UNPACKING TRANSDISCIPLINARITY IN AGING AND TECHNOLOGY




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INTRODUCTION

Aging and technology is an applied research field that seeks to develop 'real-world' technological solutions that can support older adults and carers to live well for as long as possible (1-3). Developing technologies that are useful and meaningful to older adults and carers, and also readily accessible to them is a complex process that requires input from diverse stakeholders across academic/scientific, industry, government and citizens. Supporting active collaboration between these stakeholders ensures that the development and commercialization of technologies is driven by the necessary experiential and professional expertise (1-3). One mechanism to support such engagement is the application of a transdisciplinary approach to research (TDR) (4-7). Although TDR is well established as a mode of knowledge co-production in fields such as sustainability science and translational medicine, it is relatively new to the field of aging and technology, and there is limited understanding of its principles and methods in this area. Further, there remains confusion about the principles and practices that this approach entails including its distinction from multi- and inter-disciplinary research. Further, criteria have yet to be developed to guide individuals and funders when assessing the design, process, and outcomes of such initiatives (6, 8). Finally, no systematic evaluation of the effectiveness of TDR has been conducted to date. This is problematic given how time and resource intensive TDR is.

In Canada, efforts to mobilize transdisciplinary approaches in the field of aging and technology have culminated in the establishment of AGE-WELL, a pan-Canadian research network dedicated to the creation of technologies, services and best practices that benefit older adults and formal and informal care providers. AGE-WELL has a cross-cutting activity on Transdisciplinary Working (CC3) whose co-leads (Dr. Judith Sixsmith and Dr. Pia Kontos) and team members (Dr. Alisa Grigorovich, Ms. Mei Lan Fang, Dr. Mineko Wada) are developing principles and evaluation criteria to help define and assess TDR research quality and outcomes. One component of this effort has involved undertaking a scoping review (9) of aging, health/medicine, and technology literatures to unpack transdisciplinarity in aging and technology. Specifically, this scoping review captures the current state of peer-reviewed empirical evidence on the evaluation of TDR initiatives in terms of their research processes, outcomes (e.g. products, tools, technologies, guidelines, etc.), and uptake of the knowledge (e.g. evidence of social impact of research such as the adoption of evidence/outcomes/ products) in the real world.

To guide this scoping review, we asked the following question:

How have transdisciplinary research processes, outcomes, and impacts been evaluated to date?

We also set three objectives to address this question:

i. Develop a comprehensive understanding of how TDR is defined across the literature, and its key principles;
ii. Determine the benefits of this approach for enhancing research processes, outcomes and impacts; and
iii. Identify the facilitators and barriers to success.

METHODS

The search strategy and set of search terms (see Table 1) were informed by a preliminary literature search to identify a set of relevant articles on TDR (and its evaluation) across academic databases and Google Scholar. Using a series of scoping trials, we tested and refined our set of search terms across academic databases (e.g. Scopus, Medline). We also used these trials to identify and test our search strings to determine the optimal strategy to yield the most relevant articles without excessive irrelevant results. Given our interest in capturing a breadth of literatures on TDR across aging, health/medicine, and technology literatures, and in identifying articles that reported on the evaluation of TDR, our refinement of the search terms (Table 1) was a very time-intensive and iterative process. In particular, we found it challenging to operationalize our interest in capturing the influence of TDR on processes and outcomes, and to identify articles that exclusively focused on TDR, rather than treat it as a family of related approaches (e.g. many articles interchangeably used TDR with inter-disciplinarity and multi-disciplinarity).

Database Searches

The search strategy was restricted to English-language sources indexed in 3 databases (Medline/OVID, EBSCO, and ProQuest); peer-reviewed journal articles published between January 1, 2005 to December 31, 2015; and both empirical studies (all data types) and reviews. Based on the initial scoping trials, the focus was streamlined to include only articles that reported on TDR across three fields: aging, health/medicine, technology. Given that a key element of TDR is *an awareness of the problem context* — the broad social (or environmental) structure that creates and sustains the problem (6) — focusing our search on these fields ensured that we would review literature most relevant to understanding TDR in the context of aging and technology.

