;15] ▪ Certain tenets of quality remain regardless of whether research is ID: originality, scientific merit, relevance [7] ▪ Will need to meet standards of quality for each discipline involved [7;10]	▪ Review of study evaluation plan and related documents ▪ Interviews
Coaching and reflection	▪ Researchers should be encouraged to reflect on their involvement in the ID process and whether they are achieving its goals [15] ▪ Reflexivity allows researchers to consider possibilities and new knowledge beyond their own disciplinary boundaries [67;68]	▪ Examination of reflective exercises ▪ Interviews/Focus groups
Examination of communication and interaction patterns	▪ Understanding the frequency and type of communication between research team members can provide insight regarding emergence of new knowledge [10] ▪ Type of exchanges between researchers is important to delineate (i.e. factual knowledge; learning how to do something; learning about new methods; access to contacts, etc). [47]	▪ Social network analysis ▪ Document review (i.e. meeting minutes) ▪ Interviews/Focus groups
Knowledge integration and synthesis	▪ At the onset of a study, researchers should consider what integration looks like and how they will know that this has been achieved [10;15] ▪ Synthesis provides broad foundation for conducting research as well as understanding its impact [7] ▪ Main focus is knowledge creation as a process versus examination of outcomes [69]	▪ Survey ▪ Bibliometric/citation analysis

Table 2: Structure-Process-Outcome Evaluation Framework as applied to interdisciplinary health research

| Donabedian (1988) definition of quality	Components for evaluating interdisciplinary health research & representative quotes
Structure Attributes of setting in which care occurs	*Attributes of a setting in which research occurs* • Institutional culture 　*There's a funny lingering problem about authorship…I know of one particular individual who left an interdisciplinary study because her career requirements were that she had to publish solo papers. And if any of these papers came out of this particular study, if she was going to spend time on them, she would want to get credit for them. But she wouldn't get credit because they would always be co-authored. So there was no point in her spending time and energy on them … she couldn't participate and that's crazy. [Int15-43]* • Funding 　*Funding is a big barrier, because in interdisciplinary things you can always find somebody who doesn't know enough about another area. And often sometimes their lack of knowledge is expressed in inappropriate reviews or comments. Second, interdisciplinary research often is only worth it in very large studies, so there's a sticker shock, there's high costs, or they are relatively high in costs. So funding and peer review are major barriers. [Int19-41]* • Communication infrastructure 　*So we know that communication is important…and make sure that the way that you communicate is appropriate to your members. If your members want to go for a cup of tea at 4:00 every Tuesday then you build that in and that's your way of communicating with the team. If your group wants to receive monthly newsletters, let's do that. And probably the bottom line is that you need to do a combination of different things but I think that communication is really, really quite critical.[Int11-33]*
Process What is actually done in giving and receiving care	*What is done in conducting interdisciplinary research* • Team formation 　*So I guess an evaluation of interdisciplinary or multidisciplinary or transdisciplinary team would have to have the researchers say, 'was this worth the effort'. People on the outside world really believe that in the academy there's an opportunity to have great debates, interesting discussions and advance your thinking, and it's a crock, it doesn't happen unless you create those opportunities. So sometimes you hang in with the team just cause one hour a week you get to sit down with colleagues and talk about your passion, whatever that passion is. That's pretty powerful stuff, it's like going to therapy, it's intellectual therapy. So you would move anything else in your calendar but not your research team meeting. [Int9-27]* • Leadership

Donabedian (1988) definition of quality	Components for evaluating interdisciplinary health research & representative quotes
	... the process matters are important you know, the leadership is important and I think we tend to forget about those by being fixated on the outcomes. [Int8-67]- • Knowledge sharing *Well I guess one way to think about it would be, when I think of some of the recent projects, one would be whether people have used theories to inform their research and if so from which disciplines they come from. Because theories tend to be very much an attribute of discipline. .. And I think we are quite able to articulate how the theory informed, whether it be the over-arching framework, whether it informed approach to sampling, whether it informed the interview guide, whether it informed the analytical template for the analysis of the data, all of that can be specified. [Int7-23]*
Outcome Effects of care on health status of patients and populations	*Impacts of interdisciplinary research on researchers* • Satisfaction with team *I think a more intangible [measure] would be a good team experience where you want to work with the people again, you want to repeat it and which comes to one of my prime criteria for doing any kind of research, it's got to be, it's got to be fun. It's got to, by fun I mean, you've got to go to the meetings, you <u>want</u> to go to the meetings that the team calls, you want to do the research. You feel whatever the outcome in some way, you're going to get a good experience.,[Int8-21]* • Satisfaction with research & research productivity *I was just thinking what would be a real interdisciplinary coup for publication; I guess a real challenging thing would be if you were able to, pick one discipline, if a paper or perspective from one discipline were able to publish in another discipline's journal; sort of a cross fertilization because then you could be sure something was being learned and something was being changed. [Int10-35]* *Impacts of interdisciplinary research on health and health policy* • Improved health *And we take some of the high impact papers and we track citations. And we track them in our field; if we do trials, we see if our trials are replicated by other people with the same findings. ... So[then] you know [if] your study had an impact.... [Int19-35]* • Change in health policy *...what data we collected from the clinicians, that influenced the way that the research went, it influenced the findings and the recommendations. [Int12-47]*

Table 3: Framework for Interdisciplinary Research Assessment: Key elements and associated indicators related to interdisciplinary success

	Research conduct: opportunity for and development of interdisciplinarity		*Knowledge production:* new knowledge shared or generated; research methods used; # of publications and citations	
	Element	**Indicator**	**Element**	**Indicator**
Structure	Funding	▪ Funding exists for interdisciplinary research ▪ Funding requirements specify what is meant by interdisciplinarity	Institutional support	▪ Departments recognize co-authorship of publications in the tenure/promotion process
	Proximity	▪ Team is situated in a manner that fosters ID work		
Process	Team composition	▪ All team members are aware of their role and expected contribution	Leadership to foster knowledge sharing	▪ Opportunities for exposure to new theories, methods
	Communication Reflexivity	▪ Regular communication between team members ▪ Reflexive thinking encouraged and discussed between members	Leadership to foster knowledge production	▪ Authorship guidelines delineated
Outcome	Satisfaction with team	▪ Team members	Productivity	▪ # of publications,

	Research conduct: *opportunity for and development of interdisciplinarity*		Knowledge production: *new knowledge shared or generated; research methods used; # of publications and citations*	
	Element	**Indicator**	**Element**	**Indicator**
		want to work with each other again		presentations, etc ▪ Composition of disciplines on each paper, presentation ▪ Citations
			Impacts	▪ Impact on health ▪ Impact on policy change

Figure 1: Interdisciplinarity Evaluation Triangle
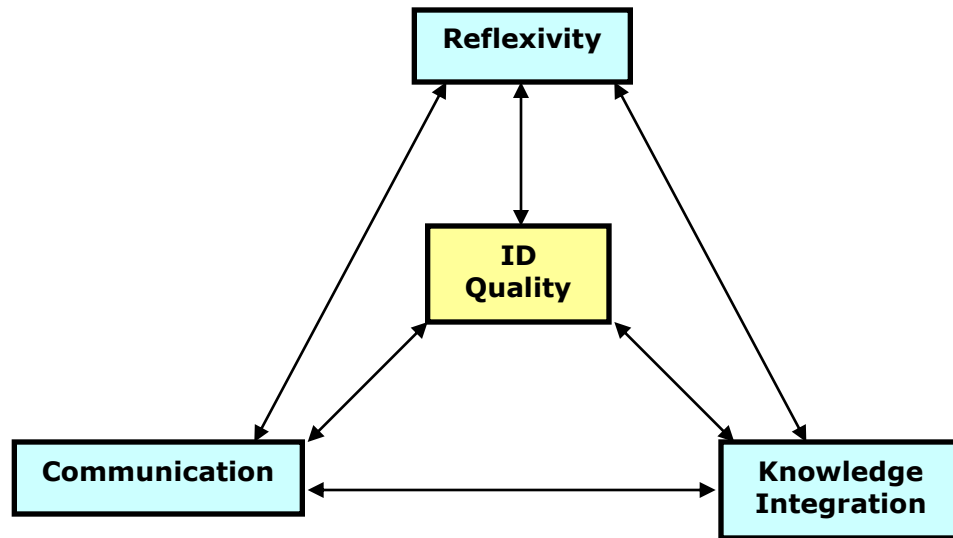
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Evaluating interdisciplinary health research:

Implementing the Framework for Interdisciplinary Research Assessment

(FIRA)

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ABSTRACT

Introduction: The use of interdisciplinary (ID) teams of investigators in health research has become expected and customary when exploring complex research questions that can't be answered by one discipline alone. However, the "added value" that ID brings to research and how to properly evaluate this aspect of research in practice has not been fully explored. The main purpose of this study was to understand and evaluate the application of a framework designed to capture indicators of interdisciplinary health research, the Framework for Interdisciplinary Research Assessment (FIRA).

Methods: This study utilized a concurrent triangulation mixed methods design. Participants completed individual qualitative interviews as well as a survey, the Partnership Self-Assessment Tool – Interdisciplinarity (PSAT-I).

Results: Two interdisciplinary teams were studied. Qualitative findings suggest that both teams' members were situated at institutions that supported ID research; though, neither consciously implemented processes to capture the ID benefits of their work. Most respondents noted learning something new as a result of team membership and expected a larger diversity of productivity measures due to the ID nature of their team. The survey results affirmed participant satisfaction on their team and that most had acquired knowledge about research methods, theories, or content from other disciplines. Some participants felt underutilized in their teams. In both teams, participants questioned the value of considering discipline over knowledge and skills when forming ID research teams and some

noted a lack of explicit attention to fostering interdisciplinarity within their research team.

