Implementation Science

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Building capacity in dissemination and implementation research: the presence and impact of advice networks

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Abstract

Background As dissemination and implementation (D&I) research increases, we must continue to expand training capacity and research networks. Documenting, understanding, and enhancing advice networks identifies key connectors and areas where networks are less established. In 2012 Norton et al. mapped D&I science advice and collaboration networks. The current study builds on this work and aims to map current D&I research advice networks.

Methods D&I researchers in the United States (US) and Canada were identified through a combination of publication metrics, and key persons identified networks and were invited to participate ($n = 1{,}576$). In this social network analysis study, participants completed an online survey identifying up to 10 people from whom they sought and/or gave advice on D&I research. Participants identified four types of advice received: research methods, grant, career, or another type (e.g., work/life balance). We used descriptive statistics to characterize the sample and network metrics and visualizations to describe the composition of advice networks.

Results A total of 482 individuals completed the survey. Eighty-six (18%) worked in Canada and 396 (82%) in the US. Respondents had varying D&I research expertise levels; 14% beginner expertise, 45% intermediate, 29% advanced, and 12% expert. The advice network included 978 connected nodes/individuals. For all research types, out-degree, or advice giving, was higher for those with advanced or expert-level expertise (6.9 and 11.9, respectively) than those with beginner or intermediate expertise (0.8 and 2.2, respectively). Respondents reporting White race reported giving (out-degree = 5.2) and receiving (in-degree = 6.1) more advice compared to individuals reporting Asian (out-degree = 2.9, in-degree = 5.3), Black (out-degree = 2.3, in-degree = 5.2), or other races (out-degree = 2.5, in-degree = 5.4). Assortativity analyses revealed 98% of network ties came from individuals within the same country. The top two reasons for advice seeking were trusting the individual to give good advice (78%) and the individual's knowledge/experience in specific D&I content (69%).

Conclusions The D&I research network is becoming more dispersed as the field expands. Findings highlight opportunities to further connect D&I researchers in the US and Canada, individuals with emerging skills in D&I research, and minoritized racial groups. Expanding peer mentoring opportunities, especially for minoritized groups, can enhance the field's capacity for growth.

This work was primarily conducted while the first/corresponding author was affiliated with Washington University in St. Louis.

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Keywords Social network analysis, Mentoring, Capacity building, Training, Dissemination research, Implementation science, Knowledge translation, Knowledge mobilization

Contributions to the literature

- Identifying experienced individuals in the dissemination and implementation research (D&I)/knowledge translation advice network is a vital resource for individuals new to the field.
- Study findings highlight opportunities to further connect three groups who are less networked within the D&I researcher network: researchers in the US with those in Canada, individuals with emerging skills in D&I research, and minoritized racial groups.
- This work outlines gaps in the current D&I research network and opportunities to expand peer networking and mentoring structures to enhance the field's capacity.

Background

The dissemination and implementation (D&I) research field has rapidly expanded over the past decade. During this time, an increasing number of D&I capacity building initiatives have emerged, including graduate certificate programs, PhD training, mentored training programs, and short courses [1–4]. These initiatives enhance knowledge, skills, and confidence in conducting D&I research and foster the expansion of and engagement in research networks [1, 5]. Mentored training programs typically use a team-based mentoring approach and demonstrate benefits for career development and network expansion. These programs also connect with and contribute to peer-to-peer mentoring (Table 1) [6, 7]. While mentored D&I training programs are highly valued, they require significant time, infrastructure, and leadership to develop [8]. Unfortunately, the demand for such training programs outpaces the current infrastructure, indicating a need for creative solutions to expand D&I capacity [1, 9].

D&I capacity building is further hindered by the relatively limited number of senior, experienced mentors of diverse genders and racial backgrounds [2, 11, 12]. Consequently, peer mentoring has gained recognition as a valuable resource within the growing field of D&I research [10]. Peer mentoring helps individuals connect through shared experiences and career levels, providing an environment where individuals may feel more comfortable seeking advice compared to hierarchical mentoring structures [10]. Trainees in D&I training programs have consistently identified peer mentoring as a key benefit, supporting their network expansion and skill development [6, 13].

While rigorously developed training programs are vital to advancing the field [2], it is also essential to recognize the value of less formal advice-seeking behaviors. Advice seeking complements mentoring and can help advance the field. Individuals training in D&I research report preferences for engaging in mentoring over time in which they can seek advice on an ongoing or as needed basis [8]. Team-based mentoring programs encourage mentees to seek advice from multiple individuals because each individual may present different perspectives on the same work [7]. Particularly in the early career stages, individuals are encouraged to proactively seek advice from others to support their training, career, and scientific development [7].

Despite the importance of advice-seeking [14], and its investigation in other realms of healthcare and research [15–18], advice-seeking has received limited attention in D&I research. In 2012, Norton and colleagues conducted a survey mapping D&I advice and collaboration networks in the United States [19]. They found that the D&I advice network was sparse and contained many isolates (i.e., individuals who had not given advice to nor received

Table 1 Characteristics of mentored training programs and peer-to-peer mentoring groups

Mentored training programs	Peer-to-peer mentoring
Application-based	Less structured; structure determined by peer mentoring group
Structured	Builds on the concept of a learning collaborative
Mentor–mentee pairing	Multidisciplinary
Multidisciplinary	Includes individuals at similar career stages
Often, a multi-year commitment	Within a single institution or across multiple institutions
Target early to mid-career trainees	Complements traditional mentoring
• Within a single institution or across multiple institutions	Key resource: Dickson et al. (2021) [10]
Key resources: Huebschmann et al. (2022) [3] and Davis & D'Lima (2020) [1]	

advice from anybody in the network) [19]. Norton et al. also identified individuals who held key positions within the advice network by providing advice to many individuals [19]. Given the growth in the field over the past 10 years, it is important to evaluate how D&I advice networks have developed and evolved.

As a tool for studying advice networks, social network analysis (SNA) supports the investigation of patterns of relationships among individuals [20]. The current study used SNA to investigate D&I advice networks in the United States (US) and Canada. SNA allows researchers to investigate the underlying structure of advice networks, how information is exchanged between individuals and groups, and potential intervention points (e.g., connecting isolated individuals) [6]. Advice networks can encompass mentoring relationships and less formal advice from peers. Documenting current D&I advice networks will identify key connectors in the field and areas where networks are less established. The current study expands Norton et al.'s work [19] by including researchers in the US and Canada. We expanded the sample to Canadian researchers due to Canada's robust D&I research infrastructure that includes a focus on training and mentorship [8]. This study addressed the following research questions within the US and Canada:

1) How do D&I advice networks differ based on demographic characteristics such as career stage, D&I expertise level, race, and gender?
2) To what extent are D&I researchers in the US and Canada connected?
3) What factors contribute to advice-seeking?
4) Within the network of those engaged in D&I research in the US and Canada, from whom do members most frequently seek advice on D&I related work?

Methods

This cross-sectional SNA study aimed to examine D&I advice networks in the US and Canada. Study participants completed an online survey using Qualtrics between April 2023 and July 2023. Throughout all study procedures, the terms dissemination, implementation, and knowledge translation/knowledge mobilization were used and defined due to the different terminology used in the US and Canada [21, 22]. For this paper, we use the term D&I for simplicity. This study adhered to the Social Networks in Health Research reporting guidelines [23]. The Institutional Review Board at Washington University in St. Louis approved this study as exempt research.

