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Philosophical intervention and cross-disciplinary science: the story of the Toolbox Project

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Abstract In this article we argue that philosophy can facilitate improvement in cross-disciplinary science. In particular, we discuss in detail the Toolbox Project, an effort in applied epistemology that deploys philosophical analysis for the purpose of enhancing collaborative, cross-disciplinary scientific research through improvements in cross-disciplinary communication. We begin by sketching the scientific context within which the Toolbox Project operates, a context that features a growing interest in and commitment to cross-disciplinary research (CDR). We then develop an argument for the leading idea behind this effort, namely, that philosophical dialogue can improve cross-disciplinary science by effecting epistemic changes that lead to better group communication. On the heels of this argument, we describe our approach and its output; in particular, we emphasize the Toolbox *instrument* that generates philosophical dialogue and the Toolbox *workshop* in which that dialogue takes place. Together, these constitute a philosophical intervention into the life of CDR teams. We conclude by considering the philosophical implications of this intervention.

Keywords Toolbox Project · Philosophical intervention · Applied epistemology · Cross-disciplinary research · Collaboration · Communication

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1 Introduction

Philosophers like to think of their subject as the mother of all disciplines. Typically, this is served up as a historical claim concerning disciplinary origins (see, e.g., Russell 1997, Chap. XV); however, one could also interpret it as a claim about philosophy's deep concern for the character of the various intellectual disciplines. Philosophers are often philosophers *of* things—e.g., mathematics, language, science—and as such focus critical attention on the fundamental conceptual and methodological principles of the disciplines associated with these topics. It should come as no surprise, then, that philosophy has something to offer the growing number of cross-disciplinary projects[1] that dot the research landscape. These projects typically involve combinations of disciplines that employ different technical vocabularies and examine different aspects of the world. Disciplinary membership is marked by a set of commitments, often unconscious, that condition what one takes the world to be and what one seeks to know about the world. These metaphysical and epistemological commitments constitute *worldviews* that frame disciplinary research.[2] Because of its connection with a wide range of disciplines and its appreciation for their conceptual foundations, we believe philosophy can be systematically employed to help collaborators abstract away from specific disciplinary differences toward epistemic common ground,[3] thereby facilitating development of the mutual understanding necessary for successful cross-disciplinary research (CDR).

The epistemically multicultural character of collaborative CDR creates many challenges for those involved, including some that are institutional and logistical in nature (NAS 2004). Among the central challenges that confront CDR are those that involve working together with representatives of other disciplines, sharing information and perspective, and collectively forging a collaborative identity. We argue that the challenges included in this set are, crucially, *communication* challenges. Effective communication is essential for the success of cross-disciplinary collaboration; without it, the ability to combine disciplines to the degree necessary is compromised (Winowiecki

[1] We use the term 'cross-disciplinary' in this article instead of 'multidisciplinary' or 'interdisciplinary' to press the point that philosophy can facilitate the combination of disciplines regardless of the degree to which the combination requires epistemic integration. Typically, a term like 'multidisciplinary' marks a low degree of epistemic integration whereas 'interdisciplinary' marks a higher degree (Eigenbrode et al. 2007). While it may be the case that philosophy can be more valuable in this facilitative role as the level of integration increases, consideration of this possibility is beyond the scope of this essay. 'Cross-disciplinary' should be read as a generic term under which these specific terms fall.

[2] We take *worldviews* to be sets of more or less tacit beliefs held by researchers about what they are studying and how to study it, as well as views about the nature of the output of their inquiry. The idea that these issues are central to scientific practice is as old as the study of science itself (examples include Aristotle's *Posterior Analytics* and Bacon's *Novum Organum*), but came to prominence in the work of Kuhn (1970), who spoke of worldviews as "paradigms", and in the work of Polanyi (1958), who referred to them as "interpretive frameworks". Work on these issues is ongoing (Bird and Kuhn 2011, Sect. 6.4). Our use of the term 'worldview' is *not* intended to mark allegiance to any one of these views but rather to refer to their common insight regarding the ways in which prior intellectual commitments (e.g., those that structure disciplinary training) shape the work a researcher undertakes. We say more about what we take to be key aspects of scientific worldviews in Sect. 4.1.

[3] For more on common ground, see Clark (1996, Chap. 4).

et al. 2011). The Toolbox Project[4] is built on the premise that philosophy can be deployed to enhance cross-disciplinary communication through greater mutual understanding of assumptions about the research process (e.g., background assumptions, methodological assumptions) made in different disciplines (Eigenbrode et al. 2007). Focusing primarily on CDR in the sciences, we have developed an approach that uses structured dialogue in a workshop setting to encourage collaborative teams to examine key aspects of their scientific projects from a philosophical perspective. This is a perspective that scientists seldom adopt and it can reveal project dimensions that are otherwise rarely examined explicitly as part of collaborative efforts. After conducting 80 of these workshops, we have gained insight into the collaborative process and the unique epistemic perspectives that collaborations involve.