Discussion: The elements of the FIRA model were able to be mapped through the interviews and the PSAT-I survey suggesting that this model has utility for ID health research teams. Interdisciplinarity adds value to a health research team through learning and knowledge sharing and increased academic productivity measures, contributing towards moving science forward faster.

INTRODUCTION

The use of interdisciplinary (ID) teams of investigators in health research has become expected and customary when exploring complex research questions. Funders have fostered this trend through the creation of specific requirements in grants. For example, in Canada, the Canadian Institutes of Health Research (CIHR) developed the Interdisciplinary Capacity Enhancement Grant (ICE) to bring together teams of new and established health researchers within a transdisciplinary environment.[1] Additionally, the Natural Sciences and Engineering Research Council of Canada (NSERC) created guidelines for grant submissions and review related to interdisciplinary research.[2] Their website explicitly states that they support research "that occurs at the interface between disciplines or that requires the skills of several disciplines" and that their "programs, policies and procedures are designed to break down barriers against interdisciplinary research".[2] Furthermore, academic institutions increasingly have established interdisciplinary departments or programs with the understanding that the next generation of graduates and scholars should be capable of functioning and contributing towards knowledge generation outside of disciplinary silos. Programs such as Art History, Health Policy, or Health Geography have arisen as a result of emerging knowledge areas that require input from more than one disciplinary area. Interprofessional curricula have been developed in the health sciences whereby clinicians from different disciplines (e.g. nurses and physicians)

participate in joint learning in an attempt to simulate real-world interprofessional team experiences.

It is clear that interdisciplinarity as a concept has been embraced by the academe. What still remains unsubstantiated, however, is the "added value" that ID brings to research and how to properly assess this component of research in practice. The ID component of research tends not to be examined and when it is, is often an ad hoc activity with little forethought given by funders and researchers themselves.[3]

Our own research has found that few researchers evaluate the interdisciplinary aspect of their research but would consider doing so if given appropriate tools and guidance as a mechanism to increase their awareness of their involvement in the research process.[3] The Framework for Interdisciplinary Research Assessment (FIRA) was developed from an examination of the literature combined with qualitative interviews with health researchers engaged in interdisciplinary research.[3] This comprehensive framework of evaluation is focussed on measurement of indicators related to structure, process and outcome evaluation that need to be in place to support the actualization of interdisciplinarity. Indicators of impact are specifically highlighted for 2 broad areas: 1) research conduct and, 2) knowledge production at 3 different levels

(structure, process, and outcome), and possible methods for measuring each indicator are suggested.

Table 1 builds on the original FIRA model[3] by providing information about the evaluation strategies used in this study. This framework acknowledges that *structural* elements are needed to create an environment conducive towards the conduct of ID research (i.e. through adequate funding and institutional support) to harness its benefits. *Process* elements related to research conduct include team members who are aware of their role and expected contribution, and having mechanisms in place to foster communication and reflexivity. Knowledge production is dependent on having leadership to foster knowledge sharing and creation. Finally, *outcomes* related to team satisfaction, productivity measures, and impacts on health and health policy can be tracked to help establish whether the benefits of ID have been maximized.

Moving forward, it will be important to determine whether implementation of this framework is feasible by health researchers and evaluators engaged in interdisciplinary research. The proposed study will build upon the foundational work that has already been completed by our group[3;4] by assessing the implementation of this framework. The main objective of this study was to validate the Framework for Interdisciplinary Research Assessment in a real-world setting. This study contributes valuable programmatic and methodologic

knowledge that is applicable to a wide range of health research conducted in

Canada and beyond. Within this study, interdisciplinary research is defined as

research that includes at least 2 disciplines, with researchers engaged in a program

of research that consists of multiple, connected research studies.

METHODS

Study Purpose & Research Questions

The main purpose of this study was to understand and evaluate the application of a framework designed to assess the impacts of interdisciplinary health research (FIRA). There were 2 research questions addressed in this study:

1. How is interdisciplinarity operationalized by researchers working in interdisciplinary health research teams?

2. What indicators of interdisciplinary research are described and monitored by interdisciplinary health researchers?

Design

This study utilized a concurrent triangulation mixed methods design.[5] Mixed methods designs have become recognized as a suitable route for examining questions that utilize both quantitative and qualitative data collection strategies. In the concurrent triangulation mixed methods design, both quantitative and qualitative data are collected at the same time with neither taking precedence.[5] The concurrent triangulation approach is the most commonly used mixed methods design[6] and its purpose is to corroborate findings within one study.[5] This design maximizes the strengths of both quantitative and qualitative approaches by providing unique and complementary findings.[6]

This study utilized a convergence approach, which is the most common type of triangulation mixed methods.[6] Each type of data is collected and analyzed separately and they are brought together at the interpretation stage.[6] In this model, quantitative and qualitative data are compared and each data type is validated by the other.[6] While an efficient and instinctive design, challenges can occur if sample sizes are different for each data collection type or if results do not converge.[6] In this study, sample sizes where the same for both qualitative and quantitative phases and a matrix, a conventional step, was used to compare findings from each type of data.[6]

Participants

We invited Principal Investigators (PIs) from a large Canadian university who headed nationally funded programs of research to take part in this study. The CIHR Funding Database was used to identify these PIs. Only programs that included a specific mandate related to interdisciplinarity (e.g. team grants such as New Emerging Team (NET) or ICE) were invited to take part.

Data collection

Qualitative

Semi-structured interviews with a variety of research team members were conducted. The PI from each of the programs, co-investigators, program staff (including research coordinators and research assistants), and trainees were

invited to take part in an interview. Interviews were scheduled to be

approximately 30-60 minutes in length and were completed by one investigator

(KN) to ensure consistency in data collection. The interviews were based on a

semi-structured interview guide that included questions related to the two facets

of research impact being explored (research conduct and knowledge production).

Specific questions about how interdisciplinarity had been operationalized and

what impacts were monitored were also discussed. The research proposals used to

seek funding were examined for each of the cases to determine how

interdisciplinarity was delineated and what evaluation measures were in place.

Study publications were also looked at to document the disciplinary composition

of the author team and type of journals that articles were published in (i.e.

whether these were interdisciplinary or disciplinary journals).

Quantitative

Research team members were also asked to complete the Partnership Self-

Assessment Tool-Interdisciplinarity (PSAT-I). The PSAT-I is a modified version

of the PSAT (Partnership Self-Assessment Tool, PSAT)[7;8] that was developed to

assesses factors known to influence synergy (leadership, efficiency,

administration and management, and sufficiency of resources), as well as

satisfaction with the partnership.[8;9] Synergy reflects the "breakthrough in thinking

and action" that results from successful culmination of knowledge, skills, and

resources[7] and in many ways is a concept similar to interdisciplinarity. This self-

report tool provides an overall synergy score that indicates "the extent to which the participants in your partnership are accomplishing more together than they can on their own"[10] as well as subscale scores for each of 9 areas that contribute towards synergy. These 9 areas include: 1) Leadership; 2) Efficiency; 3) Administration and Management; 4) Non-Financial Resources; 5) Financial and Other Capital Resources; 6) Decision-Making; 7) Benefits; 8) Drawbacks; and 9) Satisfaction. Some subscales consist of items that are rated on a scale (e.g. leadership; decision-making) and others have items where one indicates whether something is present or absent (e.g. benefits; drawbacks).

The PSAT was designed to be used as a guide to identify partnership strengths and weaknesses. The PSAT was originally developed by Lasker and colleagues to examine partnerships between community organizations and has demonstrated sound validity and reliability.[8] Internal consistency for subscales ranged from 0.82 to 0.97 and construct validity showed high correlation (r=0.71, p<0.01) with a measure of collaborative group performance, though principal components analysis demonstrated that synergy was a distinct factor from collaborative group performance.[8] The PSAT-I predominantly has wording changes to language that better reflects interdisciplinarity and the research environment (e.g. 'partnership' has been changed to 'research team').

Prior to use with the present study, the PSAT-I, was tested with 4 health researchers to ensure that wording and flow (i.e. face validity testing) was clear and appropriate. This involved asking each person to indicate what each item meant and looking at consistency of responses from each of the 4 reviewers. Those items where there was difference in opinions regarding meaning were examined and reworded. Overall, there was little difference in perception from each of the reviewers, suggesting that the slight modifications that were made from the PSAT to the PSAT-I resulted in acceptable face validity of this tool.

Analysis

Qualitative

Analysis of interviews involved open coding to generate themes. Verbatim transcripts were generated for each interview by a professional transcriber. One researcher completed the analysis independently. A codebook was created and was modified throughout the analysis process in an iterative process to incorporate emerging themes. A content analysis approach was used.[11;12] During the analysis process, information from each team's research proposal regarding definition and evaluation of interdisciplinarity was extracted and included in the analysis. As well, the number and composition of author discipline was examined for publications and presentations to determine whether these were reflective of interdisciplinarity (i.e. more than 2 disciplines present). This was a component of

the FIRA model and these findings were inserted directly into the model

summary.

Quantitative

The PSAT-I was administered online via Survey Monkey

(www.surveymonkey.com). Descriptive statistics were generated for responses to

the PSAT-I.[9] A mean overall synergy score, and mean scores for factors that

influence synergy (leadership, efficiency, administration and management, and

sufficiency of resources) were generated. All subscales resulted in a mean score

that ranged from 1 to 5, with higher scores reflecting a more positive result.

Frequencies were calculated for all other questions, including benefits and

drawbacks to being on the team. PASW Statistics 18 (SPSS) was used to analyze

this data.

