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PERSPECTIVE

# Diverse perspectives on interdisciplinarity from Members of the College of the Royal Society of Canada

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## Abstract

Various multiple-disciplinary terms and concepts (although most commonly "interdisciplinarity," which is used herein) are used to frame education, scholarship, research, and interactions within and outside academia. In principle, the premise of interdisciplinarity may appear to have many strengths; yet, the extent to which interdisciplinarity is embraced by the current generation of academics, the benefits and risks for doing so, and the barriers and facilitators to achieving interdisciplinarity, represent inherent challenges. Much has been written on the topic of interdisciplinarity, but to our knowledge there have been few attempts to consider and present diverse perspectives from scholars, artists, and scientists in a cohesive manner. As a team of 57 members from the Canadian College

of New Scholars, Artists, and Scientists of the Royal Society of Canada (the College) who self-identify as being engaged or interested in interdisciplinarity, we provide diverse intellectual, cultural, and social perspectives. The goal of this paper is to share our collective wisdom on this topic with the broader community and to stimulate discourse and debate on the merits and challenges associated with interdisciplinarity. Perhaps the clearest message emerging from this exercise is that working across established boundaries of scholarly communities is rewarding, necessary, and is more likely to result in impact. However, there are barriers that limit the ease with which this can occur (e.g., lack of institutional structures and funding to facilitate cross-disciplinary exploration). Occasionally, there can be significant risk associated with doing interdisciplinary work (e.g., lack of adequate measurement or recognition of work by disciplinary peers). Solving many of the world's complex and pressing problems (e.g., climate change, sustainable agriculture, the burden of chronic disease, and aging populations) demands thinking and working across long-standing, but in some ways restrictive, academic boundaries. Academic institutions and key support structures, especially funding bodies, will play an important role in helping to realize what is readily apparent to all who contributed to this paper—that interdisciplinarity is essential for solving complex problems; it is the new norm. Failure to empower and encourage those doing this research will serve as a great impediment to training, knowledge, and addressing societal issues.

**Key words:** interdisciplinarity, academic institutions, universities, funding, scholarly activity, boundary crossing, barriers

## 1. Introduction

The words "interdisciplinarity," "multidisciplinarity," and "transdisciplinarity" are commonly used by academic institutions, granting agencies, and scholars. These terms and concepts have rather specific definitions (see Zeigler 1990; arj.no/2012/03/12/disciplinarities-2/; **Fig. 1**), and are often misused and misunderstood. For the sake of brevity and inclusivity, the term "multiple disciplinarity" (as per Dick et al. 2016) is often used to describe all types of crossing and integration between disciplines and professions and (or) nonacademic institutions (Pooley et al. 2014). Some have argued that the various terms are so normalized as administrative labels that in practice they are virtually meaningless (Wasserstrom 2006). However, many scholars, particularly emerging scholars and those at the early stages of their careers, increasingly identify as being engaged in one or more of the multiple disciplinary realms. The topic of multiple disciplinarity has been front of mind in the global context, but is particularly salient in Canada, where it has been identified as a thematic priority area for exploration

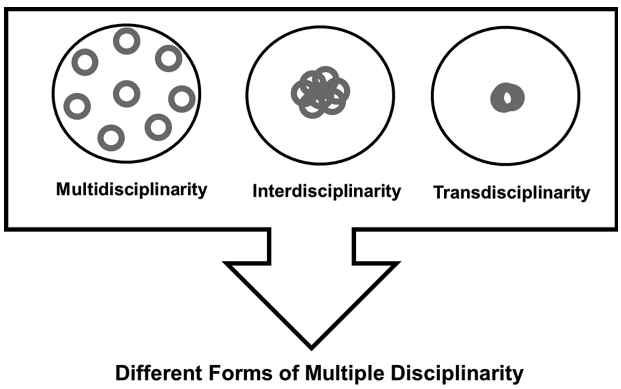


**Fig. 1.** Different forms of multiple disciplinarity. Inspired by Zeigler (1990) and arj.no/2012/03/12/disciplinarities-2/.

by the recently formed College of New Scholars, Artists, and Scientists of the Royal Society of Canada (the College).

Much has been written on the topic of multiple disciplinarity, including deep philosophical treatments (Klein 1990; Metzger and Zare 1999; Smelser 2004; Repko 2008; Barry and Born 2013), empirical case studies (e.g., Cummings and Kiesler 2005; Rhoten and Pfirman 2007; Huutoniemi et al. 2010), frameworks (e.g., Jantsch 1972; Gunawardena et al. 2010; Siedlok and Hibbert 2014), perceptions (e.g., in education: Hasni et al. 2012), the nature of design thinking (e.g., Antle 2017; Lindgaard and Wesselius 2017), and even "how-to" guides directed towards scholarly activity (e.g., Weingart and Stehr 2000; Lattuca 2001; Graybill et al. 2006; Hirsch Hadorn et al. 2008; Frodeman 2010). Some have advocated for multiple disciplinary approaches (e.g., Rhoten and Parker 2004; Pfirman and Martin 2010; Dick et al. 2016), whereas others have leveraged significant criticisms or identified major challenges (e.g., Brewer 1999; Jacobs and Frickel 2009; Alvargonzález 2011). Inter-, multiple-, post-, and trans-disciplinarity have also been explored in environmental, feminist, and Indigenous scholarship—important perspectives for the Canadian context (Smith 1990; Cruikshank 2005; Kitch 2007). In some cases, various institutions have provided guidance intended to facilitate multiple disciplinarity (e.g., The Canadian Academy of Health Science (Hall et al. 2006); National Academy of Sciences (USA) 2004; American Academy for the Advancement of Science (Derrick et al. 2012); National Research Council (USA) 2014). There are many examples of where these concepts have been discussed in the context of emerging research areas that bridge existing disciplines or fall between them (e.g., environmental conservation, Andrade et al. 2014; eco-health, Wilcox and Kueffer 2008; mechatronics engineering, Habib 2008). Interprofessionalism emerged in Canada as an effort to overcome confusion with interdisciplinarity in health care (D'Amour and Oandasan 2005). An interprofessional framework was developed to conceptualize links between education and clinical practice. This framework has since been used for research exploring determinants and processes inherent in interprofessional collaboration. Yet, despite these efforts, to our knowledge there have been few (except Blackmore and Kandiko 2011) attempts to consider and present diverse perspectives on multiple disciplinarity from emerging scholars, artists, and scientists that identify as multiple disciplinarians.

Here we share our collective experiences and wisdom related to working in multiple disciplinary spaces with the broader community (e.g., any such institution or organization that wishes to bring together people from various disciplines). Our team of 57 coauthors are emerging scholars, artists, and scientists from a Canadian academy, the College, who self-identify as being engaged or interested in multiple disciplinarity and who provide unique intellectual, cultural, and social perspectives from across Canada. Young Academies around the world are viewed as a nexus for diverse thought leaders, idea generators, and communities of action needed to tackle complex problems (e.g., the grand challenges, Douagi and Svahn 2012) at national and global scales (i.e., Global Young Academy, see Brück et al. 2010). The diversity of members and collective interest, creativity, and expertise, along with demonstrated multiple disciplinarity thinking, is part of what makes the Young Academy movement so unique and potentially transformational (Alberts 2011). We recognize that given the authorship (i.e., all affiliated with a Canadian institution at time of election) the paper has an inherently Canadian context. Nonetheless, we are confident that the messages here are relevant to those working in other jurisdictions, especially those in developed, democratic countries that value and support the academy. For sake of clarity, we focused our perspectives on "interdisciplinarity" given that it is probably the most used and best understood term. We explore the reasons for engaging in interdisciplinary scholarship, as well as the facilitators, the barriers, and the risks of doing so. We hope to stimulate ideas and debate on the merits and challenges associated with multiple disciplinarity while also providing tangible examples of what has worked, so they can be embraced by others, and what has failed or represent risks or barriers so that we can work as a community to improve or overcome

them. The only other scholarly paper we have found that exploits the notion that emerging scholars can offer a valuable, alternative perspective is Bridle et al. (2013), where the early-career authors muse about the facilitators of interdisciplinary research.