In this article we describe in detail the nature of our engaged philosophical work, focusing on the role that philosophy can play in improving the effectiveness and efficiency of cross-disciplinary communication. We begin by sketching the scientific context within which the Toolbox Project operates, a context that features a growing interest and commitment to CDR. After adducing an argument in support of the leading idea behind the Toolbox Project, we describe our approach and its output in some detail. In particular, we emphasize the Toolbox *instrument* that generates philosophical dialogue and the Toolbox *workshop* in which that dialogue takes place. Together, these constitute a philosophical intervention into the life of CDR teams. We conclude by considering the philosophical implications of this intervention; specifically, understanding philosophy in both its critical and facilitative roles, we outline how Toolbox inquiry informs our understanding *of* interdisciplinarity and how it counts as an instance of philosophy *as* interdisciplinarity.

2 The scientific context

CDR is increasingly employed to address urgent, persistent, and complex problems confronting contemporary societies, such as climate change (Eaglesham and Hardy 2009) and the human and ecological costs of war (Machlis et al. 2011). Because of their complex, contextual, and dynamic nature, these problems require CDR responses that integrate knowledge from different intellectual disciplines. Work on climate change, for instance, requires input from geography, meteorology, hydrology, sociology, ecology, and ethics, among others (Hanson et al. 2006). An increase in the number of cross-disciplinary projects has led to an increase in the status of CDR, motivating many institutions of higher learning to reconceive their research and teaching missions in terms of interdisciplinarity (Crow 2010), and many funding agencies, such as NSF, NIH, and NIFA in the United States, to give it greater emphasis.

As a result of the increase in attention and funding, there is a rapidly growing community of scientists deeply committed to doing CDR and doing it well (NAS 2004). Yet CDR is challenging and difficult, forcing researchers out of their disciplinary comfort zones and into situations where they must balance the need to contribute as experts with the need to learn as students. The challenges that confront scientific CDR are manifold.

[4] More detail about the Toolbox Project can be found at its website: http://www.cals.uidaho.edu/toolbox.

At the institutional level, they include the academic reward system (NAS 2004) and the lack of conducive institutional cultures (Klein 2010). At the project level, challenges include articulating a truly integrative research question (Baron 2010), finding common ground between CDR team members (Miller et al. 2008), creating an analytical framework for combining and analyzing data sets (Graybill et al. 2006), and developing a meaningful final product (Lélé and Norgaard 2005). As we argue below, many of these project-level challenges are rooted in philosophical differences that can divide collaborators. While there are a growing number of efforts devoted to addressing these challenges by enhancing cross-disciplinary process,[5] work remains to be done, and this is especially true of work related to the largely ignored philosophical dimensions of CDR. In what follows, we report on efforts by the Toolbox Project to investigate these foundations and use what is discovered to facilitate scientific CDR.

3 The Toolbox idea

The main idea behind the Toolbox Project is that a targeted application of philosophical analysis can enable teams to identify and surmount the project-related challenges mentioned above. As we will detail in the next section, this application involves using conceptual analysis to structure a philosophical conversation by collaborators in a workshop setting. While we believe that a good philosophical conversation is hard to beat, we acknowledge that this is not a widely held view in the scientific community. As it turns out, though, scientists are often happy to talk philosophy if you give them a reason to value the conversation when they have it. The reason we supply is that philosophical conversation can engender a type of mutual understanding that has clear benefits for a CDR team, vis-à-vis the aforementioned challenges. Specifically, enhanced conceptual understanding can lead to enhanced communication, and this can enable teams to meet certain project challenges more effectively. In this section, we develop this idea into an argument for the Toolbox intervention.

One fundamental relation underpinning the Toolbox approach obtains between the more specific, project-level challenges listed above and *group communication*. Group communication can be resolved theoretically into the "affective or expressive dimension" and the "instrumental, or task-oriented dimension" (Keyton 1999), that is, dimensions associated with collective relationship and identity formation and with the transfer of information. Project-level challenges reflect both dimensions—collective identity is built around research questions adopted by collaborators as the focus of their work, methodological compromises, and common ground, while fruitful pursuit of research goals requires the efficient exchange of information often couched in different disciplinary vernaculars. Progress on these complex research challenges requires collective, coordinated effort. In a scientific context, effort of this type increases the demand on groups to communicate in ways that lie outside the bounds of conventional, disciplinary scientific inquiry. The difficulty of this sort of communication is reflected

[5] These efforts come in a variety of forms, such as books (e.g., Klein 1990, 1996; Frodeman et al. 2010), professional societies (e.g., the Association of Integrative Studies), and centers (e.g., the National Center for Ecological Analysis and Synthesis at the University of California, Santa Barbara).

in the following exchange from a Toolbox workshop, between a group of biophysical and computational scientists:

> P8: … I mean, every time I hear the word 'diversity' I have to look to see who said it. Because if X said it, X means something completely different than if Y said it… these terms are funny in terms of who's saying it and what the purposes are if they mean somewhat the same things, but not exactly the same things.
> P7: [overlap] 'Replication'
> P8: 'Replication' is another one.
> P7: 'Representation'
> P6: 'Model'
> P1: 'Artificial', 'natural'

Because the project-level challenges to CDR mentioned above are essentially related to group communication, we argue that we can address the former by enhancing the latter. To identify what should be the focus of this enhancement, it is important to identify aspects of group communication that are related to the project-level challenges. These aspects include the existence of different disciplinary languages and the false appearance of agreement that can arise when the same word is unknowingly used with different meanings (Schoenberger 2001), managing disagreement and conflict (Bennett et al. 2010), and building and maintaining a productive mutual identity (Littlejohn and Foss 2008). Underlying these aspects is the fact that representatives of different intellectual disciplines view the research landscape from different perspectives; that is, they have different research worldviews constituted by how they conceptualize their research projects. These different research worldviews, or research *philosophies*, support different ways of conceiving the research problem space, and these differences can manifest as semantic and conceptual obstacles to effective communication. Consider the following workshop exchange about hypotheses between an ecologist (P01) and an economist (P02):

> P01: [On] intuition and predispositions?
> P02: Yeah, that's how I build my hypothesis.
> P01: But that's not quantitative.
> P02: But then I develop a hypothesis and I test a hypothesis and it's done [using] quantitative methods.
> P01: But that's not research, that's just freeing stuff … boiling down to a hypothesis.

In another workshop, a biophysicist contrasted the role of hypotheses in his discipline with its role in the medical disciplines of his collaborators as follows:

> Physics is not so much hypothesis driven…. [Physicists] feel that they're testing models, that they're testing theories of nature. They don't frame it as a hypothesis per se…

Of course, the point of CDR is to bring different research worldviews to bear on complex problems, so differences in how CDR participants conceive of and speak about their shared problem are essential. Further, the fact that CDR is often quite successful implies that there is no necessary relationship between these conceptual and semantic differences and communication breakdown; nevertheless, communication

breakdown can arise due to such differences (Lélé and Norgaard 2005; Thompson 2009). One way to mitigate the negative effects of these differences is to make them mutually known, but this can be difficult for the philosophically uninitiated and is often not seen as relevant enough to project business to be worth the effort. As Frank (1961) noted more than 50 years ago, unspoken disciplinary assumptions are "rarely formulated" and "are taken for granted by the members of each group who imply but do not explicitly disclose them in their attempts at communication" (p. 1801). But failure to articulate these assumptions can leave them unidentified, making possible misunderstanding and disagreement that can undermine a CDR project. In describing the contribution made by the Toolbox workshop to their professional development, one participant put it this way:

> This exercise helped to illuminate many of the group's defaults and hidden assumptions. These can cause problems later that might manifest as a topical disagreement, but which actually are philosophical differences. The exercise helps to address these areas early and in a more abstract way, so that it's easier for individuals to become familiar with differences and biases in a neutral setting.

Emphasizing the importance of mutual understanding about research assumptions, another said, "Failure to understand these can lead to false agreement, and could in the end undermine the project."

Given that one way to avoid communication problems arising out of conflict among unspoken disciplinary assumptions is to make those assumptions common property of the research team, a systematic, user-friendly approach to their identification and articulation would be a salutary contribution. Since these assumptions form the conceptual foundation of one's research worldview, we take philosophy to supply a medium within which to articulate them. In particular, a discussion about the epistemology and metaphysics of science can be used to generate and structure a dialogue among collaborators about their research assumptions that focuses them on key framing elements, such as methodological commitments and confirmation standards. By focusing collaborators in this way, the dialogue engenders mutual understanding of the various research worldviews involved in their CDR project. The hypothesis behind the Toolbox Project is that the mutual understanding generated by this type of dialogue will support enhanced group communication, thereby improving the project team's ability to identify and surmount CDR challenges as they arise.[6]

This hypothesis is a testable claim, and below we describe how we have operationalized it and report on some early project output. It is important to note that we do not claim that philosophical dialogue can be used to address all challenges to CDR, at least not directly; its principal value will be in connection with communication about

[6] Noting the fundamental relationship between group communication and the challenges that confront collaborative CDR, one might wonder why *philosophical* dialogue would be superior to, say, a conversation about baseball or any other activity that could help a group become a more tightly-knit team. We do not deny that there are other ways to enhance group communication, but philosophical dialogue allows teams to enjoy the benefits of a good conversation *and* come to realize and appreciate the fundamental commitments their collaborators (and even they themselves) make as research scientists. The latter benefit involves the kind of understanding that can facilitate scientific negotiation and enable more effortless scientific collaboration.

science that reflects disciplinary difference. Thus, we agree with the observation made in NAS (2004) that communication is the "heart" of cross-disciplinary activity, understood as comprising "the conversations, connections, and combinations that bring new insights to virtually every kind of scientist and engineer" (p. 19). By enabling collaborators to see their shared research project through each other's eyes, structured philosophical dialogue can enhance group communication, thereby generating a range of beneficial effects for a CDR team.