We intended to have 3 rounds of screening for the inclusion of articles in the scoping review (title; abstract; full article), however title-screening did not provide sufficient information to determine accurate inclusion/exclusion. Thus the screening process proceeded by applying two rounds (abstract and full article) of review. Review of abstracts was undertaken by at least two team members independently and concurrently using the following inclusion/exclusion criteria: 1) Is the article located in one of these 3 fields: health/medicine, aging, technology? If not, exclude; and 2) Does the article describe how TDR influenced research processes, outcomes or impact?

In cases of uncertainty, articles were included in the next round of review. Full article screening was similarly completed by at least two team members independently and concurrently. Final decisions on inclusion of contested articles were made by consensus among the four researchers. Using a written audit trail we tracked and resolved any disagreements and reached consensus through discussion among the four team members. Inter-reviewer agreement of >70% was achieved. Screening identified 996 articles, of which 23 met the criteria for inclusion. The breakdown of our search results is summarized below in Figure 1. An Excel spreadsheet was created with conceptual categories to guide data extraction of selected articles. These included the following: full article citation, geographic area, topic area (health, aging, or technology), research question, definition of TDR provided, how TDR was evaluated and the results of the evaluation (for process, outcomes or impact, barriers and facilitators noted).

A quality assessment framework was also developed to assess the quality of TDR in each article (Table 2) based on our preliminary literature review of key literature describing the principles of TD and TDR (5, 8, 10-12).This was based on three principles that we identified as

being central to transdisciplinary research, and which distinguish this approach from other cross-disciplinary research approaches (e.g. multi-disciplinarity). All three were determined to be equally necessary for optimal transdisciplinary research. The principles were translated into three questions that were used to evaluate each article included in the review:

1) Was there attention to complexity and holism?
   a. Did the initiative seek to address wicked, needs-driven, real-world problem? OR
   b. Does the design/analysis demonstrate an attentiveness and appreciation of complexity? (e.g. use of multiple methods, cross-disciplinary theoretical framing)

2) Did the initiative involve inter-sectoral collaboration between academics/researchers and another stakeholder sector (e.g. citizens, industry, policymakers)?

3) Was transformation achieved (e.g. did the TDR initiative lead to a real-world impact?)?

Data from the articles were extracted manually by two team members into the Excel spreadsheet. A thematic approach (13) was used to sort, identify patterns, and synthesize information within and across categories. Given the substantial heterogeneity of the articles, we opted to summarize our data descriptively to characterize different aspects of the existing literature.

Ensuring Rigor

Traditionally, scoping reviews rely on several strategies to ensure rigor, including having two reviewers for every step of the review process, developing a systematic search strategy based on a series of scoping trials, and searching for sources across multiple academic databases. We have used all of these in this review. However, the lack of universally accepted definition and criteria for defining and evaluating TDR (as well guidelines for how to distinguish it from other related cross-, multi- or inter disciplinary approaches in the context of a literature review) required that we develop and adopt additional rigour enhancing quality strategies. This was done through consensus-building, multiple rounds of discussion, and applied trial and error. As a first step we attempted to apply the eighteen principles described by Boger et al (3) to published literature to establish that the initiative was in fact TDR, and assessed its quality.

While these principles were helpful for grounding our discussions of how to define and evaluate TDR, we found that articles rarely provided sufficient information about the initiative that would allow us to conclusively determine whether it was in fact TDR and/or apply these principles to assess evidence of its effectiveness. Articles also varied widely in how they approached "evaluation" of TDR and its successes (or failures), and rarely explicitly assessed how TDR influenced research processes, outcomes, or impact directly. As such, we chose to adopt a more holistic understanding of evaluation that was not specific to a type of method or design, and to distil from the eighteen principles three key ones (e.g. complexity, inter-sectoral collaboration and transformation). We then created a working definition for each principle and assessed whether we could apply them to our screening and extraction efforts.