## 2. Approach

The authorship team for this project spanned Canada in terms of region, institution, culture, language, and discipline, but all have a common thread of being scholars who have engaged or do engage in multiple disciplinarity. Members of the College must be nominated for membership within 15 years of their terminal degree. At the time of launching this initiative (November 2017) the College counted 284 members representing diverse backgrounds, expertise, regions, cultures, and institutions. Given that the College is Canada's first formal national system of interdisciplinarity (this term is used in the formal mission of the College), with recognition for this emerging generation of Canadian intellectual leadership focusing on a highly productive stage of their careers, there is much potential for this group to influence the Academy and scholarship in Canada. By creating a single collegium, new advances in understanding will emerge from the interaction of diverse intellectual, cultural, and social perspectives. Indeed, one of the tenets of the College is that it represents the generation of emerging scholars and artists exploring multiple disciplinary research across established boundaries of scholarly communities through experimentation with new theoretical perspectives and methodological tools. However, is this being realized? What is working and where are the systemic barriers or challenges to doing multiple disciplinary work?

We emailed an information request to all members of the College (from the first three cohorts, 2014–2016). The members had the opportunity to contribute their input (in silico) after which the data were thematized to help structure a paper. The information request was framed such that it was not a survey (see Rhoten and Parker 2004 for a survey specific to environmental interdisciplinarians)—that is, it was a way of soliciting perspectives from diverse College members who would become co-authors on this paper. This paper is a perspective article representing our collective thoughts on the topic. We present no formal quantitative analysis, nor do we attempt to scale up our specific experiences to the broader academy. Instead we use quotations, word clouds, and other creative approaches to paint a picture of what interdisciplinarity means in our varied professional contexts. There is certainly much room for quantitative surveys on this topic (see Rhoten and Parker 2004; Mâsse et al. 2008; Schary and Cardinal 2016; Milman et al. 2017), but our paper is deliberately qualitative to obtain detailed and nuanced insights. This qualitative approach could inform future quantitative approaches. In many ways, our paper represents the synthesis of a brainstorming session for which we think there are messages worth sharing with the broader community—a commentary on interdisciplinarity from our collective and individual perspectives. Perspective articles (also termed opinion, editorial, commentary, and viewpoint articles depending on the outlet) are common and provide an opportunity for different voices to be heard (Fontanarosa 2014; Kolar et al. 2016). We also acknowledge that this paper serves a secondary goal of helping to define what it means to be a member of the College. Although on the surface this may not be inherently interesting to the broader community, it is useful for establishing an "identity" for the College and in understanding the extent to which members of the College or other young academies may differ from that of the broader community.

## 3. What does interdisciplinarity mean to College members?

The "textbook" definition of interdisciplinarity (or interdisciplinary) is the combining of two or more academic disciplines into one activity (e.g., a research project; see Jacobs and Frickel 2009; Borrego and Newswander 2010; Strober 2011). It is about creating something new by crossing and then integrating across boundaries (Aldrich 2014). However, this group of authors has diverse perspectives

on the meaning and interpretation of interdisciplinarity. Here, most authors define or view interdisciplinarity as an enrichment to "ways of knowing" (methods, theories, concepts, tools) and to interpersonal relationships (collaborations, team-work, understanding), as well as enrichment from an epistemological perspective in which researchers learn new ways and perspectives to understand the world and the various problems they seek to understand and to solve them. According to our members, interdisciplinarity is a way of building and creating new and multifaceted knowledge:

> "Interdisciplinarity necessarily invokes thoughts of collaboration and teamwork, a coming together of people from different disciplines to bring their expertise to bear on a common problem or set of problems. It summons the adage that the 'whole is greater than the sum of its parts.' "

> "Interdisciplinarity involves more than just crossing boundaries. It involves taking on a new lens and new perspective for seeing a topic, and importantly, going outside of your comfort zone. It involves questioning one's own 'ways of knowing,' challenging the ways in which one has been trained and opening new possibilities for creating, conceptualizing, and building knowledge."

A frequency word analysis of responses revealed that many valued interdisciplinary for its ability to bring together different knowledge, views, and approaches to solve problems (as shown in Fig. 2). Many people understood that engaging in interdisciplinary research is solution-driven and produces deliverables for the greater good.

In contrast, some felt that interdisciplinarity is simply an academic buzzword, used to signal an openness to other disciplines:

> "I consider it a mostly meaningless academic buzzword. I do use it, however, but largely in grant applications and similar genres of writing in which I try to give institutions the kinds of text that I presume they are looking for."


Fig. 2. What does interdisciplinarity mean? A word cloud of the top 50 words from text written by the authors describing what interdisciplinarity means to them. Larger words illustrate greater frequency counts. (Word cloud created with Nvivo v. 12, QSR International Inc., Burlington, MA.)

There are other challenges such as finding a shared language (every discipline has its own buzzwords too) and transcending disciplinary norms to forge something new. This can sometimes be tricky, such as with contrasting disciplinary conventions around authorship or in terms of ethics. In qualitative research for example, there are very different disciplinary norms in terms of the naming of individual informants, narrators, interviewees, and participants and in data sharing or secondary reuse of data. Even collaborative writing can be a challenge, as disciplinary norms range widely in the use of the first person ("I" and "we") versus third person ("the paper argues"), or even in the use of tense as historians often insist on the past tense (High 2018).

Interdisciplinarity increasingly means not only crossing boundaries, but also working across both scientific and nonscientific boundaries as well as integrating other forms of knowledge. For example, some of our team members felt that interdisciplinarity had become too narrow or confining in an age where more and more university researchers are working in partnership with the communities that we study. A commitment to "community–university collaboration" (High 2015), "decolonizing research" (Smith 1990), or "sharing authority" (Frisch 1990), has deep roots in feminist and liberatory (Freire 2007; Miller et al. 2017) praxis, but it has been given new momentum with policy changes by the major academic funding councils favouring research done in partnership, ethical sharing, and the new political environment following Canada's Truth and Reconciliation Commission. More recently, the Canadian Institutes of Health Research (CIHR) have encouraged an integrated knowledge translation approach with knowledge users (including patients, policy-makers, practitioners) on research teams to identify the research question, design the recruitment strategy, and select the relevant outcomes (cihr-irsc.gc.ca/e/45321.html). Hence the encouragement to consider various perspectives when designing research, interpreting findings, and disseminating the results. How we collectively respond to, or think about, the questions raised about inherited structures of power and the politics of the interdisciplinary gaze itself is an open question, particularly as interdisciplinary scholars have not necessarily been any more willing to change the academy's overall relationships with those we study (or reconsider who the "we" is within the research process).