4 The Toolbox approach

As indicated above, the Toolbox approach[7] aims to address philosophically-based communication issues through a structured dialogue in which participants abstract away from specific disciplinary differences toward the conceptual common ground they share as research scientists (or as in Galison 1997, "trading zones").[8] This dialogue is intended to reveal their research worldviews, integration of which will be crucial to CDR success. As such, our approach involves an *intervention* into the life of the participating team that puts them in a position to engage in an atypical but probing self-evaluation. The approach consists of two main parts, the Toolbox instrument and the Toolbox workshop, with the instrument deployed in the workshop to structure the dialogue. We consider each of these in turn.

4.1 The Toolbox instrument

Using the tools of analytic philosophy, we have designed an instrument—the "Toolbox"—that reveals scientific commitments through responses to pointed statements about scientific knowledge and practice. The Toolbox is a structured set of 34 philosophical statements that illuminate fundamental research assumptions. These statements are divided into two broad categories: what we are like that we may know the world (i.e., the *Epistemology* category) and what the world is like that we may know it (i.e., the *Metaphysics* category) (Kornblith 1993, p. 2). Each category is divided into three sections, and each section begins with a Core Question that announces the

[7] The Toolbox approach grew out of an NSF-sponsored Integrative Graduate Education and Research Traineeship (IGERT) project that focused on biodiversity conservation and sustainable production in tropical and temperate fragmented landscapes (http://www.cals.uidaho.edu/igert/). This project required graduate students in the biophysical and social sciences to work together on their PhD projects in cross-disciplinary teams. Many of the project challenges mentioned above were encountered, and a few of the students concluded that philosophical tools could be used to meet them. "Philosophical Issues in Interdisciplinary Research" became the topic of the project seminar in spring 2005, co-taught by an entomologist and a philosopher, and the seminar hatched the Toolbox idea that was later published as Eigenbrode et al. (2007). Toolbox workshops were originally pilot tested with the IGERT teams, and this approach has been built into the renewal project that focuses on the resilience of social-ecological systems in Idaho and Costa Rica (http://www.cals.uidaho.edu/igert2/).

[8] Galison (1997) introduced the metaphor of the *trading zone* in part to highlight the fact that parties interested in communication can succeed in exchanging information even though they differ significantly in assumptions about the items exchanged or the exchange process. Trading zones are the locations where exchanges of this type take place. For more detail about trading zones and their relationship to cross-disciplinary activity, see Gorman (2010).

section theme and five to seven Probing Statements that express aspects of the theme. The Epistemology category is subdivided into the Motivation, Methodology, and Confirmation sections. The Metaphysics category is subdivided into the Reality, Values, and Reductionism sections.

The Epistemology sections were identified by top-down, a priori consideration of the nature of scientific research. Specifically, they correspond to stages of the "research trajectory": what motivates researchers to initiate a research project, how as researchers they collect and evaluate relevant data, and how they identify when they have knowledge. In contrast, the metaphysics sections were identified through a bottom-up, a posteriori examination of the literature about CDR process. These sections capture three aspects of the world under investigation that often divide researchers, namely, whether the world is independent of the investigators, whether values are an essential part of the world, and whether the world must be reduced for explanatory purposes to more basic elements.

Both a priori and a posteriori considerations informed the identification of Core Questions and Probing Statements in the Toolbox instrument. This methodologically heterogeneous approach to Toolbox design reflects our view that research worldviews are both highly systematic, and so logically constrained to a significant degree, and highly idiosyncratic, based on individual research experiences. In sum, they are at once both substantially universal and individual. Attention to universal features reveals categorical structure that frames what sort of problems a worldview should address and what counts as solutions to those problems. Attention to individual features reveals particular disciplinary choices about how to instantiate categorical features, yielding insight into the variety of conceptual conflicts generated by different disciplinary combinations. Design pressures were also exerted by the need to develop an instrument that balanced philosophical accuracy and comprehensiveness against brevity and practical utility. Participants read and respond to the instrument in a workshop setting, and it is important to have this be brief enough to leave room for the dialogue. Practical utility motivated two specific design decisions: (a) inclusion of Values in a section in the Metaphysics category, as opposed to a third category of its own,[9] and (b) association of Likert scales with each Probing Statement, to generate data and ensure that the respondents were pushed off the fence and into dialogue with one another.[10]

To illustrate, consider the Confirmation section of the Epistemology category, supplied in the Appendix. The Core Question expresses the main theme of this section: what does knowledge in a given discipline require? The remaining statements are designed to reveal aspects of the process of confirmation that can divide representatives of different disciplines, such as the nature of measurement and the role of

[9] Conceptually, it arguably makes more sense to include the Values section as a third category, alongside Metaphysics and Epistemology, but we felt the need to balance philosophical elegance against overall instrument length. The key in these workshops is to get values-related issues into the dialogue, which was accomplished by including them as a section in the existing structure.