For example, inter-sectoral collaboration was defined as an initiative that had a research team made up from stakeholders from 2 or more sectors (e.g. academia/science, experiential, industry, government). An article that did not report on the make-up of the research team, or only included non-academics as test subjects was deemed inconsistent with the principle of inter-sectoral collaboration. We also used these principles to refine our inclusion criteria and develop a

template to guide extraction and analysis of data. Following this, we piloted our template (and its categories) with all four researchers independently extracting information from four articles into the categories and then meeting to discuss our results and discrepancies, and to refine definitions of the three principles further to ensure consistency. These additional strategies ensured that we were as rigorous and systematic as possible in identifying the articles included in this review and analyzing the evidence on the effectiveness of TDR.

FINDINGS

Overview of Selected Articles

Our final subset of selected articles for inclusion in the scoping review includes 20 articles (see Table 2 for description); 3 articles were removed at the extraction stage, one on the basis of not reporting on an evaluation of a TDR (14), and two for not reporting on a TDR initiative (15, 16). Any articles that were identified for potential exclusion during the process of extracting the data were reviewed by one of the study co-leads (JS, PK) who made the final decision.

Although the subset of articles included in the review represents a diversity of disciplines, all were from the fields of health/medicine with the majority focused on evaluating TDR in the United States (n=16) or Canada (n=6). No articles on TDR in the context of technology, or technology and aging were found which met our inclusion criteria. A large proportion of articles were descriptive program evaluations or quasi-experimental in design (n=7) rather than empirical analyses. A variety of methods was utilized to evaluate TDR: qualitative methods (e.g. interviews, focus groups, document review) to explore stakeholders' perspectives on their experiences (typically these were students or trainees of a university-based research and training program, or scientists collaborating on a TDR initiative), and quantitative methods (e.g. survey, bibliometrics, network analysis) to assess outcomes and interactions between stakeholders in terms of number and diversity (e.g. within and across sectors or disciplines). Nearly all included studies were restricted to a single phase of the research process and assessed TDR in the context of one research study/institute/program using traditional criteria for evaluating scientific excellence' (e.g. number of academic publications, number of trainees graduated, number grants received). Few articles formally evaluated the process of 'doing TDR as part of a research study, and even fewer evaluated the societal and 'real-life impacts of knowledge produced *specifically* as a result of TDR.

Definitions of TDR

The majority of articles defined TDR with direct citations or adaptations of Rosenfeld's (10) original definition (17-21). For example, some articles described TDR as research that involves collaboration between scientists from 2 or more academic disciplines (22-26). Others described TDR as an approach that aims to integrate and transcend disciplinary knowledge or perspectives through the development of a shared conceptual framework, and the use of methods or methodological approaches from multiple disciplines (23, 25-30).

Several articles also specified that a TDR approach is particularly useful to adopt in the context of developing solutions to complex social problems, or when seeking to develop a more holistic understanding of the research problem (24, 28, 30, 31). Only five articles explicitly defined TDR as research that either involves non-academic actors in the research process or includes them

in some way in knowledge production and exchange (27, 31-34). Two articles (35, 36) offered no definition or description of TDR.

Evaluation of the Effectiveness of TDR: Process, Outcomes and Impact

The influence of TD on the research process

TDR was reported to support the research process by enhancing integration of diverse knowledges from across disciplines and sectors. For example, Lambert and Monnier-Barbarino (24) found that this approach supported translation of uni-disciplinary knowledge into information that was readily accessible to others from different disciplines. More specifically, it allowed for frank dialogue between individuals from different disciplines (24), and supported sustained curiosity (24) or inquisitive interest in the points of view, perspectives, and concerns of others as reflected in the number and relevance of questions addressed to participants from other disciplines. TDR also enriched researchers' understanding of 'real-world' or complex issues (31), supported overcoming of disciplinary barriers (18, 24) and their detachment from personal disciplinary points of view (18). Consequently, adopting TDR enabled the generation of new ideas (23) and development of shared conceptual models that could guide future research (17, 30), or identify new directions for collaborations across research projects (20).

However, it was also reported that partial attempts at TDR can negatively impact processes as this can result in asymmetries in knowledge and authority between decision-makers and community stakeholders (27, 36). Such asymmetries may lead to tensions between community stakeholders and scientists that negatively affect potential for integration of knowledge and cause missed opportunities to enhance the applicability of research to real life (27, 36).