## 4. Benefits of engaging in interdisciplinarity

Nevertheless, some view interdisciplinarity as more natural, holistic, or organic in comparison with traditional disciplinary modes of academic production. For example,

> "... history is an ancient and broad topic that predates even the idea of disciplinary distinctions. Herodotous, for example, wrote a famous history that is, by our standards, equal parts history, anthropology, political science, and geography. I consider most of those disciplines mansions in the house of history."

Presumably, early-career scholars practice interdisciplinarity for a reason. Accordingly, the co-authors were each invited to share their top three perceived benefits of engaging in interdisciplinarity. We summarize the collective perspectives using several overarching themes (listed in bold italics) and offer a visual of word frequencies and themes (**Fig. 3**). Additionally, authors described the costs of not engaging in interdisciplinarity work, which included missing out on knowledge, innovation, perspectives, impact, funding, results, and opportunities.

### 4.1. Interdisciplinarity broadens one's toolbox and thinking

Interdisciplinarity invites scholars to make wider connections and to experiment with new tools, approaches, concepts, theories, and statistical analyses. Trying new tools, or methods, can open new possibilities and result in new solutions and insights. For example, members of the College reported that:


**Fig. 3.** What are benefits of interdisciplinarity? A world cloud of the top 25 synonymous words using authors' own descriptions of the benefits of interdisciplinarity. Larger fonts indicate greater word frequency. "Work" is the most frequent word constituting synonyms like bringing, exploit, form, processes, and make. (Word cloud created with Nvivo v. 12, QSR International Inc., Burlington, MA.)

> "As a behavioural ecologist by training, I would have little success interpreting patterns of population size in some Arctic seabirds if I did not have some appreciation for oceanography and climate research, but I would also miss much if I didn't understand international politics as they relate to wildlife management, or if I failed to look into oral history of aboriginal peoples to assess long-term cyclical patterns in wildlife abundance."

> "The team that built the Foldit protein folding game is a nice example of this—they realized that bringing the expertise of computer graphics researchers and game design experts together with biochemistry researchers could change the way that protein folding problems are solved and potentially lead to significant new insights."

What is interesting here is that the reach of interdisciplinary projects goes well beyond the old notion of "cognate disciplines." What is and is not a cognate discipline is not what it was. Increasingly, interdisciplinary projects and research centres bring together scholars from disparate disciplines, often divided by multiple administrative structures (faculties, not just disciplines) as well as bricks and mortar as these disciplines inhabit different parts of the university campus. The proliferation of interdisciplinary labs, centres, and other research units at Canadian universities have been important in bridging this social and physical distance, or disciplinary segregation, providing a physical place for interdisciplinary research to thrive. The Canada Research Chairs program, the Canada Foundation for Innovation, and other programs, have been profoundly important in effecting this seismic shift.

Interdisciplinarity offers scholars intellectual gains including a wider research horizon, the opportunity to think outside the box, and to find inspiration or insight in unexpected places:

> "It [interdisciplinarity] is intellectually stimulating. I learn WAY more when I sit down with an engineer or social scientist than when I sit down with other fish biologists that are

> just like me. Intellectual stimulation is a major personal benefit from interdisciplinarity—it makes going to work challenging and fun!"

Interdisciplinarity can also enable a more comprehensive understanding of problems, issues, and research questions, including an understanding of more complex phenomena. The aforementioned benefits of interdisciplinary research may offer stronger results and outcomes (e.g., quality, established knowledge, relevance, and impact on society).

> "For example, in the Canadian Institute for Advanced Research successful societies program, we bring together scholars with deep expertise on many aspects of societal inequality—social, racial, gender, economic, Indigenous, global—and also consider issues from multiple disciplinary perspectives (sociology, psychology, history, economics, political science, etc.). This provides perspective-changing insights and inspires theorizing and research that bridges levels of analysis in a way that rarely occurs within a single discipline."

## 4.2. Creating new knowledge

New knowledge and ground-breaking research can result from engaging in interdisciplinarity, as researchers creatively engage with colleagues and embrace different tools and ways of thinking and knowing. For instance, one author explains:

> "Being able to computationally analyse music has meant that common features can be found in what makes a hit song. I've contributed to work on addiction in slot machines because I could explain what the music was doing to manipulate people. That work changed laws in several countries."

Yet, just because an interdisciplinary approach is used does not alone guarantee that new knowledge will be useful or transformative.

## 4.3. More robust and relevant outputs

Being relevant to one's constituencies is important in the context of applied or mission-oriented research (Chapman et al. 2015). Drawing on our experiences, we note that interdisciplinary research tends to generate a deeper and broader understanding of an issue, which leads to more robust and relevant outputs. Rather than saying "we learned so much about X—if only we knew something about Y," there is opportunity for simultaneous integrated research to yield rapid outcomes. For example, one author explains:

> "I often work with people from human sciences. They are so good to capture qualitative data from surveys, interviews, and Delphi studies. This information gathered can then be used to develop and validate mathematical models that really reflect reality."

## 4.4. Interdisciplinarity offers greater opportunities and possibilities

Tangible benefits include increased publication and funding opportunities, different training opportunities, as well as more journals and venues from various disciplines to choose from when disseminating interdisciplinary research. Moreover, there is greater potential for knowledge mobilization that ensures that the public (who often fund the work) are more likely to benefit from it. Furthermore, interdisciplinary engagement also uncovers opportunities for novel and rewarding collaborations where problems that could not previously be addressed become accessible. One author shares this sentiment here:

> "A true interdisciplinary approach addresses the world as it really is, in its fullness and complexity, rather than approaching a world arbitrarily carved up into disciplinary terrains."

As a result, these collaborations can increase competitiveness for grants and awards as it can lead to more publication output, highly qualified personnel training, etc. Finally, the ultimate reward of conducting interdisciplinary research is the potential for innovation in discovery that only come when problems are tackled from multiple perspectives and viewpoints. A CIHR study focused on the outputs of grants revealed that projects that were collaborative or done in partnership yielded increased outputs and capacity building (McLean and Tucker 2013). Although the study did not explicitly assess interdisciplinarity, the report implied that the collaborations often extended across disciplines.

### 4.5. Personal and intrinsic benefits

Some co-authors feel that engaging in interdisciplinary discourse and activities offers a means for self-improvement through better understanding of what one does, challenging oneself to consider new ways of thinking, and a broader understanding of one's own research within the broader scholarly landscape. Furthermore, doing the "same old thing" can be avoided and there are possibilities for extending someone else's work in incremental ways.

> "I think borrowing from other disciplines makes my own work more innovative; I have a larger academic network and public; and I just find what I do more stimulating as I am introduced to new ideas and currents from elsewhere."

> "The questions that other RSC scholars have asked me have forced me to question the assumptions that I make about my discipline and have also allowed me to see parallels between our disciplines that I did not know existed."