[10] Underlying this approach is the assumption that an individual's research worldview is revealed in her responses to the statements that constitute the Toolbox. Thus, the responses to the Likert scales associated with each should supply a quantitative representation of these individual worldviews. Thinking of them as *conceptual architectures*, these representations are subspaces of the overall space carved out by the Toolbox statements.

replication. As a whole, the instrument can be understood as a piece of "philosophical technology" that abstracts away from the specific problems that research teams face and guides those who use it to conceptual common ground on which they can stand with fellow scientists to discuss their research perspectives.

4.2 The Toolbox workshop

The Toolbox instrument is deployed in a workshop environment. The workshop begins with each collaborator scoring the Likert scales associated with the statements on their copy of the Toolbox instrument, adopting the perspective of their own discipline. Once the statements have been scored, the collaborators are invited to discuss them from the perspective of their disciplines, beginning anywhere they choose. This freedom affords them the opportunity to initiate the dialogue with a topic that interests them, where this varies across different groups. The participants then work their way around the instrument in dialogue for 90 min, guided as they go by a facilitator. At the close of a workshop, participants fill out the Toolbox instrument again, and later they supply open-ended reactions to the experience on a survey.

We have conducted 80 Toolbox workshops over the past 7 years with many different types of participating groups: research teams collaborating on a particular project (24 workshops), administrative teams (6), researchers who aren't working together on a particular project but who belong to a research network (32), and ad hoc groups (18). The target group for the Toolbox approach is the team of scientists collaborating on a particular research project. Functioning as a team with a mutual purpose, groups of this type have a collective stake in their project and form a team identity that influences how they collect and interpret data and make scientific judgments (Campion et al. 1996). These characteristics also incline the groups to be more serious and focused about the dialogue in the workshop, since they recognize it as an opportunity to learn more about their collaborators as scientists. In what follows, this is the type of group we will have in mind as we discuss the Toolbox approach.

The Toolbox workshop is designed to be a context in which collaborators articulate their own scientific conceptual worldviews and acquire an understanding of the worldviews of their collaborators. It is not a philosophy classroom, although the participants do spend most of the time talking philosophy. We have, in designing the instrument, done the crucial, preliminary philosophical work of conceptually modeling the scientific research space; once the dialogue begins, the participants avail themselves of this conceptual model to guide them in sharing their own philosophical insights on their various research perspectives. Related to this, we have adopted a passive facilitation strategy—the dialogue has more value for the participants if it is about them and not about the facilitator. The facilitator will work to make sure that the participants discuss each section in the instrument, although it is not required that they discuss each of the Core Questions and Probing Statements. This "passive" strategy also grounds the decision not to define or disambiguate potentially confusing terms that appear in the instrument, such as 'values', 'basic science', or 'confirmation'; a primary point of the dialogue is to have the participants identify what they take these terms to mean, individually and collectively, working toward a project "pidgin" that can provide for

functional translation of terms that stand for foundational research concepts.[11] If we define these terms, participants will dutifully employ them in those ways, missing the opportunity to interpret them collectively.

5 Outputs from the Toolbox approach

The Toolbox workshop is an intervention into the life of a group that probes its functionality, and as such has a range of outputs. These outputs include practical deliverables for participating groups, philosophical implications for those interested in examining conceptual issues in the context of CDR, and research data for the Toolbox Project that inform our evaluation of the intervention. In this section, we begin by detailing the practical and philosophical deliverables, which we take to be conceptually and operationally related. We then turn to the data, which we are currently engaged in analyzing. We have developed a philosophical framework for analyzing these data that focuses on two broad types of effects: effects on the epistemic attitudes of collaborators, and on the communicative processes within the group.[12] We consider these in turn.

5.1 Practical and philosophical output: introducing the "loop"

The Toolbox Project has two modes: it is both an *outreach* project intended to improve the conduct of CDR and a *research* project designed to increase our understanding of the philosophical aspects of CDR, including both the conceptual nature of CDR and aspects of core philosophical areas (e.g., epistemology, philosophy of language) that concern themes manifest in the practice of CDR. These project modes are related in an investigative feedback "loop": philosophical research has yielded the Toolbox approach, which *informs* CDR through its outreach mode, and close attention to the Toolbox intervention as an outreach effort for CDR teams *illuminates* philosophical research.