Sampling approach and network boundaries

The study sample was defined through a combination of publication metrics and a key person identified network. We sought to include individuals across career stages including trainees and established D&I researchers.

To identify the sample of individuals engaged in D&I research we started with individuals who published in one or more of five core D&I journals between January 2018 through December 2022. We pulled the names of the first, last/senior, and/or corresponding authors on all publications, including those with affiliations in the US or Canada. We considered these individuals as the primary contributors to the work and most likely to be engaged in D&I research. We chose not to include all authors because this may have artificially inflated the sample. Core D&I journals included: *Implementation Science, Implementation Science Communications, Frontiers in Health Services- Implementation Science section, Global Implementation Research and Application, and Implementation Research and Practice*. We added *Journal of Clinical Epidemiology* as it is a common dissemination channel for knowledge translation research in Canada. Keyword title searches using the terms dissemination, implementation, knowledge translation, and knowledge mobilization were used to identify potentially relevant articles/authors within the *Journal of Clinical Epidemiology*.

The team also identified core D&I faculty and trainees from US and Canada-based Universities from Huebschmann et al.'s (2022) work outlining implementation science capacity building programs [3]. We confirmed the sample included Editorial board members of core D&I journals and members of the main study section that reviews most D&I research applications at the National Institutes of Health [24]. To identify additional researchers in Canada, we searched the following sources: (1) the Canadian Institutes for Health Research trainee database (2) KT Canada Scientific Meeting abstracts and speakers (3) Canadian Association for Health Services and Policy Research Annual Meeting abstracts (4) Center for Implementation Research at Ottawa Hospital (5) University of Toronto Knowledge Translation program, and (6) University of Manitoba knowledge translation and synthesis services. The study lead (AL) and a D&I expert (RB) reviewed trainee scientific synopses and abstracts to assess involvement in D&I research. We limited trainee and abstract searches to 2018 through 2022. The study team reviewed the sample; they added seven individuals and removed 23.

Network operationalization

Each node, or circle on the network map, represents one individual in the network. Nodes are color-coded based on a participant characteristic (e.g., country, D&I expertise). The size of each node corresponds to the overall out-degree, or the number of individuals to whom

somebody gave advice. A tie connects two nodes if one or both individuals reported giving advice to or receiving advice from the other; Fig. 1 presents a theoretical directed network. These ties are directed because they go to/from one node to another [25]. This study examines a whole, one-mode network [25] of individuals engaged in D&I research.

Data collection

Participants were emailed a personalized survey link and invited to complete a 10- to 15-min online survey using Qualtrics. The survey invitation was sent from a general D&I working group email via Qualtrics with the goal of not biasing respondents. Eligible individuals who did not respond to the survey were emailed up to four reminders one week apart, except for the final reminder, emailed two weeks after the previous reminder. Participants were offered a $20 USD electronic gift card after completing the survey.

Survey questions were informed by Norton et al.'s 2012 D&I network survey [19] and adapted based on team discussions about questions to prioritize based on how the field has evolved over the last 10 years. We further modified the survey based on feedback from researchers outside the research team with expertise in D&I research and SNA methods. Participants selected names from a pre-populated list of 1,576 individuals, which included the full list of individuals invited to complete the survey. Participants were asked to identify up to 10 people from whom they 1) received advice on D&I research issues and 2) gave advice on D&I research issues within the past two years. The question was limited to the past two years and selecting 10 individuals to support recall accuracy and to reduce respondent burden, particularly for individuals highly engaged in D&I advice networks. Participants had the option to type in the names of other individuals not included on the pre-populated list. For each individual selected, participants identified the type(s) of advice received including research methods (e.g., study design, theories/models/frameworks), grant funding (e.g., identifying funding agency or mechanism, drafting a specific aims page), career advice, or other types of advice. Participants were asked to select their top three reasons for seeking advice from the individuals they identified

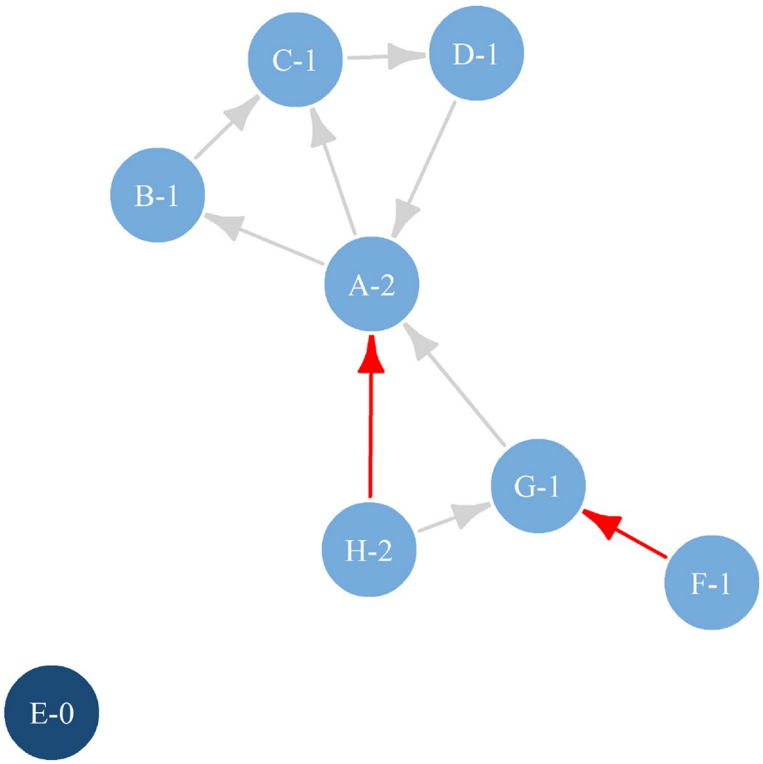

Fig. 1 Theoretical directed network. This theoretical network displays the bi-directional nature of data collection. Each circle, or node/individual, is labeled with a letter-#, where the number indicates the individual's out-degree value. For example, A-2 indicates person A gave advice to two other individuals. All gray arrows indicate the node of origin reported giving advice to the end node (e.g., C reported giving advice to D). All red arrows indicate the end node reported receiving advice from the origin node (e.g., A reported receiving advice from H). Individuals received a tally for their out-degree when they reported giving advice to an individual and when an individual reported receiving advice from them, which is considered bi-directional data

Table 2 Categorization of D&I expertise level

Beginner
• Self-rated their experience as beginner and had five years or less of experience OR • Self-rated their experience as intermediate and had less than 2 years of experience
Intermediate
• Self-rated their experience as intermediate and had 2–10 years of experience OR • Self-rated their experience as advanced and had 2–5 years experience
Advanced
• Self-rated their experience as advanced and had 6–15 years of experience OR • Self-rated their experience as intermediate and had 11 or more years of experience
Expert
• Self-rating their experience as advanced and had more than 15 years of experience in D&I research

(e.g., trust, prior experience working together). Participant characteristics (e.g., involvement and experience with D&I research, current job position, race) were self-reported. For the full survey, see Additional file 1.

Missing data

Network data were managed and stored on a secure server and in R version 4.4.1 [26]. Due to the broad boundaries of the network, there was a large amount of missing data from survey non-respondents. These data are included in network analyses because they are considered network members. Individuals who did respond to the survey could still endorse an advice-seeking connection with non-respondents, but bi-directional data were not collected when one individual did not respond. Due to the nature of the research question and large number of non-respondents, imputation was not feasible.