## 5. Fostering interdisciplinarity training

Providing opportunities for learners to develop skills related to engaging in interdisciplinarity is more important today than ever, yet formal opportunities remain scarce (Kelly et al. 2019). One co-author was part of a launch for an undergraduate "interdisciplinary design minor" that allowed students from any discipline to take a set of courses alongside their major (which could be anything, e.g., computer science, mechanical engineering, industrial design, digital media, etc.), and challenged students to view problems and design solutions through an interdisciplinary lens. A pilot interdisciplinary design course drew students from 13 different majors, from freshman through to seniors, to better understand how students work across disciplines early in their careers. The co-author learned the following:

> "One of the big takeaways for me was the fact that the seniors came to the table with a strong set of skills in their specific discipline, but also a narrow viewpoint and difficulties with being flexible in their methods (they had learned a template or process in their disciplines and wanted to apply it at all costs regardless of the problem they were trying to tackle—it's the old 'when you're holding a hammer, everything looks like a nail'). In contrast, the freshman often had underdeveloped skills in their discipline of study, but a broad set of perspectives (informed by the general education and their personal experiences) as well as greater flexibility to take on or even mix different approaches. The experience made me realize the value and importance of building interdisciplinarity into the curriculum and educational system from the outset, rather than expecting it will emerge on its own."

### 5.1. Bridging theory, research, and practice

In many cases, skilled theorists and researchers are not experienced (or not good) at application or implementation on interdisciplinarity. As a result, great ideas may never make it past the abstract

form. Effective interdisciplinary teams offer a pool of experts in aspects of basic research along with others who are experts in practice, policy, and implementation.

> "I think it is often forgotten that we need both expertise in basic research and in translation—and they are not always the same people."

Examples of successful integration of disciplines in which social sciences helped inform the relevance of research to society was provided by several of the co-authors:

> "An example from my field is the design of new human–computer interaction technologies, where psychology and social sciences help us understand user requirements and provide methods for evaluating prototypes and systems in practice; [where] design disciplines provide the expertise needed to shape the interactive experience; [where] computer science and technology disciplines are necessary to turn design concepts and prototypes into functional systems; and [where] cultural theory can help us imagine and reflect on the impact of technologies on human existence."

> "For instance, technological or medical developments are often considered in their own right—but what are the human and societal implications, how will it alter human behaviour, contribute to social interaction, health decision-making or the production of inequalities? Climate is often considered from the physical/biological science side, but human action and attitudes play a role too."

### 5.2. Interdisciplinarity challenges the status quo

Interdisciplinarity has the potential to open the door to unconventional thinking and practice, including new takes or challenges to reigning theories and orthodoxies in different disciplines. But there is nothing automatic in any of this, as always it takes hard work and creative minds. Overall, boundary crossing (or working in the space between boundaries) leads to greater potential for disruption and rejecting or refuting long-standing dogma or paradigms:

> "Counteracting the unavoidable bias that comes with disciplinary viewpoints and supporting continued learning is another important benefit of interdisciplinarity.... As we become more specialized, we limit our thinking and practices to the set of tools (both cognitive and practical) that we've mastered, and effectively become good at doing a small number of things. But with this comes a loss of the ability to step outside our own little box and engage in a broader set of views and approaches. Interdisciplinarity, and more broadly supporting connection across disciplines in parallel with specialization early in the academic experience, provides tremendous learning opportunities that can help to undo some of the biases that come with specialization. This make us both independently and collectively better equipped to tackle the increasingly complex problems and challenges that face us in the world today."

## 6. Risks and drawbacks of engaging in interdisciplinarity

Although there are many benefits with interdisciplinarity (as described above), there are also risks and drawbacks when engaging in interdisciplinary activities and exercises (**Fig. 4**).

### 6.1. Guarding against superficiality

> "Forced interdisciplinarity ignores that there is value from intensive, thick investigation from particularly disciplinary strategies."


Fig. 4. What are the risks and drawbacks to engaging in interdisciplinarity? A word cloud of the top 25 synonymous words using the thematized coded text from authors' written discussions on the risks and drawbacks to engaging in interdisciplinarity. Larger fonts indicate greater word frequency. Note that the word "lack" was associated with some of the other words (e.g., lack of knowledge, recognition, time, depth, funding, etc.). (Word cloud created with Nvivo v. 12, QSR International Inc., Burlington, MA.)

The central risk of widening our horizons as researchers is that we skim the surface rather than delving deeply into the subject at hand (Box 1). We must guard against superficiality. Just because one reads Clifford Geertz does not make one an anthropologist or even particularly knowledgeable about the debates and knowledge produced by that discipline. A number of interdisciplinary-friendly scholars have therefore warned of the danger of being disembedded altogether from disciplinary ways of knowing. Each of the authors of this article has a scholarly home-place, somewhere where we were trained, with whom we identify, teach, even belong. As interdisciplinary scholars, we also operate between, across, and through other disciplinary home-places, but our intellectual travels and interdisciplinary practices are not boundless.

> "[There are risks of] picking methods like books off a shelf and the lack of depth of understanding in theories or methodologies that weaken the research."

### 6.1.1. Career risks

The co-authors perceived a number of potential risks and drawbacks to one's career by engaging in interdisciplinarity. For instance, jobs are often posted in disciplinary categories, which thus exclude interdisciplinary thinkers. Authors also explained that there are risks in training graduate students without a disciplinary focus, which can lead to a "Jack/Jill of all trades and a master of none" (Box 1) and less competitive students within current institutional structures. One's CV may look unfocused to granting, award, hiring, or promotion/tenure committees. There is also the risk of becoming "unrecognizable" in one's field. Individuals who are early in their career or pretenure may risk decreased visibility in their department or discipline if they do not publish in traditional "disciplinary" outlets, leading to difficulties of getting promotions or tenure. Authors have also described a negative perception or lack of respect by other disciplinary colleagues and difficulties on being judged for intellectual competencies (see Lattuca et al. 2013). One may be perceived as a "dabbler" or as having superficial skills and knowledge. Others raised concerns about feeling like a traitor or not being serious or focused if engaging with many disciplines, which may lead to an exacerbated "imposter syndrome," particularly among early-career researchers (Box 1).

**Box 1.** Is a Jack/Jill of all trades a master of none?

Much discourse and debate exist relating to depth versus breadth when it comes to interdisciplinary teams, research, and training (e.g., Rossini and Porter 1979; Carey and Smith 2007; Lau and Pasquini 2008); leading to the primary question being: Are researchers with interdisciplinary training a Jack/Jill of all trades and master of none? The likely answer is "yes." Carey and Smith (2007) assert interdisciplinary health researchers do not have an intellectual home but often forge a "virtual intellectual home." These interdisciplinarians view themselves as "interlocutors" in future health research with the privilege of breadth of understandings across disciplines, rather than a depth in one. In that article, the PhD students admit they are a Jack/Jill of all trades and master of none, but is this a problem? These new types of interdisciplinary health researchers find themselves in a disciplinary role of "bridging disciplines," where their roles have emerged out of a perceived health need and is likely to be their disciplinary home throughout their careers and not just as PhD students.

Members of the authorship team for this article discuss the risks of training students in interdisciplinary programs (see section 6.1.1) as "they end up with a broad but shallow knowledge base" and are "at risk of being uncompetitive against their more specialized peers and of not being familiar enough with any one discipline to really conduct meaningful research." Some believe that to be successful, one must be very well grounded in a discipline before exploring interdisciplinary research, e.g.: "It is important to recognize that not all breakthroughs occur in interdisciplinary contexts (we can push too far in that direction too). There often needs to be deep, careful theory and research within a discipline first, before there is value in bringing those insights to an interdisciplinary team. When work is interdisciplinary too early in the process, it can sacrifice depth and innovation for breadth and application. Both are important to support."