Integration of Findings

Data integration took place by the creation of a 'convergence coding

matrix' whereby findings from each data collection source were compared to

establish whether there was: agreement, partial agreement, silence, or

dissonance.[13] This process allows one to better understand what each data

collection method contributes to the overall analytic picture. Completion of the

matrix involved placing each finding on a row, with agreement ratings in

subsequent columns. An example of this process is provided in Table 2.

Narratives that incorporated information derived from both data sources were created, and organized according to the FIRA. Narratives were presented to the PI of each team for review and any feedback was incorporated into the final analysis. The ultimate goal was to be able to populate each section of the Framework for Interdisciplinary Research Assessment.

This study received Research Ethics Board approval from St. Joseph's Healthcare Hamilton (#07-2905).

RESULTS

Two research teams were examined. Each team was a large, multi-faceted program of research where multiple, related studies were conducted. Demographic characteristics for all participants are provided in Table 3 and team details are described below.

Team 1: In team 1, the principal investigator provided the names of ten possible participants (study co-investigators), representing two studies from the ten studies within the larger grant. Seven agreed to take part. This team was interviewed in the 3rd year of a 5-year grant. Most team members had not previously worked together. This team focussed on a research area whose content had the potential to be emotionally taxing and sensitive. This team included clinicians and social scientists.

Team 2: In team 2, the study research coordinator provided the names of potential participants, and there were twenty-three possible participants within the program of research comprised of six studies. This team was unique in that aside from investigators and research staff, there was a group of field workers who collected data and interacted with the community of interest. Seventeen participants took part in at least one data collection component (interview or survey). Qualitative data was available for thirteen participants (four co-investigators; four field workers; and five research staff), and there was representation for each of the six

studies. The team was interviewed in the second year of a three year grant. Some team members had previously worked together. This team's research was based on work within a specific community and was expected to have significant national, and potentially international, health policy implications. This team included clinicians, epidemiologists, statisticians, as well as students and administrative staff.

Question 1: Operationalization of Interdisciplinarity

In team 1, the research proposal explicitly indicated the value of interdisciplinarity and included objectives related to ID capacity building. For example, it was acknowledged that having an understanding of basic research practices in different disciplines would be important and this would be achieved through regular meetings, seminars, and web-based learning formats. In its first year, a general seminar was given to all team members at its annual meeting related to interdisciplinary health research. In team 2, the value of having multiple disciplines was present in its research proposal, though specific objectives were not construed. There was a general consensus that as long as the research question warranted an ID perspective, this was the best process to use and would lead to advanced learning:

> *... it's[interdisciplinarity] just a really important way to make a team, I really do think that. It's exciting and challenging for me to have people with different perspectives because I learn a lot more that way too. And so it's hard to manage that team a little bit because everyone is thinking differently. But I think again, if you've got a good group who recognizes the value of having people with different ways of looking at things, my*

goodness you accomplish a lot more. I think we are going to discover new things, as frustrating as it is for people that want to keep it single minded. You know, we can go off on a little bit of tangent and discover some totally different that they never even thought of. That's really exciting for me and research, that's the whole point of it for me. (Case 2)

Despite the apparent acknowledgement of the importance of interdisciplinarity in each of these teams, neither team had defined what interdisciplinarity meant for them and how it would be achieved. As well, throughout the interview discussions, it was evident that expertise, experience, and personality were how other team members were considered and there was some sense that discipline was not an appropriate consideration:

I would say that interdisciplinarity may not even be the right way to frame it anymore, it's more, it's more about team work and collaboration and understanding the individuals that are in the team and how they, what they bring to the table. And one of the things they bring to the table is their, their academic expertise, or whatever you call it, then their personality, then their experience… so you have that mix of each person, probably is a more realistic way to think about it then discipline. (Case 1)

Furthermore, there was also the sentiment by some that discipline was too restrictive a conceptualization as discipline itself has become diluted over time:

…I think that day is long gone where you can predict someone's perspective or skill set based on explicit discipline that they have on their diploma. (Case 1)

Disciplinary affiliation had lost its intended meaning given researchers' shifting interests over time and engagement in research that crossed boundaries. A more holistic view was taken of 'who' a researcher was, with discipline being only consideration.

Question 2: Impacts of Interdisciplinarity: Application of FIRA

Table 4 summarizes the main themes that emerged from the qualitative interviews for each component of the FIRA model. Key findings are elaborated below.

Structure

Research Conduct

Both research teams studied were recipients of team grants that were in place for interdisciplinary health research, affirming the notion that funders are interested in ID research. Neither team noted whether there would be specific metrics related to interdisciplinarity that their funder required. Both teams experienced geographic dispersion and generally this was managed through regular phone and electronic communication. In team 2, both the investigators and field worker teams were geographically scattered which contributed to some communication and resource constraints. The administrative support for the field workers was located in a different province, which caused an increased workload for investigators.

Knowledge Production

Overall, participants indicated that there was departmental and even university support at their institutions for interdisciplinary research. Many felt that their departments were inherently interdisciplinary and this type of research would be typical of what they do. None of the participants, including those from

social sciences, felt that they would be penalized for their interdisciplinary work with this team.

Process

Research Conduct

Participants generally had little awareness of the disciplinary backgrounds of their other team members. It was stated that team members were chosen based on the skills and knowledge that they could contribute to the team and this was not necessarily related to disciplinary affiliation. There were a variety of communication mechanisms in place to facilitate information and knowledge sharing, with email and teleconferencing occurring most frequently.

In team 1, some participants voiced concern that there had not been explicitness within the team regarding how interdisciplinarity would be operationalized and assessed. This was a minority view however, with most participants only considering interdisciplinarity as a result of their participation in the interview.

In team 2, both investigator and staff teams had only recently formed and many had not met each other or had not worked together. The investigator team was conceptualized as a "hub and spokes" with the PI as the hub. Most felt that the PI was fairly hands off and they appreciated staff support that was available.

Some expressed feeling that their potential contributions were underutilized and felt that clarifying roles at the beginning of the project would have been helpful. They anticipated increased use of each person later in the project (i.e. analysis and write-up phases). Two investigators who had previously not worked together discussed at length the learning that had been achieved from working with a different discipline and the continuous "assumption checking" they engaged in.

Knowledge Production

In team 1, although there were not any overt opportunities for knowledge sharing, participants did indicate that they had learnt new things. All participants expected, and had experienced, tangible benefits that they attributed to being part of an ID team, including academic measures such as publications and presentations for their CV. In this team, authorship guidelines had been delineated, and there was some sense that being part of this team allowed for exposure to publication possibilities that would not have been otherwise considered. All participants, including junior investigators, felt that they had received appropriate credit for their contributions to publications. Senior researchers saw themselves in a mentoring role to new or more junior investigators and staff.

In team 2, it was evident within the field staff team that there were concrete efforts to foster knowledge sharing, through the implementation of

weekly meetings. The field staff appreciated the regular opportunities to interact with research staff and study investigators and felt that this assisted with timely resolution of issues, although this had been a challenge initially. There was less sharing of knowledge within the investigator team and some voiced wanting more opportunities to keep up-to-date with what was happening within the larger team. Overall, knowledge sharing in the field group and the investigator team was less related to disciplinary knowledge and more focussed on general study issues. However, smaller groups of investigators who worked more closely together had taken initiative themselves to become familiar with what others were doing and how their work and perspective could impact the study. Most investigators were confident of the knowledge products that would result from the study and expected significant policy implications from this work.

Outcome

Research Conduct

Overall all participants expressed satisfaction with their team despite some initial issues related to communication and uncertainty with role. In team 1, participants were pleased to be involved in a study that was national in nature and connecting with researchers that they had not worked with before, particularly more senior researchers who were known in the field and those from other disciplines. There was a sense that collaborative or ID research made one "stronger in terms of your ability to articulate what your own disciplinary

perspective is" and provided more confidence regarding contributions to the team. In team 2, learning and knowledge gains in new content areas were evident for some and this contributed towards increased team satisfaction.

Knowledge Production

Team 1 was actively productive and all members discussed presentations and papers that had resulted through their participation. Overall, there were 6 publications and 16 presentations that had resulted and most had at least 3 disciplines represented. Most were presented at conferences and submitted to journals that were interdisciplinary in nature. Impacts of their research on health and health policy were not explicitly discussed. Participants, however, stated that there was better dissemination of findings due to the variety of disciplines that were on the team and that different disciplinary contributions would lead to a better final product.

In Team 2 participants were confident that the expected productivity outputs would be achieved and a number had already been involved in abstracts and presentations. There had been 2 publications and 6 presentations documented by this team and all involved at least 3 disciplines. It was also anticipated that a variety of publications would be produced based on the disciplinary affiliation and perspective of the various investigators involved. Knowledge transfer back to the communities involved in the study was also discussed by a number of

participants. All participants talked about the potential positive impact that this study could have on health and health policy.

Partnership Self-Assessment Tool - Interdisciplinarity

The PSAT-I took an average of 17 minutes (SD=10; range=7, 59) to complete; however, it should be noted that these figures were derived from data of how long each person kept the electronic survey open. Most participants completed the survey within a week of receiving the request for completion. Results from the PSAT- I found moderate synergy scores for teams 1 and 2 (x=3.7 (0.3) and x=3.9 (0.2), respectively). Synergy is a concept that captures the result of collaborative work and scoring guidelines indicated that means in this range reflected that 'more effort was needed to maximize collaborative potential', which is in keeping with the qualitative findings. Table 5 summarizes the main subscale scores for factors impacting the team`s collaborative process.

Overall, survey results were positively skewed for both teams suggesting that participants were generally satisfied with the research team that they were engaged with. Frequency scores for decision-making were predominantly positively skewed. However, responses for the question about "Feeling left out of the decision-making process" found that 28.6% of team 1 participants and 41.2% of team 2 participants indicated feeling left out 'some', 'most' or 'all of the time' for these categories combined.