Data analysis

Demographic characteristics were summarized using descriptive statistics. A new variable was created representing each individual's D&I expertise level based on two survey questions: self-rated level of D&I experience (beginner, intermediate, advanced) and number of years engaged in D&I research (<2 to >15). After combining these two variables, D&I expertise level was divided into four categories: beginner, intermediate, advanced, and expert (Table 2). Participants had the option to select 'other' when reporting demographic characteristics.

When respondents typed in names not included on the pre-populated list, our team reviewed these responses to assess if the names were included in the original list. When a write-in response was a duplicate of an individual already in the network, these responses were merged with the original sample. Based on write-it responses, we added two individuals to the network. More than ten respondents wrote in the names of these individuals.

Connectedness Based on D&I expertise and demographic characteristics

To describe the network, or to what extent D&I researchers are connected, we explored visualizations (graphs) and common network metrics to describe each of the five networks (any advice, research methods, grant funding, career, and other advice). Metrics calculated included the number of connected actors or nodes, total number of ties or advice given/received, number of isolates or actors without any ties, density, largest component size, average geodesic distance, average degree, and each network's transitivity or clustering coefficient. These metrics are further defined in the results section. To understand if some groups of researchers differ in the number of advice connections, we examined the average out-degree (number of nodes that were provided advice from one node) for each group (country, expertise, gender, and race) and each of the 5 advice networks with Kruskal–Wallis rank sum tests. We explored the tendency for researchers to connect or form ties with other researchers who share similar characteristics (country, expertise, gender, or race) calculating assortment coefficients and the proportion of within group ties shared [27, 28]. Our goal was to analyze a complete network.

Reasons people seek advice

To understand what factors contribute to advice-seeking, we examined differences between participant characteristic (experience level, gender, race) by advice reason type with chi-square tests.

Prominent individuals in the D&I advice network

We used out-degree calculations to identify prominent individuals in the D&I advice network. Each individual's out-degree score was ranked, with those having the highest out-degrees (giving advice to more contacts) ranked for the US and Canada, and for researchers with beginner or intermediate D&I expertise level. All data were cleaned, analyzed and visualized in R version 4.4.1 using the *tidyverse*, *arsenal 3.6.3*, *igraph 2.0.3, and assortnet* packages [26, 29–32].

Results

A total of 1,576 individuals were invited to participate in the survey via email: 1,221 (77.5%) in the US and 355 (22.5%) in Canada. Of these individuals, 1,518 were eligible to participate and 482 completed the full survey (response rate = 32%); 396 (82%) respondents worked in the US and 86 (18%) in Canada. The distribution of US and Canadian participants is in alignment with the

different population sizes of these countries (337 million versus 41 million) [33, 34]. Individuals were considered ineligible to participate when 1) they responded "no" to the initial screening question [($n=8$); have you given or received advice related to D&I research in the past 2 years?], 2) an email address was not publicly available online ($n=102$; more than half were based in Canada), 3) an email bounced and another email address was not identified ($n=25$), 4) there was an out of office message indicating the person was on leave for the entirety of the study period ($n=20$), or 5) an automatic reply email indicated the individual left the institution and there was no forwarding email address ($n=5$).

Participants covered a range of professional levels from graduate students (6% of total sample) to full professors (20%). In the US sample, the largest portion of the sample was at the Assistant Professor rank (32%). In the Canadian sample, most individuals identified as 'Other' professional rank (22%) or graduate student (15%). Additional demographic characteristics are available in Table 3.

Network metrics

Overall findings reveal a network with relatively low density (0.0014), meaning that there are a large number of individuals in the network who are not connected to each other. Although many individuals in the network are not connected, there is a relatively small average geodesic distance, or number of degrees of separation between individuals, for all advice types (5.39). This means that on average, any individual in the network can reach another individual in the network through about 5 connections or introductions. The average geodesic distance was larger, meaning greater separation, for grant advice (7.96) and was smallest for career advice (3.43). This means people would need to talk with a larger number of their connections to connect with a random individual in the grant advice network compared to the career advice network. The average degree for all advice types is 4.29, indicating the number of ties between nodes in the network. This means that the average individual in the network engaged in advice-related connections with a total of about four individuals. For specific advice types, average degree is highest for research advice (3.6) followed by grants (1.96) and career advice (1.6). Table 4 presents the network metrics for the full sample. Additional file 2 presents network metrics for the United States and Canada cohorts separately.

Network visualizations—advice network maps

Figure 2 depicts advice networks based on level of D&I expertise where each node, or circle, is color-coded based on the individual's expertise level from beginner to expert. Gray nodes on the map depict individuals who were either invited to participate in the survey and did not respond or those who were not included in the initial sample, or network bounds, but were identified by survey respondents. Although most connections involving gray nodes predominantly consist of connections to single individuals, the research advice map (Fig. 2b) reveals certain instances where gray nodes are more centralized and larger. This pattern indicates advice was provided to several individuals. Overall, these maps demonstrate that advanced and expert-level individuals provide advice to larger numbers of individuals. Further, grant (Fig. 2c) and career (Fig. 2d) advice maps have a larger number of individuals on the periphery who are not connected to the larger network. In Fig. 2d, an example of a zoomed in isolated network is provided. Here, three individuals with advanced D&I expertise are connected to each other and they are further connected to several earlier stage investigators (beginner and intermediate). These individuals have their own small network that is not connected to the broader career advice network. Alternatively, the left center of Fig. 2c provides an example of how individuals on the periphery of the network are still connected to the larger network based on their connection with one individual.

Figure 3 depicts D&I advice networks for the US and Canada where the node color represents each country. These maps demonstrate limited overlap in advice networks between the US and Canada. However, most individuals in the network can be connected through a small number of key individuals. Again, grant and career advice maps are more dispersed with more individuals on the periphery of the map with limited or no connection to the main network. There are relatively few primary connections between individuals in the US and Canada on grant and career advice.

Access to advice (researcher connectedness)

Table 5 presents degree and assortativity statistics. Out-degree represents the number of connections individual (or node) gave advice to, and in-degree represents the number of connections from whom an individual received advice. For all research types, out-degree is much higher for those with advanced or expert-level expertise (6.9 and 11.9, respectively) compared to those with beginner or intermediate-level D&I expertise (0.8 and 2.2, respectively). Interestingly, in-degree is also somewhat higher for advanced (6.9) and expert (6.7) groups compared to beginner (4.4) and intermediate (5.6) groups. Men report giving more advice than women (7.6 versus 3.8 out-degrees, respectively), but they report receiving advice from a similar number of individuals (men in-degree = 6.1, women in-degree = 5.8). However,