The influence of TD on outcomes

Successful implementation of TDR enhanced researchers' scientific productivity and capacity (20, 23, 25, 26, 32, 33, 35). For example, it augmented their cultural and social preparedness to conduct research, their existing understanding of health disparities, and their research skills or capacity. It was also reported to have increased academic outputs (e.g. number of peer-reviewed publications, scientific presentations, proposals submitted, and funded grants received) (25), joint-collaborations when writing articles (23), diversity of research disciplines represented by investigators on awarded grants (22), and the number of new investigators (23). Further, their engagement in TDR facilitated cross-disciplinary (26) and cross-institutional collaborations (22, 26), which supported international competitiveness (23). It was also found to have benefited trainees and early career researchers as it increased mentorship opportunities (24), and advanced career trajectories (22).

The influence of TD on impact

Six articles evaluated the contribution of TDR to knowledge and society beyond that of measuring traditional markers of 'scientific excellence' (e.g. number of publications, number of trainees graduated, number grants received). For example, Snow et al (29) and Orozco & Cole (31) evaluated the added value of a post-graduate program in TDR for enhancing the research preparedness and critical thinking skills of trainees. In particular, these two articles note that TDR enabled trainees' exposure to diverse methods and concepts not covered in their disciplinary training, and led to greater understanding of the research problem, including awareness of the "real-life" context. They also noted that TDR increased their tolerance for, and appreciation of,

diverse forms of knowledge and led to expressed personal commitment to conducting applied or translational forms of research. Harper et al (28) also noted that adoption of TDR led to positive changes in structure and functioning within research organizations that improved the quality of work life, including enhancing communication, professional development, and promoting supportive interpersonal relationships.

Three articles described how TDR also enhanced social impact through facilitation of public involvement in the research (22, 27, 36). These specifically noted how TDR enabled the development of stimulating and supportive partnerships between researchers and experiential stakeholders (22, 29), and led to community driven policy changes (36). Gutman et al (22) suggest that TDR facilitates public involvement by encouraging researchers to create opportunities to engage with public stakeholders and to seek their perspectives and feedback.

Ottoson et al (36) add to this by proposing that TDR can also raise public and policymakers' awareness of relevant research that requires public action through community demonstrations and networking. Finally, Daudelin et al's (27) evaluation of an unsuccessful attempt to integrate experiential stakeholders into a research network demonstrates that meaningful public involvement requires "deliberate, sustained efforts from all participants and institutions" (p.263). In particular, they suggest that it is important to invest in increasing the research skill and capacity of experiential stakeholder, as well as, modifying established research practices to fit experiential stakeholders' participation needs.

Finally, it was also noted that the 'social impact' of TDR may be difficult to assess in practice because this often exceeds the primary objectives of individual studies and also requires a longitudinal research design which necessitates additional time and resources (36). Another challenge to measuring social impact may be related to the tradition of evaluating contribution/impact of the research on policy by 'counting' or assessing policy outcomes (e.g. creation/change in legislation). This assumes that the relationship between research and policy is linear and ignores other types of research-related contributions to social knowledge that may be more difficult to capture numerically, such as lobbying efforts that inform policy (36). In particular, a focus on policy 'events' (e.g. counting number of bills drafted/acts enacted) ignores how policymaking is a process, and how research contributes to policy pre- and post-enactment (e.g. through framing the issue, mobilizing partners, evaluation of implementation).

Facilitators and Barriers to TDR

Within the selected articles for this scoping review, several facilitators to TDR were identified. First, we found that TDR is facilitated by significant and unique investment in resources and research infrastructure, including: administrative 'coordination centers' and other institutional management mechanisms (e.g. project team/working group) to facilitate/broker communication between dispersed stakeholders; organization and the sharing of data; and other forms of support such as quality monitoring and targeted feedback, and facilitating discussion forums or advisory groups (17, 20, 23, 25, 26, 28, 29). Given the time intensive nature of TDR, multi-year funding for research is particularly important (17, 29).