One of the authors discusses their sentiments: "It [being interdisciplinary] likely means that I overlook some details but try as much as possible to collaborate with specialists when I feel I am outside of my comfort zone. This kind of work can also take more time, as one might not get it right on the first go."

The depth versus breadth debate also occurs at a project- or group-level. One of our authors explains: "Too many perspectives on one problem (project) can reduce the depth at which the problem is addressed. There may be a lack of substance or depth if working from the lowest shared common denominator across disciplines. Finding common grounds and vocabulary across several disciplines can come with some level of 'vulgarization'."

One author links the "Jack/Jill of all trades and master of none" to scholars disengaging in interdisciplinary work as the "limits in time and mental space provide some resistance to interdisciplinary work, in part because depth is sacrificed for the breadth. We all have a finite amount of day in the day."

Being a Jack/Jill of all trades comes with pros and cons. Early career researchers may find themselves with an exacerbated "imposter syndrome" when interacting with peers who have disciplinary depth and expertise. However, as Carey and Smith (2007) suggest, interdisciplinarians are a new type of researcher who can afford the role of being the "bridge."

> "I hesitate to train students in an interdisciplinary context if they want to seek an academic job in the discipline—I think (with some exceptions) it can weaken their chances and water down a CV. I encourage students who are considering jobs in government, industry, etc., to get cross-disciplinary experience."

Although potential career challenges exist, it is encouraging to see emerging undergraduate and graduate interdisciplinary training programs (e.g., McMaster and Carleton Universities) in recent years and demand as well as appreciation for people with skills to integrate and synthesize different perspectives and knowledge.

## 6.2. Funding challenges

There are also the procedural drawbacks of engaging in interdisciplinarity. Navigating funding sources becomes difficult (which source to go for when engaging in many disciplines?) and securing funds becomes more challenging and potentially riskier. Given the Canadian context, this was deemed to be particularly important for the Tri-Agency grants (Natural Sciences and Engineering Research Council (NSERC), Social Sciences and Humanities Research Council (SSHRC), and CIHR). The venues for publication of interdisciplinary content are often not as well recognized as disciplinary domains, which can be a major drawback. Communicating interdisciplinary research becomes challenging because of the wide readership, which can lead to simplification of the research and loss of information and depth. Often, being a bridge between academic units can also come with additional administrative burdens. Traditionally, a common sentiment toward funding agencies has been, "There are no funding mechanisms that encourage these collaborations."

However, the scientific landscape is changing, and funding agencies and institutions are realizing they must also adapt and foster interdisciplinary work (see section 7.3).

## 6.3. Execution and implementation challenges

The actual execution of interdisciplinarity can be risky because it can require additional time and energy, and some may say it requires more "intellectual space." Some may consider it to be a large opportunity cost—spending time doing interdisciplinary work means you are not spending time working exclusively within your discipline. It is time-consuming because one must navigate across the politics of knowledge production and find ways to speak a language that is sometimes foreign to one's training. It also requires a collaborator who is willing to take the time to share their knowledge in ways that articulate with that of others. Building relationships with other disciplines does not happen overnight and this "relationship building" often goes unnoticed and unrecognized by conventional Faculty Evaluation Committees until there is a "scholarly product." Vulgarization to find common grounds, navigating different disciplinary politics, and reconciling different disciplinary recognition (e.g., author order) and research focuses (e.g., basic vs. applied) all emerged as potential concerns. Establishing rigour (scientific quality) across disciplines also requires careful thought, and accommodating different perspectives takes patience and effort. Lastly, it becomes difficult to keep abreast of multiple scholarly topics while still driving deep into the knowledge sources that represent one's core focal area.

> "At times, working with colleagues in other disciplines sets up tensions around issues of rigour and currency. That is, which field has more or less currency and which field offers more or less rigour. For instance, I research in literacy studies and my research involves humans, whereas social science and humanities scholars consider ideologies and social theory more than human-driven research."

## 6.4. Challenges associated with measuring the success of interdisciplinarity

There are risks and drawbacks related to the outcomes of interdisciplinary engagements (or lack thereof), especially if interdisciplinarity is forced. Sometimes there may be risks to rendering simple problems more complex. Some interdisciplinary attempts bear no fruit and are costly. Because of this

and the nuances of interdisciplinary engagement, there is a higher chance of failure if the interdisciplinary engagement is not done properly. Failure to fully comprehend the nuances of other disciplines can create the risk that the interdisciplinary analysis is not as fulsome as it could be. Furthermore, there is the risk of not successfully concluding interdisciplinary projects when multiple perspectives must be accommodated. There is also a risk of diminishing the depth of knowledge when engaging in interdisciplinarity (Bridle et al. 2013). Some have argued that the substantive knowledge in one's own discipline may languish if everyone is engaged in interdisciplinary work (Brewer 1999). Perhaps there is an optimal level of interdisciplinary research—something that requires further consideration. And perhaps it is something that has to be developed in a gradual way, instead of being rushed or forced, for its added value to be secured and perceived.

> "Building relationships with other disciplines does not happen overnight and this 'relationship building' often goes unnoticed by conventional Faculty Evaluation Committees until there is a 'scholarly product'."

## 7. Challenges and barriers that impede interdisciplinary research and scholarship

Barriers and challenges to engage in interdisciplinarity have been discussed in prior literature but often come from the perspective of a discipline or field of study (e.g., Fox et al. 2006). Here, we list the challenges and barriers that were experienced from a range of disciplinary perspectives by College members and depict the most frequent words used by authors to describe the challenges in a word cloud (Fig. 5).


Fig. 5. What are challenges and barriers to engaging in interdisciplinarity? The top 25 synonymous words using the thematized coded text of authors' discussions on the challenges and barriers to engaging in interdisciplinarity. Larger fonts indicate greater word frequency. The most frequent words "funding" refers to barriers in funding mechanisms and "different" was often associated with challenges with different fields, norms, departments, work, etc. The word "work" also describes processes, and "structure" was often associated with challenges in funding, institutional, and organizational structures. (Word cloud created with Nvivo v. 12, QSR International Inc., Burlington, MA.)

## 7.1. Challenges and barriers created by organizational and funding structures

We, as humans, love to create boundaries—countries, genders, race, religion, and political perspectives, etc. We do the same in the academy and often build academic silos. Such academic silos are not explicitly designed for interdisciplinary research, e.g., a strong proposal can be kicked around from funding agency to funding agency simply because it does not fit the template of any single one. For example, a recent federal funding review in Canada acknowledged that there were instances in which research fell through the cracks in that it was not appropriate for the rather siloed agencies (see page 123 of sciencereview.ca/eic/site/059.nsf/vwapj/ScienceReview_April2017-rv.pdf/$file/ScienceReview_April2017-rv.pdf). We acknowledge that efforts are underway to create more interdisciplinary funding opportunities (e.g., recent New Frontiers in Research Fund; sshrc-crsh.gc.ca/funding-financement/nfrf-fnfr/index-eng.aspx), which should be lauded but more such opportunities are needed. Such interdisciplinary peer-review systems have existed in the United States for some time through the National Science Foundation flagship grant program currently called the Dynamics of Integrated Socio-Environmental Systems (CNH2; see nsf.gov/pubs/2019/nsf19528/nsf19528.htm), which is focused on addressing complex, interdisciplinary problems using individuals from the natural and social sciences to assess grants. However, that is not the norm. Peer-review committees may lack the expertise to competently assess the quality and value of interdisciplinary projects. Such a model creates financial and administrative complexities when engaging in interdisciplinarity. For example, interdisciplinary teams are challenging to assemble simply because students or other scholars are scattered across various units, which creates administrative complexities and logistical challenges. This model also creates a barrier to access other scholars to engage with interdisciplinary work. Another challenge is initial access to other scholars in other disciplines and finding people with analogous interests with whom to engage. For example, a couple of authors mentioned:

> "I am a nobody in other fields, so it is not easy to get serious treatment from top folks in the other fields if I ask for help."