Table 3 Participant characteristics

	Total Sample ($n=482$)	US ($n=396$)	Canada ($n=86$)
Gender	n (%)		
Woman	371 (77)	297 (75)	74 (86)
Man	103 (21)	93 (24)	10 (12)
Non-binary	2 (< 1)	1 (< 1)	1 (1)
Prefer not to answer	6 (1)	5 (1)	1 (1)
Race[a]			
Asian	63 (13)	49 (12)	14 (16)
Black, African American, African-Canadian, Afro-Caribbean	31 (6)	28 (7)	3 (4)
Indigenous, American Indian, or Alaska Native	4 (1)	4 (1)	0
Native Hawaiian or other Pacific Islander	1 (< 1)	1 (< 1)	0
White	378 (78)	312 (79)	66 (77)
Other[b]	17 (4)	11 (3)	6 (7)
Prefer not to answer	14 (3)	10 (3)	4 (5)
Ethnicity: Hispanic/Latino			
Yes	32 (7)	26 (7)	6 (7)
No	441 (92)	363 (92)	78 (92)
Prefer not to answer	6 (1)	5 (1)	1 (1)
Missing	3 (< 1)	2 (< 1)	1 (1)
Age			
< 40	202 (42)	155 (39)	47 (55)
40–49	160 (33)	142 (36)	18 (21)
50–59	75 (16)	61 (15)	14 (16)
60 +	38 (8)	32 (8)	6 (7)
Missing	7 (1)	6 (2)	1 (1)
Current Job Position			
Professor	98 (20)	86 (22)	12 (14)
Associate Professor	93 (19)	83 (21)	10 (12)
Assistant Professor	138 (29)	126 (32)	12 (14)
Instructor/lecturer	6 (1)	6 (2)	0 (0)
Funder	5 (1)	4 (1)	1 (1)
Staff scientist	59 (12)	41 (10)	18 (21)
Postdoctoral researcher/fellow	34 (7)	22 (6)	12 (14)
Graduate student	31 (7)	18 (4)	13 (15)
Other[c]	18 (4)	10 (2)	8 (9)
D&I expertise			
Beginner	67 (14)	54 (14)	13 (15)
Intermediate	217 (45)	178 (45)	39 (45)
Advanced	138 (29)	116 (29)	22 (26)
Expert	60 (12)	48 (12)	12 (14)
Organization type where they work			
University or research organization	368 (76)	309 (78)	59 (69)
Hospital, health system, healthcare delivery organization	70 (15)	52 (13)	18 (21)
Governmental public health organization	16 (3)	10 (3)	6 (7)
Research funding agency	5 (1.0)	4 (1)	1 (1)
Community-based organization	2 (< 1)	2 (< 1)	0 (0)
Other[d]	21 (4)	19 (5)	2 (2)

Table 3 (continued)

	Total Sample ($n=482$)	US ($n=396$)	Canada ($n=86$)
Setting where they conduct most of their D&I/KT research			
Academic medical center or clinical settings	272 (56)	224 (57)	48 (56)
Community settings	153 (32)	134 (34)	19 (22)
Policy settings	18 (4)	11 (3)	7 (8)
Health departments	11 (2)	6 (1)	5 (6)
Other[e]	28 (6)	21 (5)	7 (8)
Academic area of graduate degree/fellowship[a]			
Behavioral or Social Sciences (e.g. social work, psychology)	239 (50)	212 (54)	27 (31)
Public Health (e.g., epidemiology)	209 (43)	177 (45)	32 (37)
Health Services Research	177 (37)	132 (33)	45 (52)
Medicine	93 (19)	78 (20)	15 (17)
Policy	29 (6)	25 (6)	4 (5)
Natural Sciences (e.g. biology, chemistry, physics)	12 (3)	9 (2)	3 (4)
Other[f]	73 (15)	48 (12)	25 (29)

[a] Percentages may total more than 100% as participants could select multiple response options

[b] Other self-reported races included: Indian, South European, Middle Eastern (3), Euroasian, Jewish, Acadian, Biracial, Mixed, and Slavic

[c] Other job positions included: Knowledge Translation Lead, Administrator, Chief Operation Officer, Biostatistician, among others

[d] Other organization types included: Veterans Affairs, Health Technology Company, Nonprofit organization, University and Government, management consulting firm, among others

[e] Other research settings included: Health system, long-term care homes, K-12 schools, public child and family service, US Department of Veterans Affairs medical centers, Safety-net healthcare systems, low- and middle-income countries, among others

[f] Other academic areas included: Nursing ($n=18$), regulatory affairs, management, business, learning health systems, exercise physiology, rehabilitation sciences, nutrition and physical activity, implementation science, among others

there were no statistically significant differences in out-degree for all research types by gender based on Kruskal–Wallis rank sum test; H = 3.22, $p=0.07$. We observed significant differences based on race. Respondents reporting White race reported giving (out-degree = 5.2) and receiving (in-degree = 6.1) more advice compared to individuals reporting Asian (out-degree = 2.9, in-degree = 5.3), Black (out-degree = 2.3, in-degree = 5.2), or other races (out-degree = 2.5, in-degree = 5.4). Kruskal–Wallis rank sum test revealed statistically significant differences based on out-degree for all research types based on race; H = 12.71, $p=0.01$. Post-hoc tests showed differences between Asian and White races were driving the significant racial differences (Z = -2.99, $p=0.028$). Across countries, expertise levels, genders, and races, individuals predominantly give and receive the most D&I advice on research initiatives, followed by grants and then career advice.

Assortativity coefficients are interpreted similarly to correlation coefficients (-1 to + 1) where values closer to + 1 indicate a higher tendency for individuals to form ties with other individuals who share the same trait (e.g., county, gender). Assortativity coefficients near zero indicate no tendency either way and larger negative coefficients indicate a tendency to form ties with others who do not share the same trait [27, 28]. Country had the highest assortativity across all advice types (range $r=0.88$ to $r=0.93$) with more than 95% of all ties in each network shared between researchers from the same country (Table 5). Figure 3 visually depicts the high assortativity within country. For gender, the assortativity coefficients ranged from $r=0.05$ to $r=0.11$ indicating no inherent tendency for individuals to form ties within their gender groups. Similarly, advice ties within D&I expertise level groups were not present with an assortativity coefficient range of $r=0.03$ to $r=0.05$. Assortativity by race overall did not show a high tendency to form ties with others within the same racial group (range $r=0.09$ to $r=0.20$), however, the coefficients were larger in both career ($r=0.15$) and other ($r=0.20$) advice-type networks indicating individuals may be more likely to form ties within racial groups for advice on career or other types of advice (vs. research and grants). For example, in research and grants networks, 65–66% of all ties were shared between individuals within the same racial group compared to 74% shared in the other advice network. Examples of other advice reported by participants included clinical

Table 4 Full sample network metrics

Network metric	Definition	Type of Advice				
		All	Research	Grant	Career	Other
Nodes	Number of connected people or nodes in the network	978	930	776	727	356
Ties	Links between nodes	3384	2841	1539	1262	473
Isolates	Nodes that have neither a direct nor indirect tie to any other node	600	648	802	851	1222
Density	Ratio of the number of actual links to the number of possible links in the network	0.0014	0.0011	0.0006	0.0005	0.0002
Largest connected component of advice network	Largest number of individuals who are connected to one another via direct or indirect ties	960	907	697	622	275
Average geodesic distance	Average length of all of the shortest paths from or to nodes in the network (e.g. "degrees of separation")	5.39	5.47	7.96	3.43	4.64
Average degree	Average number of ties each node has in the network (in and out)	4.29	3.60	1.96	1.60	0.60
Transitivity/Clustering coefficient	Probability that the adjacent nodes of a node are connected (clustering coefficient)	0.12	0.12	0.11	0.11	0.07

implementation, capacity building, and maintaining work/life balance.

Reasons for seeking advice

After identifying individuals from whom they sought advice, participants were asked to select the top three reasons they sought advice from these individuals. The most frequently identified reasons were 1) trust that the person would give them good advice (78%), 2) D&I content area knowledge of the individual (69%), 3) the individual is recognized as a successful researcher (42%), and 4) prior experience working together (34%). Group differences are noted in Table 6, with beginners more likely to endorse interest in pursuing similar career paths and desire to be mentored by the individual as reasons for seeking advice ($p < 0.02$), and less likely to select previously working with the individual as a reason, $p < 0.001$.