Second, many articles cited the importance of using multiple methods for communication (meetings, advisory panels), and communication platforms (face-to-face, virtual) to engage stakeholders, and to ensure that engagement is tailored to support different stakeholders' expectations/working styles/personalities and needs (17, 22-25, 27, 28, 35). In particular, it was

noted that as different stakeholders have varying levels of knowledge and use different and often discipline specific languages to communicate (academic/lay, biomedical/social), it is important to ensure that a variety of communication mediums and strategies are used. These can include the creation of targeted documents that distil and translate scientific results for community-based stakeholders (e.g. research brief), use of multiple knowledge exchange forums (e.g. large stakeholder forum, small discussion group, one-one session), and the establishment of a central 'program office' that oversees knowledge translation and exchange (22, 28).

Third, given the imperative to integrate and synthesize knowledge in TDR, it is important to engage stakeholders in collective planning/visioning around goal setting, development of a shared language, selection of research questions and methods, and at later stages, decision-making related to publication (25, 28, 29, 32). Diffusing power differentials by addressing asymmetries in knowledge (e.g. making knowledge accessible to all stakeholders) and by facilitating and validating different stakeholders' contributions in a careful, deliberate, and democratic manner (e.g. at the start, participatory or bi-directional integration that allows for direct influence on research/plans). This would ensure that non-academic stakeholders are able to participate effectively and feel that their perspective is valuable (22, 27). This is particularly important as engagement with non-academic stakeholders in the research enhances scientific stakeholders' ability to 'see' the applicability of their research in real-life (31). Examples of successful strategies applied have included the following: hosting of knowledge exchange forums (22, 28, 29, 36), and use of internships or other forms of applied or 'field-work' opportunities for trainees (31).

Finally, personal and team characteristics were cited as important. For example, having and/or developing close inter-personal relationships (e.g. built on mutual trust and respect) is an important facilitator of TDR (17, 20, 26, 28, 36). In addition, ensuring a diversity of stakeholders whose expertise is relevant to the problem space (20), and who share a personal and collective level of 'openness' or 'tolerance towards' the ideas of others, and are comfortable with uncertainty (17, 23, 32, 33) was identified as enabling TDR.

Although the articles claim that TDR generates innovative outcomes, it was noted that this approach is challenging to implement, and several barriers that can impede its success were identified. First, the elongated timespans and labour intensive requirements of TDR as compared to research that involves fewer stakeholders (17, 20, 22, 24-29, 32, 34, 35), as well as the uncertainty with respect to final outcomes of the research (32). Identified barriers may be exacerbated by the current academic reward mechanisms and modes of working (e.g. expectations of uni-disciplinary training, focus of research vs. expected focus in the field, number of products produced, competition vs. sharing of credit) that can make TDR appear as professionally 'risky' or challenging (21, 22, 28, 29, 31, 33, 34). However, given that there is also evidence that TDR may have a beneficial impact on advancing career trajectories (22), more research is needed to determine the extent to which this is primarily a barrier in attitude or knowledge, rather than in practice.

Second, the size and composition of the team, lack of knowledge on *how-to do* transdisciplinarity as well as insufficient planning and reflection around engagement of stakeholders may also act as barriers. For example, it may be difficult to attract the necessary stakeholders, especially non-academics to participate (22, 34). Geographic distance may also hamper collaboration (17, 20), and the use of online communication forums (e.g. primary or sole use of virtual communication strategies or virtual interaction forums) may make it more difficult to achieve mutual trust, complicity and diplomacy between stakeholders (23, 24). However, communication difficulties may also result from heterogeneity of background, training, and specific disciplinary language of stakeholders (17, 20, 22, 23, 29). Personal values and working practices of

stakeholders may also be problematic, especially 'closed mindedness' about the validity of the disciplinary methods and practices of others (17, 20, 21, 29, 31). Finally, unaddressed hierarchies/asymmetries in expertise and authority between stakeholders (17, 27, 28), and inflexible models of involvement (17, 27) may result in mismatches between scientific and experiential stakeholders' expectations (21) which can lead to neglect of stakeholders' concerns (27). All of these barriers may impede collaboration and knowledge integration between scientists and experiential stakeholders.