Table 6 provides the responses for the benefits and drawbacks items in the PSAT-I. The percentage of participants who indicated 'yes' for each benefit was over 70% for all items, with the exception of 'ability to affect public policy' and 'acquisition of additional financial support' in both teams, and 'use of my expertise or services' in team 2. Notably, 85.7% and 93.8% of participants, respectively, in each team stated that they had acquired useful knowledge about research methods, theories, or content from other disciplines. The majority of participants on both teams experienced the drawback of 'diversion of time and resources away from other priorities' and close to 50% experienced 'frustration or aggravation'. Despite this, in a general item weighing benefits and drawbacks, participants on both teams felt that the 'benefits of team participation exceeded any drawbacks' encountered.

Frequency scores for satisfaction were rated as 'somewhat', 'mostly', or 'completely' satisfied for all items with the exception of 1 participant in team 1 who indicated 'not very satisfied' for 3/5 satisfaction questions. Mean scores were slightly higher for team 1, however standard deviations were also larger and this is not surprising given the low number of respondents in team 1.

Integration of Qualitative and Quantitative Findings

Overall, the Framework for Interdisciplinary Research Assessment was easily populated by both data collection methods and there was convergence

between the qualitative and PSAT-I findings. For example, within both teams there was expression about uncertainty of role or lack of utilization of knowledge by some participants and this was echoed by some moderate scores on the PSAT-I. Higher means for questions related to non-financial resources that are needed for effective work (such as skills and expertise, data and information, legitimacy, and ability to bring people together) were reflected in participants' sense that the research study was progressing well. No one indicated that their study did not have adequate resources for completion. The moderate synergy score seems in keeping with qualitative findings where participants were generally satisfied, however, noted some discontent regarding communication and decision-making.

There were a few core aspects of the FIRA not covered by the PSAT-I: funder specification of what is meant by ID; reflexive thinking; delineation of authorship guidelines; and ID nature of resultant publications and presentations. The interview questions covered all subscale domains of the PSAT-I; however, some areas were addressed in greater depth in the PSAT-I. For example, participants were asked to talk about challenges with team membership, but all areas of the PSAT-I centred on drawbacks were not raised. This suggests that the PSAT-I offers more specificity in some areas than a general discussion would raise. Finally, it should be noted that both team PIs acknowledged receipt of the summary of their team's findings, however neither offered any feedback.

DISCUSSION

This study demonstrated that it was possible to populate the various elements of the Framework for Interdisciplinary Research Assessment through the use of surveys and interviews. The information gleaned from the interviews was almost complete suggesting that regular discussions within a team could be conducted using the elements of the FIRA model as prompts. The PSAT-I was very straightforward to implement and the subscales of synergy, leadership, benefits, and satisfaction seem particularly congruent with the aims of interdisciplinarity. The PSAT-I also offered greater specificity and would be useful for quickly tapping into areas that need further work in a research team.

Despite the emphasis of both teams on conducting ID research, interdisciplinarity was not explicitly operationalized by either team. For some participants, interdisciplinarity was not regarded as a useful way of considering contribution to the team; expertise, experience, and personality were all thought of as more important personal characteristics to assess. This raises the issue of when disciplinary identity comes into play. While the notion of discipline was considered to be diluted by some, it is perhaps more accurate that interdisciplinarity has become experienced as something more encompassing over time. This finding is consistent with earlier work we conducted that found that relational aspects of team dynamics were more important than disciplinary considerations.[4]

Some participants talked about feeling underutilized in their teams. This could have resulted from the lack of overt focus on each person's potential disciplinary contribution and not taking time to ensure that each person was aware of their role on the team and how their perspective could be best employed in project development and implementation. Recent work by Lasker & Guidry examined the flow of ideas within partnerships in an attempt to understand why some people have more influence than others.[14] Their research found that having influence requires a number antecedent steps, that first included having the opportunity to participate and then the ability to express their ideas.[14] Finally, communication of ideas was needed before these ideas could be used.[14] Likewise in ID teams, if an opportunity to fully participate and share knowledge and ideas is not created, there will be little ability for this knowledge to influence the research. PSAT-I results, however, confirmed that most participants had acquired knowledge about research methods, theories, or content from other disciplines.

One explanation for our findings is that ID is important in theory, yet, it does not accurately capture people and what actually takes place. It appears that what has been labelled as interdisciplinarity is more complex than disciplinary affiliation alone and this reflects the lack of mindfulness to this concept by respondents. In this study, an attention to skills, knowledge, role of team, as well as past experiences with ID informed how ID was practised and attended to. As

well, it is possible that one only becomes attuned to ID when it has been experienced in its truest sense – through knowledge sharing that leads to new ways of thinking. In team 2, there was a very clear example of 2 investigators from different disciplines that shared information and reformulated their initial way of thinking to accommodate this new knowledge. Each of these investigators extolled the virtues of ID and spoke of wanting to write about their experiences. It may also be that it is further in the research process (analysis & write-up) that disciplinary contributions become more utilized. This leads one to the broader reflection of whether it is possible to describe or evaluate something that has not been truly experienced. However, through structured application of FIRA to facilitate thinking about ID, teams have the potential to learn about their team and identify ways to exploit the ID advantages intended by team set up.

The literature on collaborative research and community coalitions offers some hope that evaluative measures such as the FIRA model can be implemented. There is a wealth of literature that points to the inclusion of evaluation within a collaborative model. Regularly assessing progress towards collaboration is not unlike measuring progress towards interdisciplinarity and we can draw inferences from the parallels between these paradigms. Evaluation should be purposeful and ongoing in order to properly assess whether success has been achieved.[15-17] Baker et al note that evaluation activities should comprise everyone and the inclusion of research staff within the application of the FIRA model further supports this

notion.[18] The work of LeGris has also suggested that evaluation should include all levels within an organization including staff.[19] Provan[20] has suggested that network effectiveness can and should be evaluated at multiple levels (community, network, and participant) and though their work was centred on public services, it is reasonable to examine ID success at varying levels such as funder, institution, and researcher.

Limitations

There were a number of challenges encountered during the conduct of this study. First, the low response rates, particularly in team 1 was unfortunate as there had been repeated attempts to engage potential participants. This highlights the challenges of implementing additional evaluative measures within health research teams who already feel that they are being stretched. The lack of data for 6 investigators in team 2 meant that the staff and field worker perspective was more prevalent in the analysis, however this proved to be enlightening. As well, while there was only one reviewer of the qualitative data, attempts were made to regularly assess assumptions so that themes were grounded in the emergent data.

Conclusions

This study makes a unique contribution by mapping the findings to the Framework of Interdisciplinary Research Assessment and the delineation of components, tools, and approaches that are feasible for evaluating

interdisciplinarity in practice. We expect that the methods employed in this study

and findings will be of interest to a broad range of stakeholders, including health

researchers, evaluators, funders, and policy planners. By sharing the products of

our research, we hope that this will further encourage other teams to consider how

they too can evaluate and further consider the interdisciplinary component of their

research.

Table 1: Framework for Interdisciplinary Research Assessment (FIRA) & Research Team Application

	Research Conduct			*Knowledge Production*		
	Element	**Indicator**	**Evaluation Mechanism**	**Element**	**Indicator**	**Evaluation Mechanism**
Structure						
	Funding	▪ Funding exists for ID research ▪ Funding requirements specify what is meant by ID	▪ Interview ▪ Grant proposal review	**Institutional support**	▪ Departments recognize co-authorship of publications in the tenure/promotion process	▪ Interview
	Proximity	▪ Team is situated in a manner that fosters ID work	▪ Interview			
Process						
	Team composition	▪ All team members are aware of their role and expected contribution	▪ Interview	**Leadership to foster knowledge sharing**	▪ Opportunities for exposure to new theories, methods	▪ Interview ▪ PSAT-I ▪ SNA Survey*
	Communication & reflexivity	▪ Regular communication between team members ▪ Reflexive	▪ Interview ▪ PSAT-I	**Leadership to foster knowledge production**	▪ Authorship guidelines delineated	▪ Interview ▪ PSAT-I

	Research Conduct			Knowledge Production		
	Element	**Indicator**	**Evaluation Mechanism**	**Element**	**Indicator**	**Evaluation Mechanism**
		thinking encouraged and discussed between members				
Outcome						
	Satisfaction with team	▪ Team members want to work with each other again	▪ Interview ▪ SNA Survey*	**Productivity**	▪ # of publications, presentations, etc ▪ Composition of disciplines on each paper, presentation ▪ Citations	▪ Interview ▪ Review of published papers
				Impacts	▪ Impact on health ▪ Impact on policy change	▪ Interview ▪ PSAT-I

Note:*SNA survey not addressed in the present study

Table 2: Convergence Coding Matrix: Qualitative Interviews and PSAT-I

	Agreement	Partial Agreement	Silence	Dissonance
Grant provided funds for ID research	Yes			
Funder did not specify what was meant by ID			Yes	
Team made efforts to manage challenges due to geographical dispersion		Yes		

Note: 'Yes' indicates level of agreement of qualitative findings with PSAT-I results

Table 3: Characteristics of Participants from Each Team

	Team #1 (n=7/10)	Team #2 (n=17/23)
Gender: Female	5/7 (71.4%)	13/17 (76.5%)
Number of distinct disciplines present on team	4	8
Number of years involved in research (mean, SD)	14.3 (7.9)	9.4 (8.8)
Length of time on study; n (%)	N=6	N=17
Less than 6 months	1/6 (16.7%)	5/17 (29%)
7-12 months	0	3/17 (18%)
13-24 months	3/6 (50%)	6/17 (35%)
25-36 months	1/6 (16.7%)	0
Over 36 months	1/6 (16.7%)	3/17 (18%)
Completed interview	5/7 (71.0%)	13/17 (76.5%)
Average interview length in minutes (SD)	41.6 (16.3)	42.3 (9.8)
Completed PSAT-I; n (%)	7/7 (100%)	17/17 (100%)