Table 6 outlines advice seeking reasons based on gender and race. Participants endorsed 'I trust they will give me good advice' (78%) and 'they have knowledge/experience in a D&I/KT content area I want to learn more about' (69%) as the top two reasons for seeking advice from an individual. Beginners (10%) were least likely to endorse 'we have previously worked together' as a reason for seeking advice compared to all other expertise levels (32–49%), $p < 0.001$. White participants were more likely to endorse seeking advice because 'we have previously worked together' (38%) compared to Non-White participants (25%), $p = 0.01$. Participants with beginner or intermediate expertise were more likely to endorse 'I am interested in pursuing a similar career path to them' ($p = 0.004$) and 'I would like to be mentored by them' than individuals with advanced or expert-level expertise ($p < 0.001$).

Key individuals in D&I advice networks

Individuals with the highest out-degree scores provide the most D&I advice. Figure 4 presents an example ego

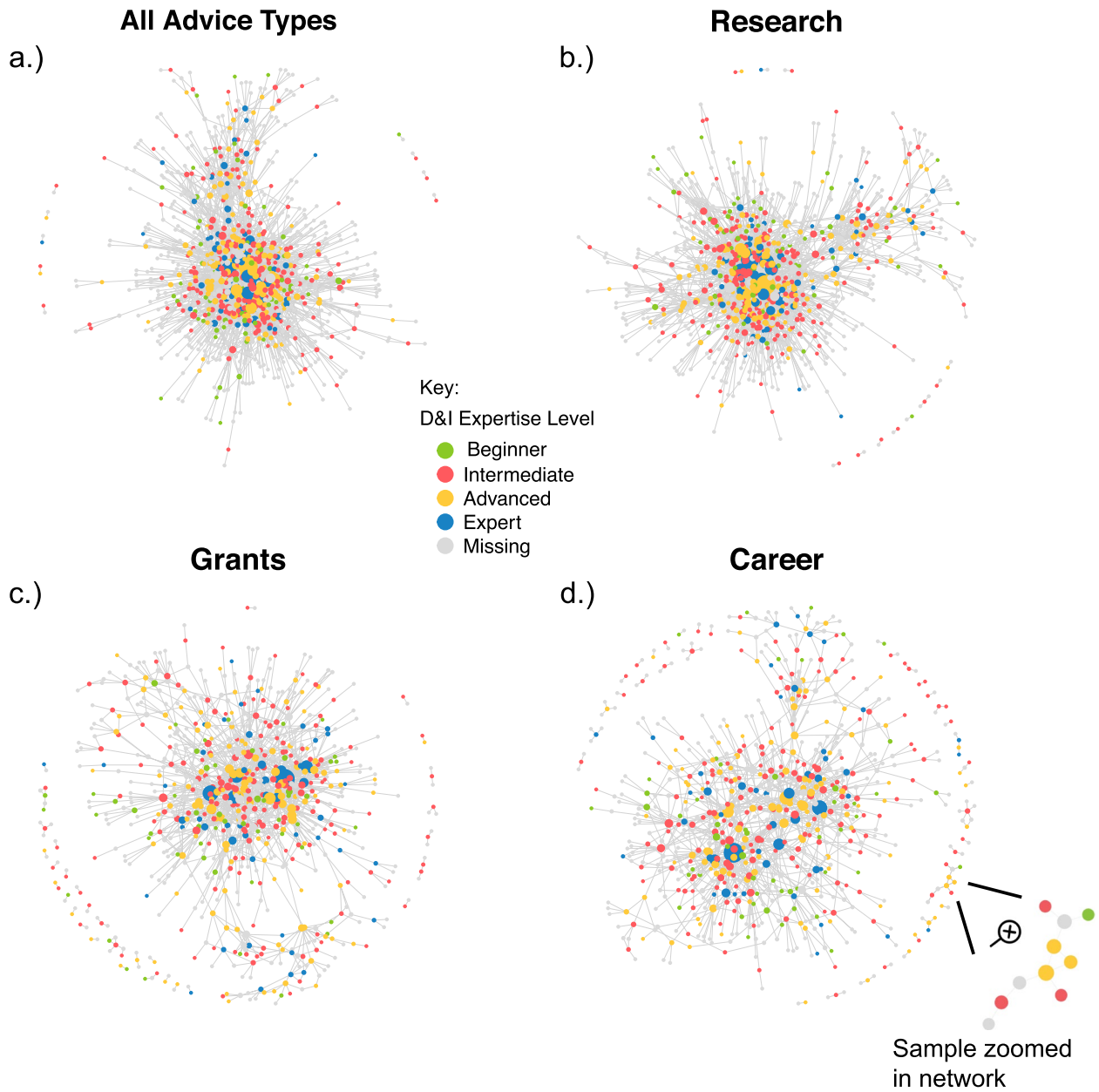

Fig. 2 Advice networks by level of D&I expertise

network, representing all the connections of one individual. The ego network depicts the broad impact one individual can have in the D&I advice network across career stages. Individuals with the highest scores for each type of advice are listed in rank order in Table 7, including 10 individuals from the US and 5 from Canada due to the smaller Canadian sample size. Individuals with any level of expertise were eligible for inclusion on the US and Canada lists, but all individuals identified with the highest out-degree scores had advanced or expert-level D&I expertise. Among these individuals, out-degree for all research types ranged from 36–76 for individuals in the US and 12–22 for those in Canada. To identify frequent advice-givers earlier in their D&I research careers we limited the sample to individuals with beginner or intermediate D&I expertise and identified the individuals with the highest out-degree scores, these individuals are also identified