Limitations

Two main limitations exist. This scoping review only included evaluations of TDR from published English-language sources from the years 2005-2015 and indexed in three academic databases. There may be relevant literature on TDR that has been produced in other languages, or may be found in other sources, included grey literature. Given this is the first scoping review of TDR in this area, we chose to focus on peer-reviewed literature. However, it will be important to include other sources in a subsequent review. The second main limitation is that we restricted our search to studies that explicitly used the term 'transdisciplinary' or 'transdisciplinarity' to describe the research approach. Although placing this restriction on the inclusion of sources was necessary in order to keep the review manageable, transdisciplinarity is a relatively new term in aging and technology research and there is some disagreement as to whether it is conceptually different from other types of cross-disciplinary research (4). As such, we acknowledge that we may have missed other potentially relevant research evidence due to our chosen methodology and inclusion criteria.

CONCLUDING REMARKS

Our review suggests that TDR is an effective research approach that has benefits for both researchers and for society. However, supporting successful implementation of TDR requires explicit and ongoing investment of personal and structural resources that build the requisite capacity needed across disciplines and sectors for engaging in meaningful dialogue and co-production of knowledge. In particular, our findings highlight the importance of attending to team composition and dynamics and supporting collaborative synergies between and across diverse and geographically dispersed stakeholders using multiple methods and means of involvement. This is crucial as synergy is not necessarily an inherent property of TDR, but rather is something that requires conscious and reflective efforts to ensure that stakeholders not only work *in a group*, but work as 'a (coherent) team' (7, 37).

Our review identified a number of significant gaps in the evidence base of TDR, and in particular, limitations of existing knowledge for guiding future TDR efforts. First, we found that evaluations of TDR continue to focus on assessing traditional outputs such as academic publications, with limited attention paid to evaluating the knowledge production process itself (including how epistemological integration of knowledge happens across diverse actors, disciplines and sectors). In particular, little research has explored how TDR enhances the impact of knowledge production and exchange on the 'real world,' through changes in practice and policy. Even fewer articles described specific social practices or strategies that were used to effect social impact or change. This was captured by our quality appraisal that found that only six articles reported that the initiative was transformative, or that TDR led to some form of social impact.

Second, articles also rarely reflected on the added value of TDR for producing complex solutions to complex problems, or how these types of solutions might have been different (or less effective) if TDR had not been used. Limited research has also explored how TDR adds value to

traditional (uni-disciplinary) academic training or advances expected career trajectories as a result of collaboration with diverse stakeholders within and across academia. Given that integration of knowledge is thought to be crucial for the creation of solutions that 'transcend' disciplines and sectors, the existing evidence base may not provide us with sufficient information for the development of robust quality criteria that can assess this in practice. As such, while there is some evidence that suggests that TDR has social impact, more research is needed to strengthen the claim that TDR produces 'socially robust results that contribute to solving' real-life problems (Polk, 2015)

Third, despite the call to adopt TDR in aging and technology, and evidence that such research (38) and practice (39) is already occurring, our review found no articles that have evaluated TDR in this context. This is concerning as this approach has the potential to enhance successful commercialization of technologies by ensuring that these are both meaningful and useful, as well as readily accessible (38). In-vivo evaluations of current TDR initiatives in aging and technology are thus urgently needed to support the design and greater adoption of TDR across Canada and beyond. This is something that the AGE-WELL cross-cutting activity (CC3) is currently involved in through our longitudinal research study exploring TDR practices across AGE-WELL network members. We hope that in demonstrating that TDR can enhance some research outcomes and processes, this review will be useful for guiding researchers, organizations and funders interested in improving the effectiveness and social relevance of research in aging and technology.

Recommendations:

1. The investment of personal and structural resources are needed to optimize the success of TDR initiatives.

2. Ensuring the composition of the research team includes representation from multiple disciplines and from academic and non-academic sectors.