In its outreach mode, the Project aims to have a salutary impact on the day-to-day life of CDR projects. As we have argued, the opportunity to engage in structured dialogue about philosophical aspects of their research worldviews can enhance mutual understanding, thereby benefiting group communication. We reinforce the initial intervention by producing a lengthy analytic report that supplies a transcript and analysis of the workshop dialogue, pre- and post-workshop Likert data, and post-workshop survey responses. To date, the post-workshop survey has generated data that strongly endorse the approach. For example, of the 53 % of 278 participants who completed these surveys as of August 2011, 83 % indicated that they found the Toolbox workshop useful and 77 % indicated that the experience was an entirely positive contribution to

[11] The idea of a "pidgin" language as an "interlanguage" has been discussed by Klein (1996, 2011), Galison (1997), Collins et al. (2010) among others. Pidgins are typically distinguished from creoles, with the former being the early, somewhat systematic attempt to bring different vernaculars together and the latter being the more well-developed medium that emerges as the pidgin develops, qualifying as a new language.

[12] As noted above in Sect. 3, we also hypothesize a causal connection between these two, with epistemic effects producing communication enhancements; however, we are not in a position at this point to assess causal correlation between effects of these types. This represents the next stage of our experimental evaluation of the Toolbox approach.

their professional development. As an example of insight gained in the workshop, one participant commented:

> My views of 'science' have broadened to encompass a less rigid definition than the one I was taught. I learned that philosophical orientations, even with the same scientist, may differ depending on the type of project. The Toolbox allowed me to get a better understanding of my colleagues' philosophies of science.

In its research mode, the Project provides data for philosophy, and in particular, philosophy of interdisciplinarity, social epistemology, and philosophy of language. It is important to recognize that the Toolbox dialogue is an unusual type of philosophical conversation. While the participants are not typically philosophers, they are research scientists who have experience generating new knowledge, and this experience informs their reflection on the conceptual foundations of research. Further, they come from different disciplines and so represent different conceptual foundations. The usual result is a stimulating conversation about issues in the philosophy of science buttressed by examples and anecdotes that bring out aspects of the issues that can be fresh and uninfluenced by philosophical trends and traditions.

The Toolbox workshop is rather like a philosophical linear accelerator, bringing focused streams of philosophical reflection together in dialogue, and Toolbox Project personnel are in attendance to observe what flies out. Among the philosophical particles generated are insights of value to philosophers interested in interdisciplinarity. For example, Toolbox workshops generate data that enable us to determine whether the philosophical categories emphasized in the instrument get at matters of central concern for CDR teams (e.g., whether issues related to confirmation divide teams), thereby yielding insight into whether standard distinctions in the philosophy of science are relevant to and valuable for the conceptual framing of CDR. Also, philosophers of language can learn from the ways in which experts negotiate linguistic differences in discourse, jointly construing terms in the co-construction of meaning. This informs semantic and pragmatic models of discourse, as well as our understanding of the collaborative character of speech as an activity (Clark 1996).

Epistemologists can also profit from close attention to the practice of CDR. This is because it puts them in a position to study conceptual aspects of knowledge construction that are typically left tacit in other circumstances. For example, recent work on reasonable disagreement (Feldman and Warfield 2010) seems to overlook the sort of disagreement that can take place within CDR and so offers a distorted view of disagreement in general. In particular current work on disagreement suggests that the correct response to it is some sort of compromise about the claim at issue (e.g., parties to the disagreement may adopt an agnostic view regarding the claim at issue). On the basis of our experience with CDR we suggest that a re-framing of the entire discussion is also an appropriate response to the situation as described.

That is, reasonable disagreement (in at least some cases) involves achieving and recognizing incompatible justified beliefs. This is a dynamic epistemic situation; it calls for the development of a new research perspective within which the incompatibility of prior work can be resolved. The key point here is that the incompatibility of two perspectives need not be resolved by rejecting one or both of the perspectives. Sometimes it can be resolved by adopting a new approach to the problem that the

perspectives are meant to address. Just as two vehicles apparently on a collision course when viewed in two dimensions are seen to be comfortably distant in three dimensions, so too one can seek to address disagreement not by rejecting one or the other point of view but rather by re-framing the issue.

5.2 Philosophical framework for data analysis I: epistemic effects

Toolbox workshops generate a variety of data that can be used to assess the impact of the intervention on the participants. As we noted above, these include Likert scores, a transcript of the workshop dialogue, and post-workshop survey data. In this article, we focus on the philosophical framework we have developed to guide our data analysis. This framework is based on the Toolbox idea that systematically induced epistemic changes can have a salutary impact on group communication. Thus, one type of effect that we hypothesize will be indicated by the data is *epistemic* and involves participant attitudes about team-related matters. At any given time in the life of a research team, collaborators will have a range of such attitudes. These will include beliefs about the contributions of the constituent disciplines to the team's research goals, beliefs about their own role in the group and the roles of others, social attitudes toward their collaborators, and attitudes concerning group direction and leadership (Thompson 2009). These attitudes are modifications of individual psychologies, although they can interweave in various ways to produce mutual, or "We", attitudes (Tuomela 2007). In what follows, we organize these into "individual" attitudes and "collective" attitudes.