> "It is more difficult to 'size up' a potential collaborator who is outside your field. You won't know them by reputation, and they might look good/bad on paper (and quite different in reality). People outside my field rarely know what kind of research we actually do, and often think that we don't do much research anyway. It's hard to get past that."

Furthermore, the current academic career framework leads to researchers who are very specialized, which we often define as an "expert" in a specific domain.

## 7.2. Challenges of publishing

Journals that currently publish interdisciplinary research are often less valued (i.e., receive fewer citations and have lower Impact Factors) than older, well-established, disciplinary journals or the broad, but often narrowly focused (at the level of the individual paper—e.g., *Science*, *Nature*), although this seems to be changing (e.g., *FACETS* model, various open access and traditional journals that embrace boundary crossing—recognizing that almost all "new" journals are open access given changes to the contemporary business model, confounding the distinction between open access and interdisciplinarity). Some authors have found that challenges emerge when tailoring one's work to publication venues for a specific discipline, making it difficult to find places to publish authentic interdisciplinary studies. In some instances, journals have rejected papers because they just could not find competent reviewers for the topic (reported by several College members). Additionally, a manuscript may go to a journal where referees do not understand the language and appreciate the value of the "other" discipline leading to suggestions to split a given paper into its disciplinary components.

> "As an example, my most cited work is a paper that showed how local ecological knowledge can be an excellent companion to western scientific knowledge but can also be quite incorrect (just like western science can). This went out for review 14 times (!!!) before it was finally rejected at a major journal, because it kept going to two empirical scientists and two social scientists, and it would come back with split reviews."

## 7.3. Challenges and barriers to obtaining funding

Authors have flagged that the funding structure gives lip service to interdisciplinarity but is silo-based in practice. For example:

> "I have had grants and student scholarship apps flagged for being too 'NSERC' in a SSHRC competition or being too 'CIHR'—yet in every case they would not have been deemed appropriate had they simply been sent to the other agency. It leads people to develop ideas that are narrowly constrained and avoid even discussing any ways in which their research could cross disciplines."

However, exceptions were noted. In NSERC partnership grants, up to 30% of the total budget can be directed towards "non-NSERC" research (e.g., social science). Moreover, the recent call on "Health and Society" by CIHR stated "Society" by CIHR. They present it this way:

> "Building on an established record of collaboration between NSERC and CIHR and SSHRC, the granting agencies will use the CHRP funding opportunity to pilot a Tri-Agency collaboration intended to support multi-disciplinary collaborations amongst researchers from natural sciences and engineering, health sciences, social sciences, and humanities."

This is a promising development. If one incorporates such thinking into one's grant it can be a positive point in the applicant's favour; but if it appears forced and unintuitive, it would reduce one's likelihood of success. Similarly, the Fonds de recherche du Québec (FRQ) provides a funding opportunity for innovative "intersectoral" projects that have the potential to radically transform research and creation called "Audace." To be eligible to apply, you must clearly demonstrate how an important problem may be solved using an interdisciplinary approach. However, they systematically reject "token" interdisciplinary teams that fit loosely or superficially together. All of this to say, interdisciplinary research must be justified and obvious, and the interdisciplinary research activity must interface directly with the core research subject that is the basis for the funding call.

## 7.4. Challenges in collaborating: time, disciplinary disagreements, and cultural differences

Collaborations take time, patience, and a team that gets along:

> "Collaborations take a lot longer and require a lot more discussion of expectations. Norms in different fields are SO much more different than what anyone expects. There are immense differences in what is considered a contribution, what the role of a graduate student should be, how quickly papers should be published, etc., and it is all stuff that we take for granted because we were socialized differently (i.e., for the past 20 years or longer)."

## 7.5. Lack of respect and distrust of interdisciplinary research

Another apparent trend is perceived lack of respect and distrust for interdisciplinary research, which is well captured by these two quotations:

> "I am recognizing that I am increasingly less of a 'good fit' within my home department. I feel that I should be cut up into pieces and spread around. Doing so would be impractical within

current institutional structures (can you imagine having to attend departmental meetings for three different units!) but I feel that I am a 'poser' in my primary department. I have to work hard to identify committee members for my grad student committees that will be appreciative of their work in boundary areas."

"Disciplines will obviously want to protect and police their borders, to hold on to their power and prestige. Interdisciplinarity is swimming upstream."

### 7.6. Limited vision and mind space constrained by institutional architecture

"Ignorance is a real problem." Often there are people who are tied to tradition and tend to teach and perform from a single point of view, which leads to discouraging different ways of doing things and being less open to new bodies of knowledge. In an academic context, silo mentality can create barriers to interdisciplinary research and scholarship. Such a mentality creates separation between culture and nature that leads us to ignore hybrid grounds for further joint investigations. An interesting barrier brought forth by the co-authors was the restricted mind space to think creatively due to the pace and organization of academic work. Interdisciplinarity requires intellectual space to imagine other ways of being and knowing. It fits well with the slow science movement—more time to contemplate, converse, create; but current institutional structures are not conducive toward this way of thinking.

"Faculty and departmental divisions hamper interdisciplinary research, as much as they pay lip-service to it. This is especially true for junior faculty members who 'stray' too far afield from a recognized disciplinary field and then have difficulty persuading a tenure and promotion committee why their work fits the department/faculty and is significant in its/their terms or metrics. Faculty and departmental divisions—including funding structures—discourage collaboration across faculties, particularly at the graduate student level. Department X does not want its graduate students to take a course in Department Y because Y is in another faculty and nobody knows who will pay whom, or X simply does not want to lose that person from its own courses, which might be under-subscribed. There is a sort of protectionism that is not always based on disciplinary ideologies, but on the practicalities of mobility across faculties."

## 8. Facilitators of interdisciplinary research and scholarship

This article brings together the diverse perspectives and experiences of scholars, scientists, and artists, which also includes individuals with deep experience in the facilitation of interdisciplinary research. A core goal of doing so is to identify how society can foster and facilitate interdisciplinarity. Ideas and experiences in facilitating interdisciplinary research and scholarship are discussed below and captured in Fig. 6 and Table 1.

### 8.1. Opportunities to network: conferences, meetings, and workshops

We believe that creating opportunities for networking and meeting other scholars can help facilitate interdisciplinary engagements. Events such as conferences, meetings, and workshops can serve as venues for different types of scholars to interact in meaningful ways, facilitating relationship-building and encouraging conversations about potential collaborations. For example:

"Working in a small university, I know many colleagues in other disciplines who are eager to collaborate. We have venues/events where we meet, we know each other, and can imagine writing a grant together."


**Fig. 6.** What are facilitators to interdisciplinary research and scholarship? A word cloud of 25 stem words from coded text of authors' discussion on facilitators to interdisciplinary research and scholarship. Larger words illustrate greater frequency. Unlike the meaning of the word "funding" in Fig. 5, here it refers to funding agencies and programs as being key to facilitating and promoting interdisciplinary work. (Word cloud created with Nvivo v. 12, QSR International Inc., Burlington, MA.)