Table 4: FIRA Application – Key Findings from 2 Research Teams

	Research Conduct		Knowledge Production	
	Team 1	Team 2	Team 1	Team 2
STRUCTURE	▪ Grant provided funds and personnel to complete research ▪ Regular communication offset geographical challenges	▪ Communication challenges due to geographical dispersion for field workers and investigators	▪ Departmental and university support for ID research	▪ Both academic and government investigators felt institutional support for involvement with research study
PROCESS	▪ Little awareness of disciplinary background of team members; team membership based on skills, knowledge ▪ PIs oversaw all aspects of each study ▪ Some sense that ID not explicitly operationalized ▪ Team dynamics not attributed to discipline but to personality	▪ Many investigators had not worked together previously ▪ PI hands off and staff support was appreciated ▪ Some investigators felt underutilized but expected this to change once analysis and write-up stages took place ▪ Regular communication processed in place	▪ No regular explicit opportunities for knowledge sharing, however all indicated learning something new ▪ Increased productivity measures due to team membership ▪ Senior researchers took on mentorship role ▪ Challenge to balance collaboration and completing study tasks	▪ Little opportunity for knowledge sharing among investigators though field workers felt that this was sufficient ▪ For a few investigators knowledge sharing led to knowledge gains ▪ Some evidence of ID learning
OUTCOME	▪ Hierarchy within team contradicts tenets of ID ▪ Unsure of what was	▪ Generally satisfied despite some initial issues with communication and	▪ Actively productive with 6 publications and 16 presentations ▪ Little discussion on	▪ 2 publications and 6 presentations ▪ Knowledge transfer back to community

	Research Conduct		Knowledge Production	
	Team 1	Team 2	Team 1	Team 2
	entitled to (i.e. resources) ▪ Appreciated working with senior researchers and new researchers	role uncertainty	research's influence on health or health policy	was seen as important ▪ All participants were proud to be part of a study that could have a discernable health impact

Table 5: PSAT-I Results

	Case #1 (n=7) Mean (SD)	Case #2 (n=17) Mean (SD)
Synergy	3.7 (0.3)**	3.9 (0.2)
Leadership effectiveness	3.8 (0.3)**	3.7 (0.2)*
Efficiency	4.0 (0.4)**	3.6 (0.3)
Effectiveness of administration and management	3.6 (0.5)*	3.5 (0.2)*
Sufficiency of non-financial resources		
Connections	3.8 (0.4)	4.1 (0.2)
Skills and expertise	4.5 (0.3)	4.4 (0.2)
Data and information	4.3 (0.2)	4.0 (0.1)**
Other research team characteristics	4.4 (0.1)	4.3 (0.2)
Sufficiency of financial and other capital resources	4.4 (0.1)	4.1 (0.4)

Note: *Range for scoring was 1 to 5; **Range for scoring was 2 to 5. Range for scoring for all other domains was 3 to 5.

Table 6: PSAT-I: Frequencies for Benefits and Drawbacks Scale Items

	Team#1 % Yes (n=7)	Team #2 % Yes (n=17)
Ben1: Enhanced ability to address an important issue	100 (n=7)	93.8 (n=16)
Ben2: Development of new skills	100 (n=7)	93.8 (n=16)
Ben3: Heightened public profile	83.3 (n=6)	58.3 (n=12)
Ben4: Increased utilization of my expertise or services	71.4 (n=7)	82.4 (n=17)
Ben5: Acquisition of useful knowledge about research methods, theories, content from different disciplines	85.7 (n=7)	93.8 (n=16)
Ben6: Enhanced ability to affect public policy	50.0 (n=6)	45.5 (n=11)
Ben7: Development of valuable relationships	100.0 (n=7)	100.0 (n=16)
Ben8: Enhanced ability to meet needs of funders, decision-makers, patients, or clinicians	71.4 (n=7)	75.0 (n=12)
Ben9: Ability to have a greater impact than I could on my own	100.0 (n=7)	86.7 (n=15)
Ben10: Ability to make a contribution to science	100.0 (n=7)	100.0 (n=17)
Ben11: Acquisition of additional financial support	50.0 (n=6)	60.0 (n=10)
Draw1: Diversion of time and resources away from other priorities or obligations	100.0 (n=7)	58.8 (n=17)
Draw2: Insufficient influence in research team activities	14.3 (n=7)	6.7 (n=15)
Draw3: Viewed negatively due to association with other team members or the research team itself	14.3 (n=7)	0 (n=15)
Draw4: Frustration or aggravation	57.1 (n=7)	43.8 (n=16)
Draw5: Insufficient credit given to me for contributing to the accomplishments of the research team	0 (n=6)	6.3 (n=16)
Draw6:Conflict between my job and research team's work	14.3 (n=7)	6.3 (n=16)

Note: n=# of participants who answered question

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Using social network analysis to understand knowledge sharing in an

interdisciplinary health research team

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ABSTRACT

Background: One of the hallmarks of interdisciplinary research teams is the potential for knowledge exchange between team members to lead to new learning and knowledge creation. Considering a person's location and connections in a network can help to identify which people are essential to ensuring knowledge flow. The purpose of this study was to understand knowledge sharing in an interdisciplinary health research team.

Methods: Social network analysis was conducted to answer 3 questions: 1) Who brings new ideas and knowledge to this research team?); 2) Who has contributed the greatest amount of new knowledge to this research study; and 3) Who would you want to work with again in the future if you had a chance? Measures of cohesion and centrality were examined.

Results: The results found that each person on the team was viewed as contributing new knowledge to the team and there was no one on the team that people would not want to work with again. Centrality measures highlighted the principal investigator (PI), 2 co-investigators, and 2 staff people as central to network activity. The PI and one co-investigator, who was from a different discipline than most, were found to be contributing the greatest amount of new knowledge to the team.

Conclusion: Social network analysis offers useful information that is not easily garnered from other methods and can help to strengthen team functioning by identifying those who play central roles within a team. This study pointed out the importance of staff as conduits of information within the research team, and this finding is an important consideration for other health research teams.

INTRODUCTION

A number of recent studies within health care have underscored how methodologies such as social network analysis can help to increase our understanding of disease transmission, health behaviours, and communication patterns.[1-3] With health researchers increasingly joining interdisciplinary research teams, social network analysis offers a promising methodology for better appreciating how these types of research teams share and utilize information. Social network analysis is a methodology that can be used for examining how actors/egos (e.g. researchers) are located within a network (e.g. research team).[4]

One of the hallmarks of interdisciplinary research teams is the potential for knowledge exchange between people to lead to new learning and knowledge creation. Considering a person's location and connections in a network can help to identify which people are essential to ensuring knowledge flow. The purpose of this study was to understand knowledge sharing in an interdisciplinary health research team through the use of social network analysis.

METHODS

Sample:

Participants in this study were part of a larger study examining assessment of

interdisciplinarity in health research teams who were federally funded and

engaged in multi-year programs of research. One team was invited to take part in

this social network analysis study. This team was engaged in a 3-year program of

research that involved 6 studies. The team's research coordinator provided a list

of all team members who were sent electronic invitations to take part in the

research. Potential participants included the principal investigator, co-

investigators, research staff, and data collection field workers.

Data collection and analysis A semi-structured survey was used to extract

information needed for the social network analysis. Data collection occurred

through self-completed electronic means with the use of Network Genie.

UCINET 6, a computer program developed for social network analysis was

utilized in this study.[5] UCINET 6 allows for both data analysis and visual display

of relations between actors in each network through its affiliated program

Netdraw.

We examined responses to three questions and each question was viewed

as its own network: 1) Who brings new ideas and knowledge to this research

team? (New Knowledge network); 2) Who has contributed the greatest amount of

new knowledge to this research study (Greatest Knowledge network); and 3) Who

would you want to work with again in the future if you had a chance? (Work

Again network). New knowledge was defined as exposure to methods, theories,

ideas that were not previously known. This study used a whole or complete

network approach (socio-centric) where each team member was asked about their

connections with all other research team members.[6]

      The composition and structure of each network (New Knowledge;

Greatest Knowledge; Work Again) was examined and included measures of

cohesion (density) and presence of components.[7;8] Ego measures (i.e. those

related to individuals in the network) included degree centrality and betweenness

centrality. Data were directed or asymmetric as the relationships were not

necessarily reciprocal (i.e. if person A chose person B as contributing new

knowledge to the team this did not automatically mean that person B chose person

A). Normalized scores were used so that networks could be compared. Table 1

provides an overview and description of key terminology in social network

analysis and metrics used in this study.

RESULTS

The 23 member research team was comprised of 1 principal investigator (PI), 10 co- investigators, 5 research staff, 4 field workers, 1 student, and 2 senior researchers/managers. Data was available for all but 6 co-investigators. Thirteen out of 17 participants were female (76.5%). Mean length of time working in health research was 9.4 years (standard deviation =8.8). All three networks were plotted as sociograms, with each person's role depicted by different symbols. Disciplinary affiliation was not included in order to maintain the anonymity of each person as in many cases there was only one person representing a particular discipline.

Network cohesion was examined through components and density analysis. For both the New Knowledge (Figure 1) and Work Again (Figure 2) networks, only one component was found indicating that everyone was reachable within the network. These results found that each person on the team was viewed as contributing to the team and there was no one on the team that people would not want to work with again. This reinforces the value of each member on the team. For the Greatest Knowledge (Figure 3) network, 6 components were found, 3 of which were isolates. There were 2 other larger components, with one consisting primarily of field workers and a co-investigator closely affiliated with them, and another centered on the PI. This finding highlights the important role and link played by that co-investigator (C2) for the field workers. The team

members in this component were involved in one of the main studies that had

been ongoing at the time of the interviews.