Individual attitudes include beliefs one has about one's own disciplinary perspective and knowledge base(s) and those of one's collaborators. Collaborators need to ascertain what aspects of their own disciplinary knowledge are relevant, and how those could be integrated effectively in a joint approach to the research questions at hand. In addition to these reflexive attitudes about one's own contributions, there are attitudes about the contributions of others, such as expectations concerning the knowledge one's collaborators have to contribute, and how that knowledge is positioned relative to project objectives. The Toolbox workshop is intended to affect these attitudes in various ways. At the project level, there is the impact the dialogue can have on the team's thinking (Bakhtin 1981); at the disciplinary level, there is the effect on how one conceptualizes one's own discipline and the effect on mutual understanding within the team of the constituent disciplinary contributions (Thompson 2009).

As we noted above, failure to appreciate salient similarities and differences can give rise to unreasonable collective states, which could be either states of agreement or disagreement that rest on confusion due to partial information or misinformation. A Toolbox workshop is intended to calibrate these collective states via dialogue, making possible various epistemic achievements. Participants can come to recognize contradiction in their own assumptions and work to reconcile some of their fundamental beliefs about science and the world. As illustrated by the exchanges above, they can also come to recognize through the dialogue that their assumptions are not shared. This can engender a greater degree of mutual understanding that can help the team avoid miscommunication rooted in confusion about collaborator attitudes concerning the collective project. Achievements of this sort enable scientists to see the research landscape through the eyes of their collaborators (Klein 1996).

Collective attitudes concern attitudes about aspects of team identity and function such as the distribution of status across the team, gender, trust, and team cohesion (Casey-Campbell and Martens 2009). Together, these aspects constrain how the team adjusts socially, functionally, and teleologically in response to new information and changing circumstance (McDonough 2000). A team's identity, or collective sense of self expressible as "We" attitudes, influences the research goals it sets for itself, the leadership structures it establishes, the roles that various participants take on within the group context (Goffman 1981), and the interactions that mark the day-to-day work of the team (Beebe and Masterson 2009). The focal dialogue within the Toolbox workshop can allow members to enhance their status within the group by virtue of their contributions, and it can also engender trust by increasing the level of mutual understanding through collective self-disclosure (Powell 1990).

5.3 Philosophical framework for data analysis II: communication effects

A second type of effect indicated by the Toolbox idea that we are looking for in the data involves group communication. As we noted above, group communication has a relational dimension and an informational dimension. The former concerns "verbal and nonverbal messages that create the social fabric of a group by promoting relationships between and among group members", while the latter concerns information exchanged among group members that enables pursuit of team objectives (Keyton 1999, p. 192). The social fabric of a CDR team is an important piece of the team's collective identity, and it is woven out of the threads of different disciplinary experiences. Disciplines can be understood as epistemic cultures, and so CDR creates a context in which communication is *intercultural*. In such a context, relationships among team members are forged in dialogue, an activity that enables achievement of a "unity within diversity" (Baxter and Montgomery 1998). The phenomenon of group communication is a multifarious one. Two specific aspects that we hypothesize exhibit effects in the wake of Toolbox workshops are the *cultural* aspect and the *discourse* aspect.

The cultural aspect can be conceived through the idea of *localization*, understood as an effort to make something foreign seem familiar to "end-users" who have not spent much time with it (Crowley et al. 2010). The Toolbox approach is a localization effort that aims to make the research disciplines within a cross-disciplinary collaboration seem "familiar" to all of the collaborators by generating shared understanding of research assumptions through dialogue. The localization effort is structured by the Toolbox instrument and guided by the facilitator, but the real work of localization is conducted by the participants themselves as they talk their way around their various disciplinary research perspectives.[13] The philosophical abstraction embodied in the instrument moves the participants away from their different disciplinary locales toward common ground that is at a remove from the potentially contentious project

[13] As noted above, the Toolbox Project supplies participating teams with a detailed analytic report intended to illuminate their range of conceptual commitments and their communication dynamic. This type of input is offered instead of an immediate, "therapeutic" response at the conclusion of the workshop by the facilitator, primarily because it is difficult to obtain a settled perspective on the epistemological and communication aspects of a team immediately after what is typically a rich and varied dialogue.

zone. By becoming familiar with their colleagues' epistemic cultures, participants can begin to see their project collectively and can thereby communicate more effectively with one another about project business.[14]