However, it can often be a challenge to find such conferences and spaces that are inherently interdisciplinary in scope. A good model for enabling such workshops are the "synthesis centers" in the United States that bring together diverse scholars to tackle interdisciplinary problems (see Baron et al. 2017).

## 8.2. Certain issues and topics demand interdisciplinarity

There are certain issues that drive and demand interdisciplinarity. For example, one author describes that working in wildlife research and management in Arctic Canada facilitates interdisciplinary research because it comes from legal or policy issues that require more than standard scientific approaches. In this case, many levels of government require a consideration of local ecological knowledge as a component of wildlife research projects. Furthermore, there are certain fields of study that need interdisciplinarity and encourage it.

> "It is highly encouraged in medicine. It is often required nowadays by funding agencies and they prefer when one uses an integrated knowledge translation (KT) approach to their research."

> "Some fields, such as memory studies, are interdisciplinary in their core. Without discussion across the disciplines (ranging from neuroscience to history), this area of study would not have emerged as it has nor have had the impact."

## 8.3. Finding the right people at the right time

Working and engaging with open-minded people can facilitate interdisciplinary activities; however, it takes time to find these people, and to build and maintain these relationships:

> "I think we tend to overlook this, as we inherently try to find explanations for why our work is rejected, or not cited as much, or whatever—sometimes it's simply because we could do

Table 1. Suite of possible actions to enable interdisciplinary to specific to different actors and institutions.

| Actions for Enabling Interdisciplinarity |
|---|
| ***Individual Scholars, Artists and Scientists*** |
| • Support colleagues engaged in interdisciplinary research recognizing that not all scholarship fits into traditional disciplinary silos |
| • Seek out fellow interdisciplinarians to create a support structure given potential for "common" problems related to barriers |
| • Create opportunities for building interdisciplinary teams that include individuals new to interdisciplinary research (e.g., ask to go for a coffee with a colleague from another faculty) |
| • Serve as a mentor for other scholars that engage in interdisciplinarity or desire to do so |
| • Create a culture of respect recognizing and celebrating the value of diverse forms of scholarship and knowing |
| • Attempt to incorporate different approaches/ways of knowing on all collaborative research teams |
| ***Employers*** |
| • Provide seed funding for small groups to assemble and explore interdisciplinary collaborations |
| • Provide work spaces conducive to creative thinking and interaction across boundaries |
| • Provide incentives and reward structures that encourage interdisciplinarity |
| • Include interdisciplinary scholars/experts on committees related to career advancement (promotion, tenure, salary adjustments) |
| • Hold regular events (formal and informal) that bring people of different areas together |
| • Recognize interdisciplinary groups and excellence through special awards |
| • Train tenure and promotion committees to be able to properly evaluate cases that are interdisciplinary, including the understanding that it takes time |
| • Value networking and relationship building as much as publications |
| ***Granting Bodies*** |
| • Proactively identify topics that require interdisciplinary scholarship and create funding calls that explicitly require interdisciplinary teams and approaches |
| • Ensure that grant review panels and referees have appropriate representation of interdisciplinarians |
| • Acknowledge interdisciplinarians through provision of awards restricted to those engaged in interdisciplinary research |
| • Celebrate successful interdisciplinary projects through external communication avenues being sure to highlight the ways in which the interdisciplinary aspects contributed to success |
| ***Mentors and Training Bodies*** |
| • Provide opportunities for trainees to learn about diverse topics beyond their core area of study |
| • Provide opportunities for trainees to learn about how to engage in interdisciplinarity thinking and collaboration (e.g., courses on collaborative team work) |
| • Foster an appreciation of all forms of knowing and areas of scholarship and creative output |
| • Develop and build curriculum around complex problems (e.g., sustainable development goals) that demand interdisciplinary approaches |
| • Provide leeway for learners to pursue lines of inquiry that do not fit within traditional structure of the training body (e.g., interdisciplinary programs/degrees) |
| • Ensure those serving as examiners (e.g., for a dissertation) embrace the concept of interdisciplinarity for trainees engaging in such work |
| ***Professional Societies and Organizations*** |
| • Create awards that recognize and celebrate excellence in interdisciplinary scholarship |
| • Create mechanisms for scholars with different backgrounds to interact and network with the hopes of enabling new collaborations |
| • Consider the development of "sub-units" dedicated to interdisciplinary pursuits |
| • Recognize the value of interdisciplinary scholarship for competitive honorifics |

> better by working with someone else and tackling a more robust question with relatively little extra work by any individual. … I feel that the days of one- or two-author papers are (largely) in the past, and that the most interesting and new and forward-thinking papers come from collaboration. I use the analogy of The Beatles—any one of them were great in their own right, but together they were unequalled."

## 8.4. Adoption of interdisciplinarity as a norm

In general, the co-authors have felt that facilitators are lacking; however, some of them found excellent examples of where interdisciplinarity is the norm.

> "I recently returned from a visiting professorship at Stanford and was impressed at how interdisciplinarity is the norm. It is part of the university culture. My highly generalized impression is that it is not fully integrated into our research culture here in Canada."

Some felt that when a university values interdisciplinarity and reflects this in its strategic plan, it can foster a greater interdisciplinary culture. However, as noted above, others felt this was simply lip service.

## 8.5. Demand (by students, society, and complex problems)

Students today want more interdisciplinary research and opportunities to be involved; they realize that this is the way forward. The demand for interdisciplinary research and activities is facilitating its realization.

> "Students and post-docs are looking for interdisciplinary opportunities so not engaging in them will potentially limit the number and quality of trainees you can attract to your research program."

Furthermore, to solve complex societal problems, it is recognized that there is a need to go beyond one's discipline, to explore new methodologies, other horizons, ways of thinking and modelling data to tackle the complexities. There is no other choice than working together if we want to solve these problems and to have the greatest impact. Indeed, demand for interdisciplinarity is facilitating its diffusion.

## 8.6. Rewarding interdisciplinarity and institutional support

Creating incentive and reward systems that recognize interdisciplinary activities can foster and facilitate interdisciplinary engagements. For example, awards, such as the RSC Sir John William Dawson Medal, explicitly intended to recognize individuals doing interdisciplinary scholarship, lend credibility to interdisciplinary pursuits. Another example of institutional support includes:

> "'Permission' to engage in scholarship that is not funded. Diligent work at my institution to consider tenure and promotion criteria that award scholarship beyond grantsmanship."

> "If our universities encouraged teaching or co-teaching outside our assigned departments this would foster interdisciplinarity among colleagues and provide examples for our students."

## 8.7. Framework for co-supervision

An effective means to facilitate interdisciplinary approaches is to foster co-supervision of undergraduate, graduate, and post-doctoral students across disciplines. Such a framework is an effective way to initiate interdisciplinary disciplines and exchange ideas across disciplines. It was also raised that

having different disciplinary training (from undergraduate degrees to graduate degrees) can help an individual better engage in interdisciplinary activities. It is important to recognize that different disciplines have different norms and standards such that students can get caught in the "crossfire." This is potentially solvable via collegiality and openness to other norms.

> "In business, many faculties have training outside their fields. For example, someone could have an undergraduate degree in sociology, and then graduate degrees in business. Also, many faculties even have PhDs in economics, psychology, engineering, mathematics, sociology, industrial relations, etc. So, there is at least an understanding that there are 'other ways of doing things' that are not necessarily wrong."