3. Future research should include evaluation of social impact and the 'added value' of TDR.

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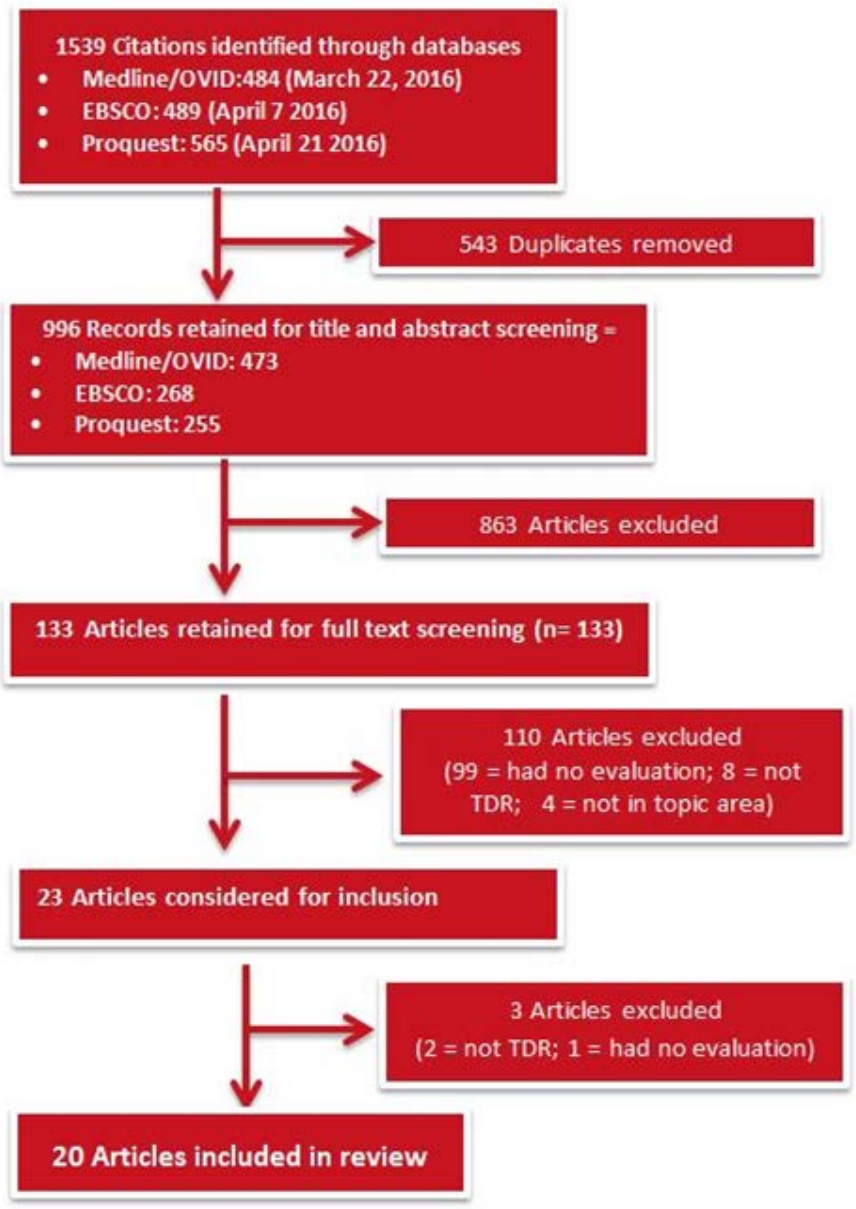
APPENDIX I

Table 1 Search terms for the scoping review

Search terms		
Set 1 (Trandisciplinary)	Set 2 (Research outcomes)	Set 3 (Social change)
Transdisciplin*	Outcome Evaluat* Output Product Solution Strategy Tool Prototype Case Model Framework Guideline Intervention Practice Evidence-based Metric Analysis Indicat*	Impact Adopt* Implementation Mobilization Translation Transfer Diffusion Influence* Transform* Usability Real-world Soci* Policy