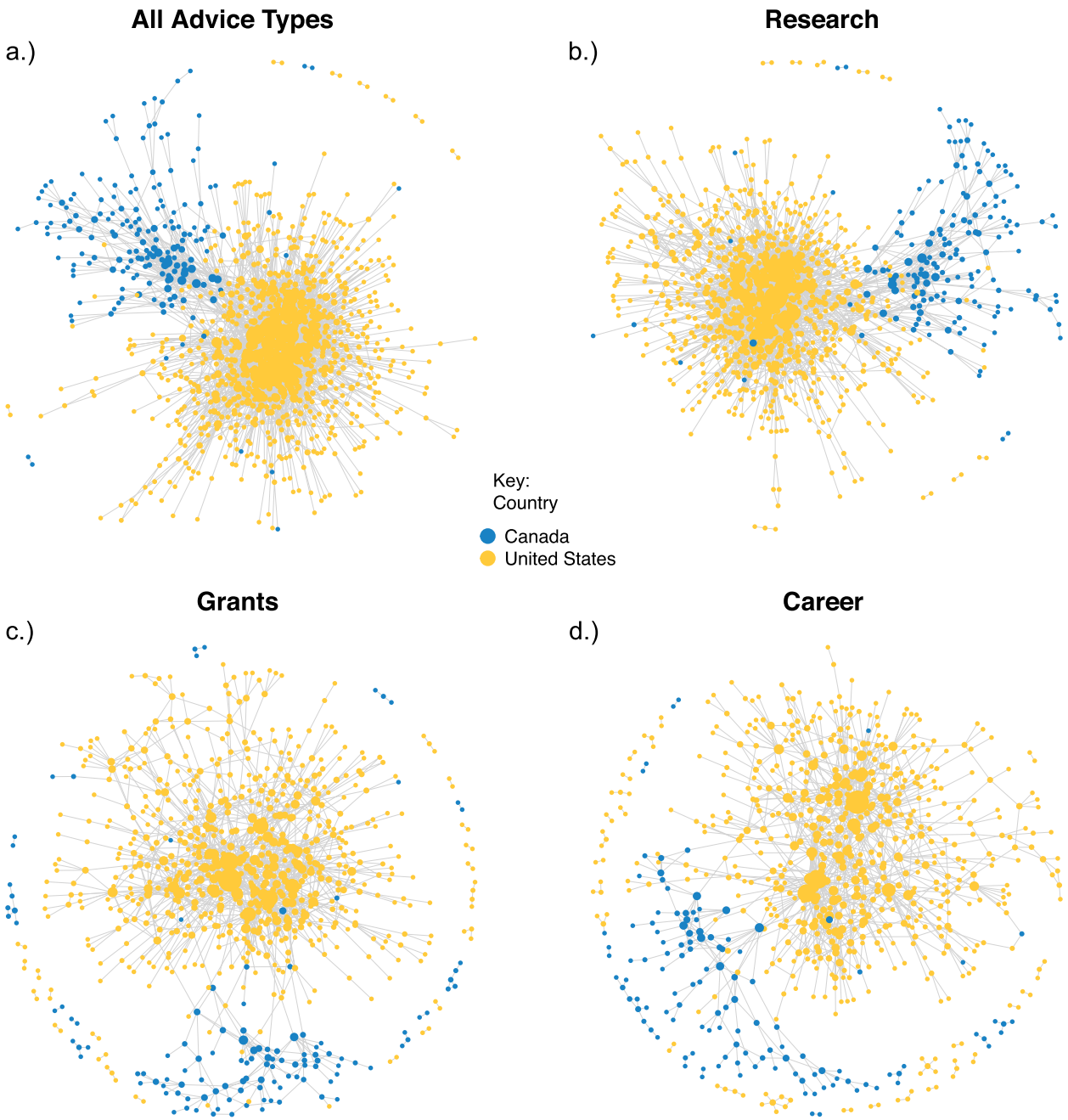

Fig. 3 Advice networks by country

in Table 7 (out-degree range for all advice: 12–13). For the presented rankings, D&I expertise level was based on the combined variable of self-rated expertise level and number of years of D&I experience. Some individuals who are more established in their overall research careers are included on the beginner/intermediate D&I expertise list based on their self-assessment of expertise and number of years of D&I experience.

Discussion

The current study documented D&I advice networks across career stages in the US and Canada. Respondents represented individuals with diverse D&I expertise levels, various practice settings, and academic training. Overall, findings demonstrate a somewhat dispersed network that still allows for relatively short paths of connection between most individuals. While the growing nature of

Table 5 Degree and assortativity statistics based on demographic characteristics and advice types

Characteristic		Out-degree Mean				In-degree Mean				Assortativity for All Research Types	
	n	All	Research	Grants	Career	All	Research	Grants	Career	r	p
Country										0.897	98%
Canada	356	1.1	0.9	0.5	0.5	1.2	1.0	0.5	0.5		
US	1222	2.4	2.1	1.1	0.9	2.4	2.0	1.0	0.9		
Expertise Level										0.04	31%
Beginner	67	0.8	0.5	0.4	0.3	4.4	3.7	2.1	2		
Intermediate	217	2.2	1.9	0.9	0.8	5.6	4.7	2.8	2.4		
Advanced	138	6.9	5.9	3.0	2.3	6.7	5.6	2.9	2.4		
Expert	60	11.9	10	5.7	5.0	6.9	5.6	2.3	1.2		
Gender										0.098	60%
Woman	371	3.8	3.1	1.7	1.4	5.8	4.9	2.7	2.3		
Man	103	7.6	6.7	3.2	2.6	6.1	5.1	2.6	1.9		
Non-binary	2	1	0.5	1	0	6.0	6.0	2.0	3.0		
Prefer not to answer	6	3.2	2.8	1.2	0.7	4.8	4.2	1.5	1.2		
Race										0.117	69%
Asian	49	2.9	2.5	1.1	1	5.3	4.3	2.6	2.4		
Black, African American or Canadian, Afro-Caribbean	25	2.3	1.7	1	0.8	5.2	4.2	2.6	2.8		
Other race or multiracial	56	2.5	2.1	1.1	0.9	5.4	4.5	2.6	2.2		
White	344	5.2	4.4	2.3	1.9	6.1	5.1	2.7	2.1		
Prefer not to answer	8	9.2	7.4	5.4	4.1	5.8	5.0	1.6	1.8		

r is the assortativity coefficient, which ranges from -1 to 1. Values closer to 1 indicate more assortativity, or a tendency to share ties across a shared attribute. Values closer to -1 indicate disassortive where there is a tendency to share ties with others outside of the specified attribute. p is the percent of all ties that are shared between notes that share the same attribute

the field is a challenge due to the increase in demands for training and mentoring, it is encouraging that most individuals in the network can still connect through a few intermediary connections. Findings highlight opportunities to further connect D&I researchers in the US with those in Canada, individuals with emerging skills in D&I research, and minoritized racial groups, who had fewer advice connections than individuals who reported White race. Training programs and structured pathways for new D&I researchers can help support these individuals and help more individuals progress toward leadership positions.

The network data highlight how information flows between countries and from individuals who are more established in the field to emerging D&I researchers. The limited overlap in advice networks between the US and Canada is not surprising due to the different funding and career structures between the two countries. Despite these differences, the wealth of knowledge and expertise offered by D&I and knowledge translation (KT)/mobilization researchers in these countries offers growth opportunities. Another example of information flow is between individuals at different career levels. The most dominant individuals in the network are those with advanced or expert-level expertise in D&I research, highlighting the need to enhance connections among early career researchers by establishing supportive structures, such as peer support groups, early career networking events, and mentoring programs. The data also revealed greater dispersion for grant and career advice compared to research advice, indicating grant and career mentorship should be the focus of future capacity building initiatives.

In comparison to Norton et al.'s 2012 D&I advice network survey [19], findings from the current study demonstrate a more dispersed network (average geodesic distance = 5.39 versus 2.60 in Norton et al.) with a higher degree of separation. The current network is also less dense (density = 0.0014 vs. 0.0027) and there is a lower probability that adjacent nodes are connected (clustering coefficient = 0.12 vs. 0.32) compared to Norton et al.'s study [19]. Comparisons between the current study and Norton et al.'s findings should be interpreted considering the differences in sample characteristics and network bounding in these studies. Based on the evolution of the field, different individuals were included in these

Table 6 Reasons for seeking advice on D&I research issues based on expertise level, gender, or race, n (%)