## 9. Conclusions

As members of the Royal Society of Canada's College of New Scholars, Artists, and Scientists we provided our collective perspectives on interdisciplinarity. Interdisciplinarity means different things to different people (see Fig. 7), presumably reflecting different experiences, cultural norms (disciplinary and otherwise), values, and motivations. Our experiences have led us to conclude that working across established boundaries of scholarly communities is rewarding and necessary, but that there are

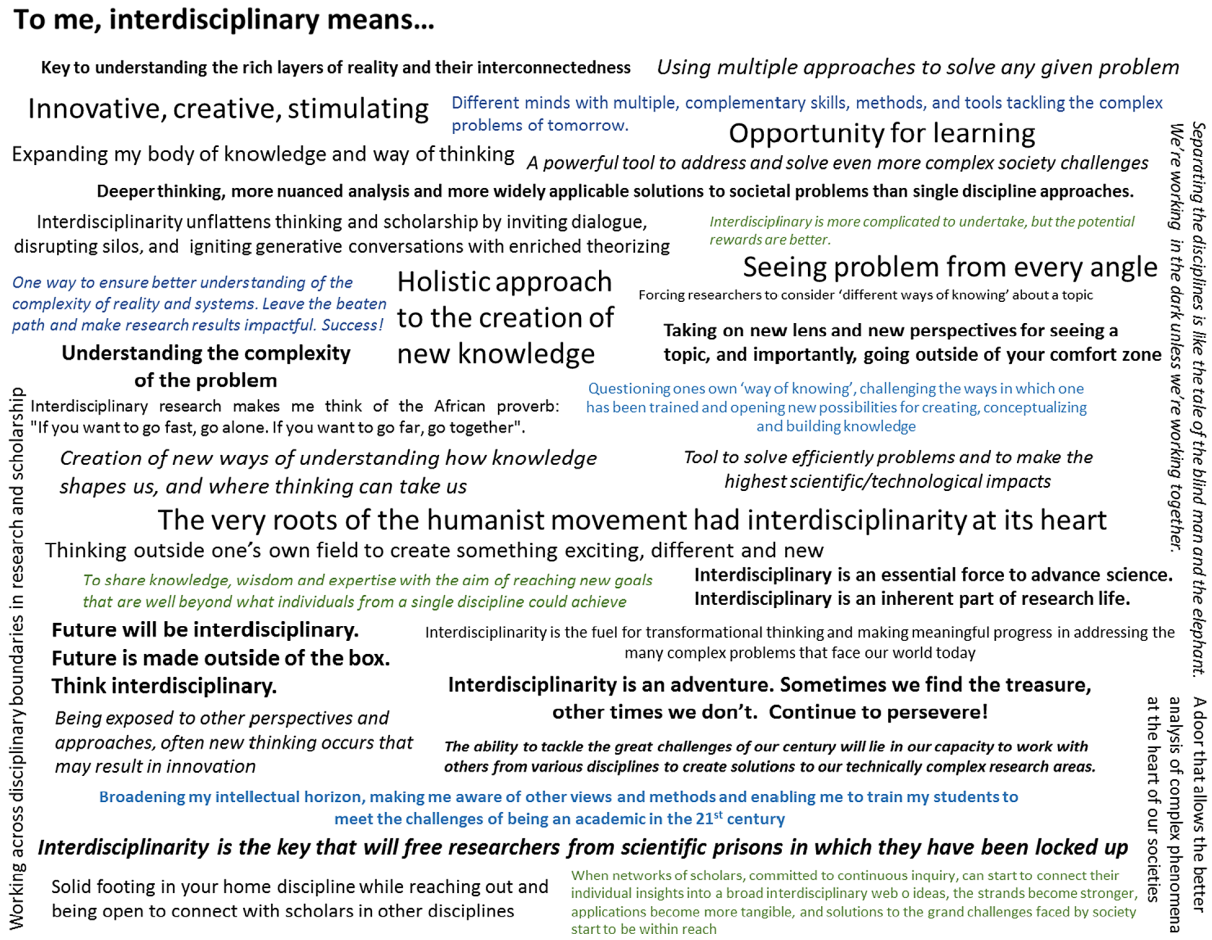


Fig. 7. Quotes from authors describing what interdisciplinarity means to them.

barriers that limit the ease with which this can occur (e.g., lack of institutional structures to facilitate cross-disciplinary exploration) and at times there can be significant risk from doing so (e.g., lack of adequate measurement or recognition of work by disciplinary peers). Of course, determining what is truly a boundary is an interesting topic in and of itself. As we move to be more reductionist in training (a trend that has occurred over the last two or three decades), even slight deviations in scope or focus could be interpreted as embracing interdisciplinarity (Gilbert 1998). As such, there is need for additional thought and discourse around what constitutes interdisciplinarity and how we value it.

Through this activity we identified a number of actions that can be taken to enable interdisciplinarity (**Table 1**). However, to do so will require the collective efforts of a variety of actors and institutions. The academy and key support structures (especially funding bodies) will play an important role in that they have a major influence on how the academy operates including recognition, incentives, networks, and opportunities. Nonetheless, there are also actions that can be undertaken by individual scholars to help codify this way of thinking, doing, and knowing. We contend that multiple disciplinarity is the new norm and that failure to empower and encourage those doing so will serve as a great impediment to training and knowledge. Moreover, such approaches should enable us to solve the many complex problems that demand thinking and working across long-standing, but in some ways restrictive, academic boundaries.



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## Author contributions

SJC conceived and designed the study. SJC, VMN, DA, SDS, MRT, AA, AH, CEM, LL, EES, DRN, KLL, AA, DA, ANA, MB, JB, DMB, RB, CB, AC, AC, BC, KC, CEC, MD, BD, EG, IG-E, SH, JMH, PLJ, NJ, MJ, AK, PK, SAL, KL, CRL, FL, NL, CL, ARL, AL, MLM, EM, AM, SJM, LLN, VO, PP, SR-K, JR, DS, SLT, DJV, AEW, and AW performed the experiments/collected the data. SJC and VMN analyzed and interpreted the data. SJC, VMN, DA, SDS, MRT, AA, AH, CEM, LL, EES, DRN, KLL, AA, DA, ANA, MB, JB, DMB, RB, CB, AC, AC, BC, KC, CEC, MD, BD, EG, IG-E, SH, JMH, PLJ, NJ, MJ, AK, PK, SAL, KL, CRL, FL, NL, CL, ARL, AL, MLM, EM, AM, SJM, LLN, VO, PP, SR-K, JR, DS, SLT, DJV, AEW, and AW contributed resources. SJC, VMN, DA, SDS, MRT, AA, AH, CEM, LL, EES, DRN, KLL, AA, DA, ANA, MB, JB, DMB, RB, CB, AC, AC, BC, KC, CEC, MD, BD, EG, IG-E, SH, JMH, PLJ, NJ, MJ, AK, PK, SAL, KL, CRL, FL, NL, CL, ARL, AL, MLM, EM, AM, SJM, LLN, VO, PP, SR-K, JR, DS, SLT, DJV, AEW, and AW drafted or revised the manuscript.

## Competing interests

All but VMN are Members of the College of the Royal Society of Canada.

## Data accessibility statement

No data were collected or formally analyzed for this study.

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