The discourse aspect is revealed by *discourse analysis*, a linguistic approach that looks for meaningful patterns of language use across discourse-level language samples (Johnstone 2008).[15] We see the workshop as an exercise in joint construal, a process by which interlocutors work cooperatively to construct meaning (Clark 1996). We hypothesize that it will be possible to identify linguistic markers that correlate with successful joint construal at several different levels of interaction. The primary objective of the dialogue is to encourage joint construal at the conceptual level, so that team members cooperate to fully specify the meaning of the statements in the Toolbox instrument, thus modifying their epistemic stance. On the relational level, we should find linguistic evidence that the workshop affected the interactional stance taken by team members toward one another. Certain linguistic features, such as the use of repetition and words per speaking turn, should indicate a high level of engagement, understood as the degree to which discourse participants are interested in and focused on their conversation; further, the way interlocutors use discourse markers, questions, and turn-taking should supply evidence of their attitudes toward one another. We conducted an analysis of 11 of our workshop transcripts, counting instances of overlap, talkover, and laughter in each transcript and then dividing them into the total number of words; we also calculated the average number of words per speaking turn and the average number of words per minute. In addition, the facilitators in each of these workshops supplied holistic, subjective assessments of the engagement level of each group. Our findings indicate that words per minute and talkover are marginally and significantly associated, respectively, with facilitator perception of engagement.

6 A philosophical conclusion

As a practice, philosophy can perform a critical function or a facilitative function. In its critical role, it seeks to evaluate claims about conceptual structures with a view to constructing adequate theories of the relevant possibilities. In its facilitative role, it supplies clarity and insight that is of use to students and practitioners,

[14] Two assumptions underpin the claims about process made in this paragraph. First, the statements in the Toolbox are written at a level of abstraction meant to capture the common conceptual province of those engaged in research in the STEM fields (i.e., science, technology, engineering, and mathematics). These commitments are reflected in their research work without being their focus; thus, the conceptual space illuminated by the Toolbox statements qualifies as ground they share in common with other scientists even though it isn't strictly part of their disciplines. Second, there is a presumption that making the details of one's research worldview explicit will have a salutary impact on self- and mutual understanding. In the context of a research project, where personnel have an incentive to collaborate successfully, the explicit articulation of the research philosophies in play can help reveal potential obstacles and opportunities, as indicated by the questionnaire responses supplied above. These revelations should then have an impact on the epistemic stances of the participants—there is no expectation of consensual adjustment, but annotation of difference should suffice to keep those obstacles and opportunities in view.

[15] We are especially grateful to Liela Rotschy for her significant contribution to the work reported in this paragraph.

inside of philosophy and out. Philosophical criticism is often reflexive, but as we noted, philosophers are often philosophers *of* something, and when so oriented turn their critical eye to some non-philosophical area. Teachers of philosophy are familiar with the power of philosophy to facilitate clear-headed thinking and writing among students, but philosophy also has the power to reframe and refocus efforts outside of the academy, as is exemplified by applications of ethics in the health sciences.

As an ongoing effort to apply philosophy, and particularly philosophy of science, to the practice of scientific research, the Toolbox Project fills both of these roles. In its outreach mode, it is designed to enhance the practice of collaborative CDR through communication improvements that derive from greater mutual understanding about scientific research worldviews. Hence, it aims to facilitate the improvement of collaborative CDR. In its research mode, it concentrates critical attention on the conceptual foundations of CDR in pursuit of two goals: (a) continued development and improvement of the philosophical ideas embodied in the Toolbox intervention, and (b) feedback for philosophers interested in traditional problems in core philosophical areas that can be helpfully reconceived in the context of CDR. Thus, philosophical insight into structural aspects of science and scientific practice are valuable not only to philosophers, but also to practicing scientists.

The dualities of criticism/facilitation and research/outreach, embodied in the investigative loop model in Sect. 5.1, correspond to a third duality that is the focus of this special issue, viz., philosophy *as* interdisciplinarity and the philosophy *of* interdisciplinarity. In its facilitative role as an outreach project, it is philosophy *as* interdisciplinarity—it is an intervention into the intellectual life of a CDR team, engaging philosophy with science in a way that facilitates the sharing of research worldviews. In its critical role as a research project, it is an example of the philosophy *of* interdisciplinarity—we apply philosophical techniques in an attempt to understand and conceptual CDR practice so that we can enhance our facilitative efforts and recover insight of interest to other philosophers. The Toolbox Project stands as an example of the fact that one needn't leave core philosophy behind when moving out into the world as an engaged philosopher. With the Toolbox Project as with all things, wherever you go, there you are, and we believe that is a good thing for science and philosophy.

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Appendix

III. Confirmation

Core Question: *What types of evidentiary support are required for knowledge?*

12. There are strict requirements for the validity of measurements.
Disagree *Agree*
1 2 3 4 5 I don't know N/A

13. There are strict requirements for determining when empirical data confirm a tested hypothesis.
Disagree *Agree*
1 2 3 4 5 I don't know N/A

14. Validation of evidence requires replication.
Disagree *Agree*
1 2 3 4 5 I don't know N/A

15. Unreplicated results can be validated if confirmed by a combination of several different methods.
Disagree *Agree*
1 2 3 4 5 I don't know N/A

16. Research interpretations must address uncertainty.
Disagree *Agree*
1 2 3 4 5 I don't know N/A

17. The members of this team have similar views concerning the confirmation core question.
Disagree *Agree*
1 2 3 4 5 I don't know N/A

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