Table 2 summarizes findings from the main analyses conducted. New

Knowledge and Work Again networks were similar in density scores with 20%

and 24%, respectively. If every person was connected with every other person,

density would be 100%. The Greatest Knowledge network had a considerably

low density due to the wording of the question where only one person could be

chosen.

Centralization examines whether the network is focused on one individual

and compares scores to a star shaped network that is highly centralized, with a

higher percentage indicating that the network is closer to this centralized star

network. Degree centralization scores were moderate for all 3 networks, with the

New Knowledge network having a higher score than the other 2 networks,

pointing out that this network is centered on fewer central people. In this network,

the PI was more clearly located at a hub than the other team members.

Betweenness centralization scores were similar between the New Knowledge

(18.86%) and Work Again (18.45%) networks. Greatest Knowledge scores were

low (0.02%) suggesting that there is little inequality in individual centrality

scores.[9]

Degree centrality was examined using in-degree scores, as there was missing data within the out-degree data (due to non-response from 6 co-investigators). The examination of in-degree scores is also a measure of influence.[10] The PI and 2 co-investigators, C1 and C2, had the highest in-degree scores for New Knowledge and the PI and 2 research staff, S1 and S2, had the highest in-degree scores for Work Again. This indicates that these people are more central to these networks. In the Greatest Knowledge network, the PI had the greatest number of lines coming in, followed by C2. For betweenness centrality, the mean score for Work Again was slightly higher than New Knowledge. In both networks, the same research coordinator, S2, had the highest scores (19.86 and 19.55, respectively), followed by a different staff member in each of these networks. This suggests that S2 would be an important person to target for information dissemination.

DISCUSSION

The application of social network analysis to study knowledge flow in this research team helped to identify which team members were central (i.e. well connected) to the team. Centrality is indicative of the amalgam of connectivity, social power, popularity and activity. The three networks provided consistent information, overall highlighting the important role of the PI and a particular co-investigator, C2 and staff member, S2. It is these people who are central to information transfer and knowledge sharing within this team. The co-investigator was from a different discipline than most other investigators and one can surmise that there was some harnessing of new knowledge contributions from this person. All team members were cited at least once as contributing new knowledge and ideas to the team, and everyone was named by at least one other person as wanting to work with again. This reinforces the overall value of each team member.

Social network analysis is useful for better understanding the informal organizational structure that may exist within a group.[11] The central role of particular research staff sheds light on an organizational structure that was not previously evident. Interestingly, interviews that had also taken place with these team members confirmed the importance of research staff, particularly for the field worker group and this was evidenced in the Greatest Knowledge network.[12] Identifying those who are in influencing positions is helpful as this can indicate

who to target interventions towards[9] or who to target for key decisions. Our interviews also identified that there were a number of investigators that were feeling peripheral and isolated within the team and focusing collaboration and networking strategies on those in 'gate keeping' roles (i.e. staff) would be one way to increase connections with those team members. It may be that staff have more time to keep engaged with other team members than the PI or co-investigators, and in many cases facilitating connections or information flow is precisely what staff are called upon to do.

In their seminal work, Rhoten and colleagues[13]examined conditions related to interdisciplinary collaboration, and they compared self-reported knowledge creating collaborations (close ties) with information sharing collaborations (collegial ties). Results indicated that there was a greater number of information sharing than knowledge creating ties between researchers of different disciplines. This supported the idea that it is those that are different from ourselves (colleagues vs. close ties) that prompt new information breakthrough. Similarly, in the present study, it was the one co-investigator who was most different from everyone else who was often cited as contributing the greatest amount of new knowledge to the team.

Some of the most interesting work in the area of social network analysis has looked at reciprocity or 2-way interactions between people. Plickert et al

examined reciprocity and found that giving social support was strongly associated with getting social support.[14] In this study, missing data from 6 co-investigators threatened the fidelity of examining knowledge exchange between team members, but it is hypothesized that just as social support tends to be reciprocal, so too would knowledge sharing. That is, if Person A shared new knowledge with Person B and this helped Person B understand a problem better, then Person B would be more likely to want to share knowledge with Person A. This underscores the value of relationships so aptly described in previous work.[15]

Limitations

Despite repeated attempts, not all team members completed the survey. As well, it became evident later in the study that the initial list of team members did not contain all students associated with the study. Given that social network analysis focuses on relationships, the exclusion of these perspectives may have impacted the findings.

Conclusion

In the crowded landscape of methodological choice, social network analysis is one method that deserves further exploration and use by health researchers. Social network analysis offers useful information that is not easily garnered from other methods and can help to strengthen team functioning by identifying those who play central roles within a team. This study pointed out the

importance of staff as conduits of information within the research team, and this

finding is an important consideration for other health research teams.

Table 1: Description of SNA Metrics[6;13;16]

Metric	Definition
Network	A distinct set of human relations
Node	A person in the network; also known as an ego
Tie	Link, bond, relationship, or connection between 2 people
Sociogram	Visual presentation of nodes and ties
Isolate	Node with no ties
Centrality	Ego measure that indicates how connected a person is in the network; measure of social power, popularity, activity; more ties equals higher centrality scores
Centralization	Network measures that indicates extent to which a network revolves around a node in a star-shaped network; star graph is highly centralized; based on individual centrality scores
Network Measures	
Network Cohesion Density	Total number of ties as a proportion of the total number of possible ties and ranges from 0% to 100%; level of connectivity across the whole network
Component	Part of a network where everyone can reach each other; isolates considered their own component
Degree Centralization	Comparison of observed network centralization with star-shaped network of the same size expressed as a percentage
Betweenness Centralization	Comparison of observed disparity in betweenness centrality scores with star shaped network expressed as a percentage
Ego Measures	
Degree Centrality	Measure of how well connected a person is within the network and counts the number of ties going to (InDegree) and going from (OutDegree) each person, with higher scores representing higher degree centrality (i.e. greater number of ties).
Betweenness Centrality	Measure of information control (i.e. gate keeping) and looks at how often a person is located on the shortest path between 2 other people.

Table 2: Summary of Social Network Analysis Results

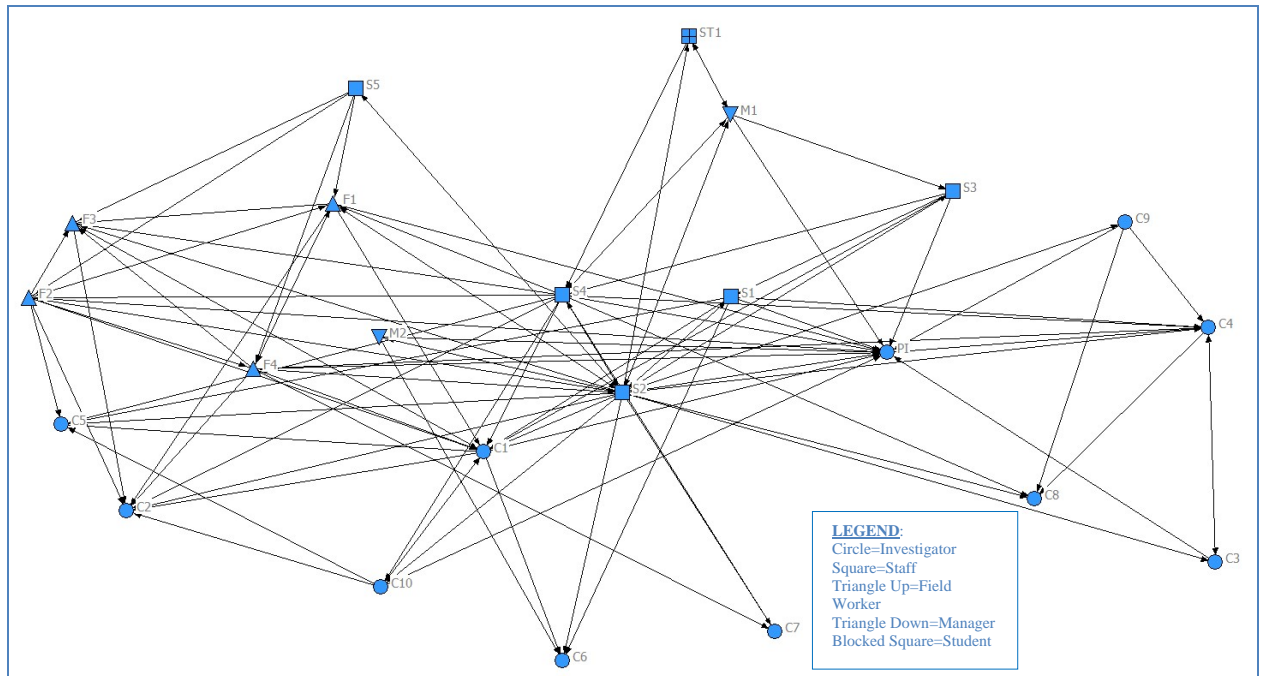|	NEW KNOWLEDGE	GREATEST KNOWLEDGE	WORK AGAIN
Density: X (SD)	0.20 (0.40)	0.04 (0.18)	0.24 (0.43)
Degree Centralization (%)	45.66	34.50	31.61
Betweenness Centralization (%)	18.86	.20	18.45
Degree Centrality X (SD)	19.96 (13.59)	3.36 (8.50)	24.31 (12.69)
Betweenness Centrality X (SD)	1.50 (4.11)	0.03 (0.07)	2.21 (4.41)