Advice Reason	Total ($n=482$)	Expertise Level					Gender			Race		
		Beginner ($n=67$)	Intermediate ($n=217$)	Advanced ($n=138$)	Expert ($n=60$)	*p*-value	Woman ($n=371$)	Man ($n=103$)	*p*-value	White	Non-White	*p*-value
I trust they will give me good advice	374 (78)	54 (81)	164 (76)	108 (78)	48 (80)	0.779	286 (77)	81 (79)	0.739	271 (79)	96 (74)	0.252
They have knowledge/ experience in a D&I/ KT content area I want to learn more about	333 (69)	49 (73)	148 (68)	99 (72)	37 (62)	0.458	264 (71)	65 (63)	0.117	235 (68)	95 (73)	0.314
They are recognized as a successful researcher	201 (42)	30 (45)	102 (47)	46 (33)	23 (38)	0.071	160 (43)	37 (36)	0.189	141 (41)	57 (44)	0.574
We have previously worked together	166 (34)	7 (10)	69 (32)	68 (49)	22 (37)	<0.001	121 (33)	43 (42)	0.085	131 (38)	33 (25)	0.010
I am interested in pursuing a similar career path to them	68 (14)	14 (21)	38 (18)	15 (11)	1 (2)	0.004	49 (13)	19 (18)	0.180	47 (14)	20 (15)	0.631
I would like to be mentored by them	72 (15)	29 (30)	40 (18)	9 (7)	3 (5)	<0.001	59 (16)	12 (12)	0.285	47 (14)	23 (18)	0.270
We are friends	53 (11)	6 (9)	17 (8)	23 (17)	7 (12)	0.070	33 (9)	19 (18)	0.006	41 (12)	12 (8)	0.185
I think they will empathize with the challenges I have experienced	42 (9)	5 (8)	20 (9)	11 (8)	6 (10)	0.936	32 (9)	8 (8)	0.782	29 (8)	11 (9)	0.991
We are at a similar professional level	26 (5)	2 (3)	9 (4)	10 (7)	5 (8)	0.339	24 (7)	2 (2)	0.074	18 (5)	7 (5)	0.947
We were/are in a training program together	28 (6)	5 (8)	18 (8)	2 (1)	3 (5)	0.054	20 (5)	7 (7)	0.586	16 (5)	12 (9)	0.059

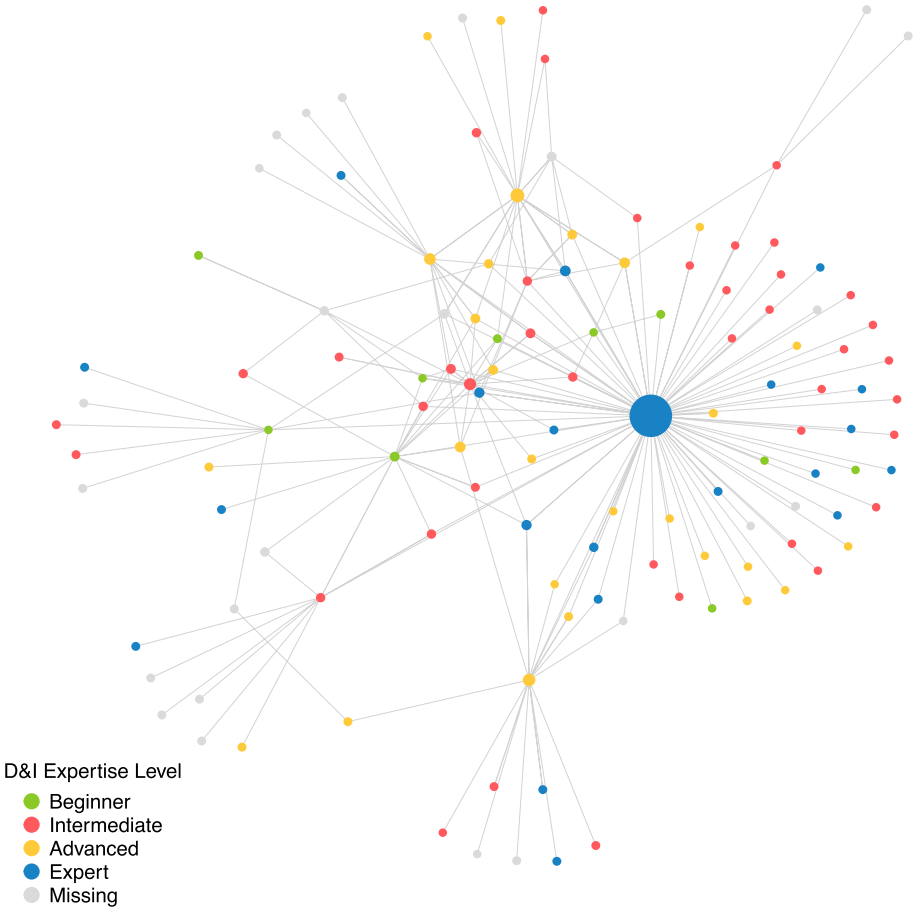

Fig. 4 Example ego network

network surveys. In the current study, there was a much larger number of nodes, or people in the network (978 vs. 421), and ties, or links between nodes (3384 versus 483). This pattern indicates that as the field has grown, there are simultaneously more individuals who are connected and an overall more dispersed network with more separation between individuals. A more dispersed and growing network may necessitate network interventions to activate novel interactions between certain segments of the network [35]. Network interventions can occur both locally, within single academic institutions and/or local communities, and nationally. Internal structures within institutions are vital to foster connections among D&I researchers and may include D&I works in progress and educational sessions. National initiatives can include structured application-based mentoring programs [6, 36], networking at conferences, and D&I special interest groups at professional or disease-specific conferences. Enhancing connections through these approaches is an ideal target for D&I scientists because diffusion of innovation theory is the foundation of network interventions [35, 37].

Six of the same individuals (G. Aarons, A. Baumann, R. Brownson, R. Glasgow, B. Powell, and E. Proctor) were identified as most influential within US D&I advice networks in Norton et al.'s work and the current study. These six individuals have been involved as faculty members in large implementation research training programs (e.g., Implementation Research Institute [38], Training Institute for Dissemination and Implementation Research in Health [5], Mentored Training for Dissemination and Implementation Research in Cancer [36]) over many years, so it is not surprising they continue to provide advice to a large number of scientists. All other top advice givers are newly identified in this study, including 12 on the US list, all individuals in Canada, and all identified with beginner or intermediate D&I expertise. In the broad, cross-cutting and interdisciplinary field of D&I research, identifying key sources of information is valuable for individuals new to the field [19, 39, 40]. Furthermore, including individuals in the earlier phases of their careers in this work is essential as we consider the capacity for growth in the field. As the field of D&I continues to grow globally, replicating these methods

Table 7 Rank order of individuals with the highest out-degree, indicating prominent advice givers, within each advice type