APPENDIX II

Figure 1 Scoping review search strategy and results



APPENDIX III

Table 2 Characteristics of articles included in review

Citation	Country	Area of focus	Type of design	Method(s) used	Evaluation of process	Identified outcomes	Identified impact
(27)	Canada	Health	Research study	Interviews, document review, observations	Assessed integration and involvement of stakeholder groups	Partial integration of experiential stakeholders in knowledge exchange and decision-making	Public involvement found to be valuable for improving social relevance of research and policy
(35)	United States	Health	Program evaluation	Survey	Assessed TD education, curriculums, training, mentorship components and processes	Enhanced research productivity	Information not available
(22)	United States	Health	Research study	Interviews, survey	Information not available	Enhanced diversity of research disciplines among investigators in awarded grants	Development of stimulating and supportive partnerships; improved career trajectories of early career researchers
(26)	United States	Health	Research study	Survey	Information not available	Enhanced engagement of researchers in cross-disciplinary collaborations	Increased number of proposals submitted and funded; increased diversity of disciplines represented
(25)	United States	Health	Quasi experimental	Bibliometric indicators	Assessed collaborative processes (e.g. interpersonal collaboration, cross-disciplinary activities, overall productivity)	Enhanced research productivity; increased number of cross-centre collaborations	Increased number of articles **published** in high impact journals

Citation	Country	Area of focus	Type of design	Method(s) used	Evaluation of process	Identified outcomes	Identified impact
(28)	United States	Health	Program evaluation	Interviews, survey	Assessed operations within TDR organizations (e.g. goal clarity, group functioning, task structure, group composition, performance)	Structural & organizational changes to enhance integration of diverse knowledge	Changes made improved quality of life of staff
(32)	United States	Health	Research study	Description	Assessed long-term trajectory of TD working and performance	Enhanced research productivity	Information not available
(24)	Canada	Health	Research study	Description	Assessed familiarization with other disciplinary languages; assessed raised awareness of TD working	Increased mentorship opportunities; enhanced knowledge translation and exchange; facilitated communication across disciplines	Information not available
(23)	Canada	Health	Program evaluation	Interviews, focus groups	Assessed logistics and practicalities of TD working (e.g. group work, interactive learning) and collective decision-making	Enhanced research productivity; increased number of new investigators; enhanced international competitiveness	Increased exposure to new and international knowledge; increased joint-collaboration on academic writing
(21)	Australia	Health	Research study	Social network analysis, interviews	Assessed hierarchal structure of roles & TDR activities: leading, decision-making, coordinating, communicating, and opinion leading	Information not available	Information not available

Citation	Country	Area of focus	Type of design	Method(s) used	Evaluation of process	Identified outcomes	Identified impact
(19)	United States	Health	Research study	Survey	Assessed psychometric properties of scales measuring collaborative processes and transdisciplinary integration	Information not available	Information not available
(31)	Ecuador	Health	Research study	Observation, interviews, graphic visualization	Assessed TD curriculums, training, mentorship components and processes; assessed multidisciplinary conflict resolution	Enhanced understanding of complexity of 'real-world' issues	Increased awareness of diverse forms of evidence and positive changes in attitudes towards other disciplines
(36)	United States	Health	Research study	Bibliometric indicators, document review, interviews	Assessed long-term trajectory of TD working & performance	Partial integration of experiential stakeholders in knowledge exchange decision-making	Community driven policy change
(33)	United States	Health	Research study	Autobiographical reflection	Information not available	Enhanced research productivity	Enhanced publically perceived impact from research outcomes
(18)	United States	Health	Research study	Network analysis, survey	Assessed output measures to evaluate TD (e.g. grant applications, conference abstracts and publications)	Crossing disciplinary barriers; detachment from own disciplinary point of view	Information not available

APPENDIX IV:

Table 3 Quality appraisal of articles included in review

Citation	Attention to complexity & holism	Involved inter-sectoral collaboration	Transformation was achieved
(27)	Yes	Yes	No
(35)	Yes	No	No
(22)	Yes	Yes	Yes
(26)	Yes	No	No
(25)	Yes	No	Yes
(28)	Yes	Yes	Yes
(32)	Yes	Yes	No
(24)	Yes	No	No
(23)	Yes	No	No
(21)	Yes	No	No
(19)	Yes	No	No
(31)	Yes	Yes	Yes
(36)	Yes	Yes	Yes
(33)*	Yes	Yes	Yes
(18)	Yes	No	No
(34)	Yes	No	No
(17)	Yes	Yes	No
(30)	Yes	Yes	No
(29)	Yes	No	Yes
(20)	Yes	No	No

Notes: Articles with perfect scores are highlighted in red. Asterisk indicates refection of one scientist about his own collaborations/body of work.