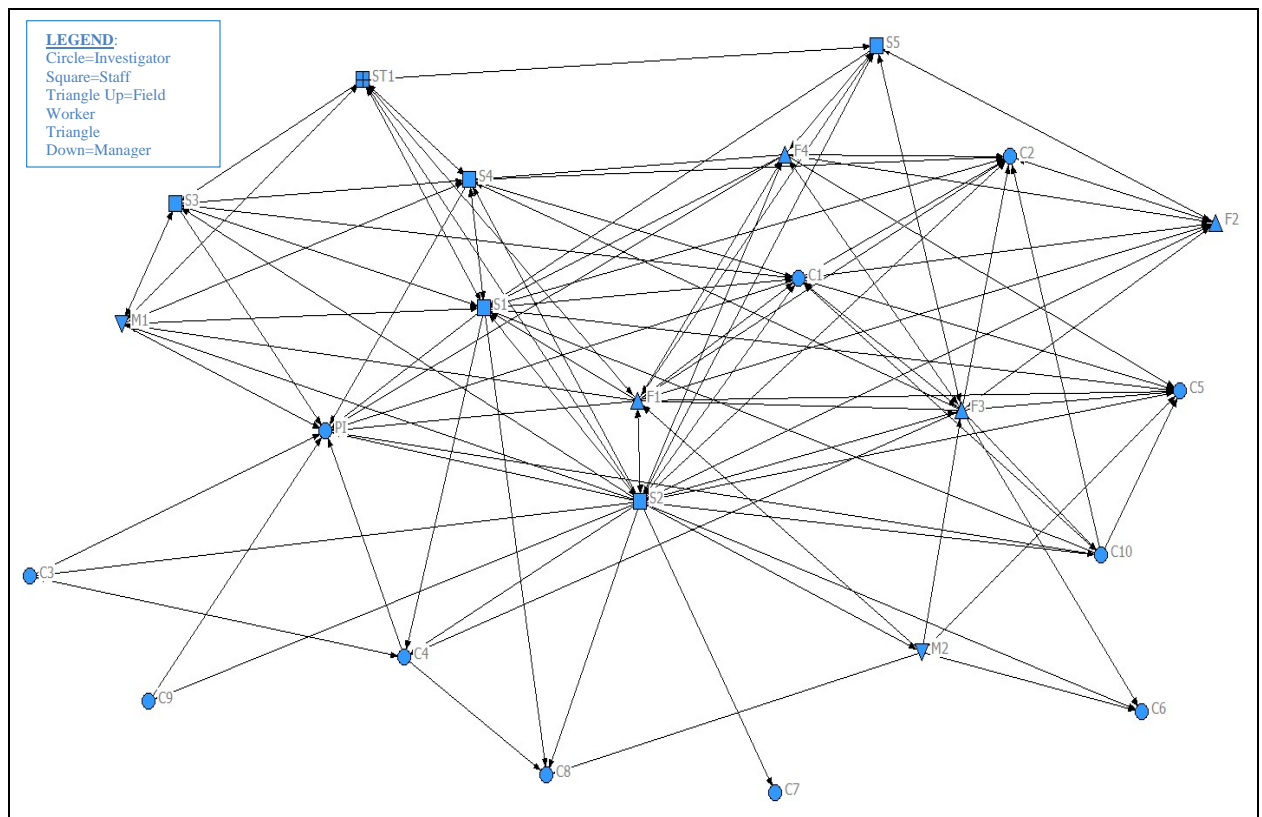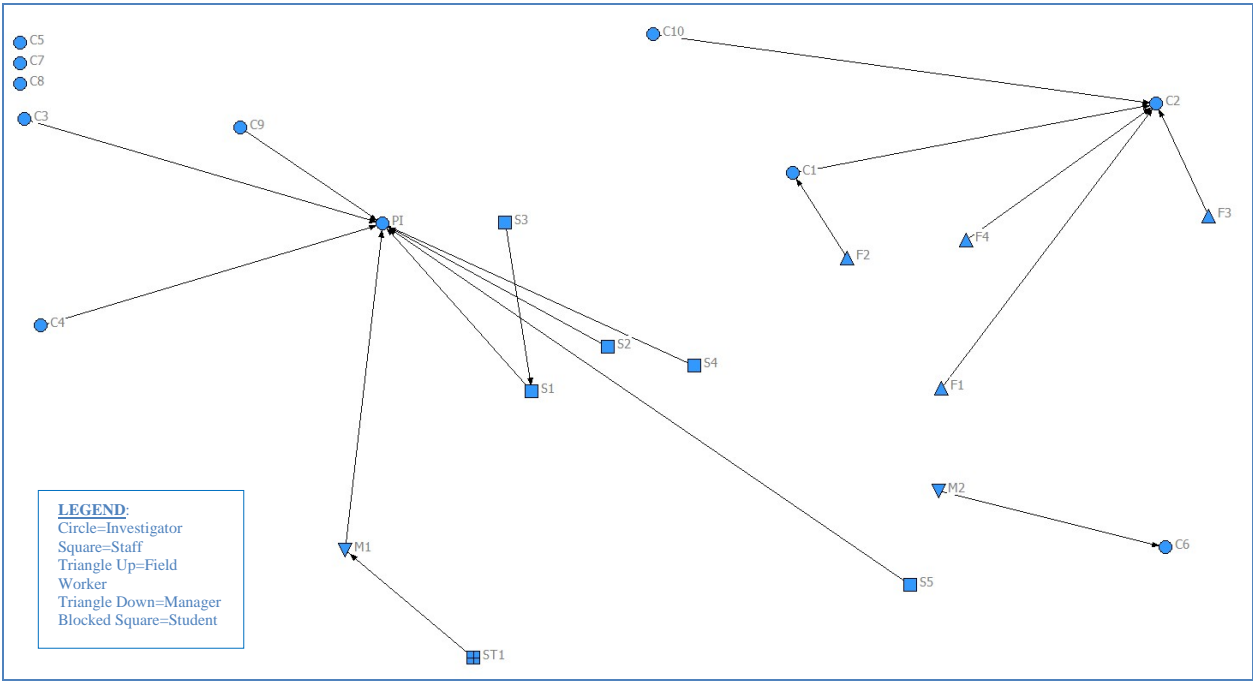**Figure 1: New Knowledge Network**

Figure 2: Work Again Network

Figure 3: Greatest Knowledge Network

LEGEND:
Circle=Investigator
Square=Staff
Triangle Up=Field Worker
Triangle Down=Manager
Blocked Square=Student

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DISCUSSION

The purpose of this thesis was to describe how interdisciplinarity is experienced by health researchers in practice and to formulate a framework, the Framework for Interdisciplinary Research Assessment (FIRA) that could be used to assess interdisciplinarity. The series of papers presented in this thesis were able to accomplish both of these goals. Summatively, these papers have provided some practical insights about forming an effective interdisciplinary team as well as methodological direction for those engaged in evaluation of interdisciplinary health research.

The main themes derived from this thesis include:

- Interdisciplinarity is implicitly valued in theory but not articulated in reality;

- Uncertainty of the value of acknowledging discipline;

- The divide between evaluation potential and practice; and

- The benefits and challenges of multiple perspectives working together.

Further elaboration and discussion is provided below.

Interdisciplinarity is implicitly valued in theory but not articulated in reality

This thesis was focused exclusively on interdisciplinarity and participants from all studies were purposefully chosen because of their participation on interdisciplinary health research teams. Despite this, ID was rarely operationalized in practice. It appeared that for these researchers ID was the norm.

The resounding comment from those interviewed in Papers 1 and 3 about their experience with ID research was "this is how I always work", and accordingly, little additional thought may have been exercised in considering whether a team was actually maximizing its interdisciplinary potential.

The standard of teamwork in health research may have also contributed to the lack of consideration of how to practice ID. It is challenging to delineate the differences between a well-functioning ID team from a non-ID team as interpersonal dynamics will be similar. It is the attention to increased knowledge sharing that is a key determinant of ID teams, and the FIRA helps to establish whether the necessary structure, process, and outcome indicators are in place to facilitate knowledge production.

Understandably, researchers are focussed on getting their research completed, but in our studies there was some sense that some participants were feeling undervalued and their knowledge and skills underutilized. This lack of articulation of what ID means for a team has implications for how team members are engaged and utilized on an ID team, as evidenced by our findings. Others have also documented this divide between interest in ID and application of it in practice.[1] This feeling of being undervalued may also be a function of larger teams, where it is more difficult to manage the involvement of everyone because of a team's size.

Some participants expressed feeling that there should be stronger leadership to ensure that everyone was certain of their role and expected contribution. Paper 1 offers guidance to researchers about how to maximize ID success by providing pragmatic solutions for some of the challenges seen with ID. Leadership, a concrete plan, and involvement from everyone are needed to ensure that the benefits of ID are realized.[2,3] Leadership was a common thread found in our studies and has also been documented in the literature as important for interdisciplinary research.[1,4] Leadership needs to be present at multiple levels and institutional support through common buildings, social space for faculty, and incentives for both junior and mid-career academics have been noted as fostering interdisciplinarity.[5,6]

Uncertainty of the value of acknowledging discipline

Discipline as a distinguishing factor in an interdisciplinary team was difficult to specify or clarify as a concept for the teams studied. A person's disciplinary shift over time or lack of alignment with one specific discipline were cited as factors for not considering their discipline and have also been cited in the literature.[7] Skills, experience, expertise, and personality were also thought of as important considerations, highlighting that it is a comprehensive assessment of what each person can contribute to a team that ultimately influences how engagement happens within the team.