Category	All advice types	Research advice	Grant advice	Career advice
Total sample was eligible for inclusion (*n* = 482)				
US (*n* = 396)	Ross Brownson	Byron Powell	Ross Brownson	Ross Brownson
	Byron Powell	Ross Brownson	Rinad Beidas	Rinad Beidas
	Russell Glasgow	Russell Glasgow	Gregory Aarons	Elvin Geng
	Rinad Beidas	Gregory Aarons	Geoffrey Curran	Geoffrey Curran
	Gregory Aarons	Rinad Beidas	Russell Glasgow	Enola Proctor
	Geoffrey Curran	Geoffrey Curran	Byron Powell	Russell Glasgow
	Elvin Geng	Elvin Geng	David Chambers	Byron Powell
	Ana Baumann	Borsika Rabin	#8, preferred to remain anonymous	Gregory Aarons
	Rachel Shelton	Ana Baumann	Lisa Saldana	Anne Sales
	Enola Proctor	Alison Hamilton	Rachel Shelton	A. Rani Elwy
Canada (*n* = 86)	Ian Graham	Ian Graham	Jeremy Grimshaw[a]	Sharon Straus
	Sharon Straus	Jeremy Grimshaw[a]	Sharon Straus	Ian Graham
	Jeremy Grimshaw[a]	Justin Presseau	Justin Presseau	Laura Desveaux
	Justin Presseau	Sharon Straus	Julia Moore[b]	Jeremy Grimshaw[a]
	Melanie Barwick	Melanie Barwick		Justin Presseau
	Julia Moore[b]	Andrea Patey		
		Julia Moore[b]		
Sample limited to individuals with beginner or intermediate expertise				
Beginner or intermediate D&I expertise (*n* = 284)	Stephanie Mazzucca-Ragan	Robert Schnoll	Robert Schnoll	Michelle Keller
	Bo Kim	Todd Wagner	Jamie Faro	Jamie Faro
	Gila Neta	Stephanie Mazzucca-Ragan	Gila Neta	Emily Becker-Haimes
	Robert Schnoll	Reza Yousefi-Nooraie	Carolyn Audet	Sarabeth Broder-Fingert
	Todd Wagner	Jamie Faro	Gracelyn Cruden	Ashley Housten
		Bo Kim	Todd Wagner	Allison King
				Robert Schnoll

The number of names presented for Canada and the beginner/intermediate expertise group varies due to the number of ties, or the same out-degree number, between individuals. All individuals provided written consent via email to have their name included in this work

The beginner or intermediate expertise rating is based on the combination of an individual's self-reported experience level and number of years of D&I experience. Some individuals listed may not hold independent D&I research grants

[a] Dr. Jeremy Grimshaw is retiring in October 2024

[b] Dr. Moore is not in an active research role. Dr. Moore's self-identified role is in implementation science/knowledge translation support

in other countries may be beneficial. Given the limited connection between D&I advice networks in the US and Canada, we expect there may be even less connection between countries across the globe. Future global advice network studies should focus on countries that have established D&I collaborations between Universities and/or health systems (e.g. HIGH-IRI) [41]. This work can build towards future network interventions to expand the exchange of D&I advice to advance the field and enhance health globally.

To support growth in the field and to combat the limited availability of mentors and funding for training programs [1, 9, 39], the D&I field needs to prepare individuals of various experience levels better to provide advice and mentorship across career stages. More experienced mentors should consider the types of advice earlier career trainees are seeking when framing their advice. While trust and content area knowledge were the most common reasons people cited for seeking advice from an individual across career stages, early career researchers were more likely to seek advice based on their desire to pursue a similar career path to the individual. Experts can consider providing broader career advice to early career trainees in addition to more specific scientific advice. Expanding peer-to-peer mentoring initiatives can contribute to the growth of D&I advice networks and support early career researchers [10]. These initiatives have the potential to reduce disparities in mentoring opportunities and foster future scientific collaborations [10], which is essential given that individuals reporting

Asian, Black/African-American/African-Canadian, and other races had far fewer connections than individuals reporting White race. While peer mentoring offers promising opportunities to expand D&I advice networks and the capacity of the field to support early career researchers, these forms of mentorship should complement, not replace, mentoring relationships with more senior researchers [10]. Training programs should consider strategies to pair trainees and faculty members based on the trainee's preferences and needs.

One barrier to establishing peer mentoring groups as a new primary avenue for D&I advice is the desire of individuals to get advice from people who are considered experts in the field as well as the need for and benefits of sponsorship from more senior mentors. To seek advice effectively, individuals should consider their desired outcome and opportunities to consult a broader network. Researchers can consider documenting their mentoring team using a tool such as The National Center for Faculty Development and Diversity's Mentor Map [42] to strategize opportunities to learn from a broad group of mentors. Individuals earlier in their D&I research careers often aim to become familiar with new content areas, which may not require consulting field-leading experts. Instead, they can seek out publicly available resources (e.g., podcasts, webinars) [43] or individuals with applicable experience, such as somebody who used a relevant framework in a recent grant proposal or somebody who is familiar with online resources on specific topics. While this approach can help expand the D&I advice network, it can be challenging to identify individuals with specific skills when they are not considered experts in the field. Researchers should consider creatively highlighting their skills through social media (e.g., to demonstrate recent use of specific D&I frameworks or methods), institutional profiles, or volunteering to present on D&I topics at their home institution or other organizations. In addition to highlighting their skills, these avenues can be used to seek advice on certain D&I topics. Academic institutions and funders should support these initiatives, as they contribute to expanding D&I networks and developing successful researchers. Documenting D&I skills helps establish individuals as accomplished researchers and enhances their impact within the D&I advice network.

These findings should be interpreted within the context of the study's limitations. Our team, including individuals with in-depth knowledge of the field, went through a rigorous process to define and identify the study sample. However, our sampling methods were limited to publicly available information, and it is likely that some individuals engaged in D&I research were not invited to participate. Identifying all individuals engaged in a large and rapidly evolving field such as D&I is challenging. A strength is that participants were able to add the names of individuals we may have missed, and these data were included in the analysis. While our 32% response rate is sufficient for survey studies and is similar to the 31% response rate in Norton et al. [19], a higher response rate benefits network surveys [44]. The response rate resulted in a large amount of missing data in the study from non-respondents, which limited our ability to interpret the findings. Last, we did not ask participants about the frequency with which they sought advice and responses were limited to 10 individuals from whom they sought or gave advice. Collecting additional information may have further contextualized our results, but these choices were made to not over-burden participants.

Conclusions

As the D&I research field expands, it has also led to a more dispersed network. While the network is somewhat less connected than 10 years ago, most individuals can still connect to the main network through a few key individuals. Advanced and expert D&I researchers continue to hold the most prominent positions in the D&I advice network, but there are concerns about meeting the needs of the changing demographics of the field and limited capacity and funding for mentorship. Moving forward, it is crucial to expand opportunities for peer networking and mentoring, especially for minoritized racial groups, to strengthen the field's capacity.

Abbreviations

D&I	Dissemination and implementation
KT	Knowledge translation
SNA	Social network analysis
US	United States

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13012-024-01408-1.

Additional file 1. Full survey.

Additional file 2. Network Metrics by Country.

Acknowledgements

Not applicable.

Authors' contributions

All authors (AL, RJ, SM-R, RG, SS, WN, RG) were involved in the conceptualization of this work, provided feedback on study materials and manuscript drafts, and read and approved the final manuscript. AL identified the study sample based on the team-defined methods and drafted the initial manuscript. RJ completed data management, cleaning, and analysis, created the manuscript visualizations, and drafted portions of the methods section of the manuscript. RB provided oversight and mentorship throughout the research process.

Funding
This research was funded in part by the National Cancer Institute (P50CA244431), the Centers for Disease Control and Prevention (U48DP006395), and the Foundation for Barnes-Jewish Hospital. The findings and conclusions in this paper are those of the authors and do not necessarily represent the official positions of the National Institutes of Health or Centers for Disease Control and Prevention.

Data availability
The dataset supporting the conclusion of this article is not made publicly available due to the identifying nature of the data.

Declarations

Ethics approval and consent to participate
The Institutional Review Board at Washington University in St. Louis approved this study as exempt research.

Consent for publication
All individuals named in Table 7 of the manuscript provided written consent via email to have their name included in the publication.

Competing interests
Wynne Norton and Sharon Straus are on the Editorial Board for Implementation Science. All other authors declare that they have no competing interests.

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Received: 12 September 2024 Accepted: 18 November 2024
Published online: 29 November 2024

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