Therefore, if discipline does not enter into a research team's day-to-day functioning, what is its value? ID is premised on the idea that knowledge contributions from another discipline will lead to more appropriate solutions to health care challenges. There were examples within this thesis of investigators being able to vividly recount how their thinking and understanding of a research problem changed as a result of knowledge from another discipline. Therefore, it is likely that discipline really is important but researchers are not attuned to thinking that knowledge gains could be attributed to the disciplinary knowledge of another team member. When typically considering the summative contributions (personality, previous work experience, skills, and knowledge) of a person, it takes a heightened awareness or reflexivity to link knowledge production to discipline. As noted in Paper 3, it was the experience of something new (i.e. knowledge gain) that pushed the importance of ID to the forefront and heightened its awareness and meaning.

Cross and colleagues' social network analysis (SNA) work found that people learn to do their jobs not from impersonal information sources but through interaction.[8] Learning to do interdisciplinary work would also seem to be premised on interactional activity; and in this way, acknowledgement of discipline may be more forthcoming. The concepts of 'discipline' and 'interaction' within the context of interdisciplinarity overlap and there is

'fuzziness" with respect to how these align with one another. A broader question

that can help clarify understanding of impact of discipline is whether ID is

achieving the end it was intended to (i.e. have researchers been able to think

beyond their usual knowledge realm and experience crossing boundaries).

The type of knowledge exchange by members of an interdisciplinary team

will also be an important area to track, as knowledge will not always follow

disciplinary lines. Haythornwaite found that there are different types of

knowledge exchange – some relate to factual knowledge and others to things such

as how to do something new or socialization into a profession.[9] Social network

analysis could be a useful method to further explore the varying exchanges that

take place within an interdisciplinary health research team.

The divide between evaluation potential and practice

We developed the Framework for Interdisciplinary Research Assessment

(FIRA), which was both literature-based and researcher-informed, to facilitate

interdisciplinary assessment. However, as noted above, it appears that for some,

ID must be experienced in its truest form (new knowledge exchanged and

reflexivity about this knowledge) in order for ID itself to have value, and then be

subsequently evaluated.[10] The FIRA model highlights the need for leadership to

foster both knowledge sharing and knowledge production. Therefore, there must

be a concerted effort on the part of Principal Investigators (PIs) to ensure that

each team member has an actual and not presumed 'seat at the table' and to champion such evaluative efforts. A fostering of reflexivity and intentionality will help with this realization.

Paper 2 highlighted the development of the Interdisciplinary Evaluation Triangle, which posited 4 areas of evaluative activity: 1) communication, 2) reflexivity, 3) knowledge integration, and 4) defining quality, which reinforces the need for evaluation to be decided and ongoing. The idea of reflexivity was not typical of how most researchers operated; while some made time for reflection about study progress, a purposeful attention to thinking about how interdisciplinarity was progressing was not commonplace. Romm has suggested that interdisciplinary practice is necessarily reflexive and that it fosters accountability to the research process.[11]

We are at the cusp of a time in health research when greater accountability for dollars spent has pushed the need for evaluation forward. Researchers are increasingly being called upon to complete pilot or feasibility studies prior to initiation of larger studies and trials and this naturally lends itself to the completion of both process and outcome evaluation. FIRA provides a useful template that could be integrated into most ID studies to capture whether the needed indicators are in place for research conduct and knowledge production.

The benefits and challenges of multiple perspectives working together

Time and resources may ultimately dictate who and how many people take part in a study's evaluation; however, this thesis highlighted the importance of engaging all team members. In paper 1, only PIs were interviewed about their experiences of ID and their perceptions of appropriate evaluation measures. This provided a useful starting place for understanding ID, but it is the multiple perspectives studied in Papers 3 and 4 that provided additional rich and valuable information. These papers helped to elucidate the role of staff in knowledge sharing, which was not evidenced from the findings described in Paper 1. As well, by interviewing investigators beyond the PI, we were able to learn that some co-investigators were not feeling valued. The low response rate of co-investigators in team 2 may further indicate that not everyone was satisfied on the team.

Certainly, there are challenges with attempting to involve all team members in an evaluation exercise. Aside from practical constraints such as timeline and funding feasibility, there are other issues to consider such as how to effectively capture the multiple voices present, particularly when there will not be equivalent numbers of participants in each group (e.g. there was only one student in the study described in Papers 3 and 4). Evaluative measure are most valuable when they represent the entirety of those involved and it can be misleading or premature to embark on changes based solely on the perspectives of a few participants. Therefore, the use of multiple forms of data collection (survey and

interviews) and multiple data collection points through an ongoing evaluation strategy will strengthen the transferability and usefulness of findings.

Methodologic contributions of this thesis

This thesis employed the use of multiple designs, both qualitative and quantitative. The mixed methods study (Paper 3) was particularly methodologically rich as it involved the use of a novel data integration method[12] as well as survey modification and implementation. The convergent coding matrix was helpful as it allowed for the deciphering of which method (interview or Partnership Self Assessment Tool-Interdisciplinarity; PSAT-I) contributed unique findings and helped to determine the ultimate benefits of each data collection method. For example, while the interviews were helpful in understanding each of the components of FIRA, the PSAT-I offered greater specificity for areas such as benefits and challenges in being part of an interdisciplinary team.

The social network exercise described in Paper 4 was particularly enlightening as it demonstrated the value of specific team members (PI, staff). It was unfortunate that discipline was not an attribute that could have been utilized (due to many disciplines only containing one person) however role on team was seen to be a useful way for looking at knowledge exchange. Social network analysis allowed one to see the informal structure of this team which was not evident from the individual interviews. Social network analysis has great potential

as a method for mapping a variety of social relationships as well as personal attributes that could influence these relationships.[13;14]

Implications for practice/researchers

There are a number of practical suggestions that can be taken from this collective work. Language and semantics need to be explicitly considered as it is clear that interdisciplinarity is not a concept that is universally understood in the same way. There needs to be clarity of terminology and clarity of how interdisciplinarity is expected to manifest within the team. This leads to the central notion of intentionality; the potential of interdisciplinarity will not be realized if there is not explicit attention given to it. Although researchers professed to value ID and its evaluation, there was little overt focus given to this.

The Framework for Interdisciplinary Research Assessment offers researchers a practical and straight forward model for assessing indicators needed for interdisciplinary success. FIRA directs researchers to think about three realms (Structure, Process, and Outcome) within the 2 areas of research conduct and knowledge production. Each of the FIRA indicators can be further operationalized to allow teams to easily assess its presence or absence. Concomitant to this is variety of data collection tools posited in this study (interviews, PSAT-I, social network analysis) that each provide an opportunity to evaluate specific areas of interdisciplinarity. The findings from Paper 3 and 4 suggest that over the course

of a program of research, the time taken to complete each survey and interview is reasonable, particularly through the use of electronic surveys. The current findings also do not indicate that changes need to be made to the surveys or interview, further reinforcing the ready applicability of this model. The FIRA's menu of options means that researchers can tailor evaluation efforts based on their needs, resources, and interests.

Implications for policy

From a policy perspective, there are 2 important messages to be gleaned from this thesis. First, evaluation of indicators of interdisciplinarity is possible. The FIRA model provides a comprehensive overview of the main areas of assessment. Certainly, interdisciplinary health research teams could self-evaluate by using the indicators as discussion points and through the use of the PSAT-I. Therefore, funders could reasonably ask researchers to incorporate an evaluation exercise into their research plans.

Related to this however, is whether funders themselves view evaluation as important. Busy academics will likely not take on additional responsibilities unless directed to by those that they are accountable to. It is incumbent on funders and institutional departments to take the lead by first being clear about what they

mean by interdisciplinarity, and then by espousing the value of its evaluation by

providing the tools and measures that can accomplish this.[15]

Limitations

As a body of work, there are a number of limitations to the findings of this

thesis. First, the PSAT-I was not validated beyond face validity. Second, sample

sizes for each team in Paper 3 were small, particularly in team 1 which only had 7

respondents. However, the similarity in themes from the qualitative interviews in

both teams does strengthen this study's findings. Finally, analysis was conducted

by one person for all of the studies, though efforts were made to minimize bias.

Achievement of higher response rates for completion of interviews and

surveys was challenging in the studies described in Papers 3 and 4. This led to the

SNA component only being completed in one research team and prohibited

comparisons between teams. Further, incomplete data meant that the perspectives

of co-investigators were not as exhaustive as intended. It is uncertain whether this

difficulty was due to this study being externally driven and whether

implementation of FIRA (including PSAT-I and SNA surveys) by team members

themselves would have yielded greater uptake.

Future areas for research

This thesis has sparked a number of avenues for future research. First, the PSAT-I requires further validation. Although preliminary work has been done to establish face validity, content validity and reliability should be rigorously explored. The PSAT-I was straightforward and easy to administer and score and as such offers the potential for utilization by busy researchers. A validated tool will improve uptake of its use.

Next, the logical future step for the Framework for Interdisciplinary Research Assessment is use by interdisciplinary health researchers themselves without outside assistance. In this thesis, the author employed the use of FIRA as a means of assessing interdisciplinarity and reported findings back to each research team. This process met the needs of the 2 teams studied and is not unlike processes used by external evaluators. Ultimately, however, the value of FIRA will be for teams to use it by themselves and this will help establish whether FIRA's use is sustainable by research teams.

Finally, the application of the FIRA model was done with those engaged in programs of research that involved multiple studies within a larger topic area. Investigators often were part of more than 1 study and therefore involved in multiple research teams. An important next step would be to utilize FIRA with singular health research teams to see if there is similarity in findings as well as uptake of this model. We hope that the work completed in this thesis will be a

springboard for other research teams to more formally and intentionally evaluate the interdisciplinary component of their research.

Conclusion

Interdisciplinarity is and will continue to be a common research team configuration. Explicit attention to its operationalization and evaluation will help to ensure maximization of its potential. The Framework for Interdisciplinary Research Assessment (FIRA) provides a comprehensive and useable framework for capturing indicators that can contribute towards interdisciplinary success.

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