Epistemic Identities in Interdisciplinary Science

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We introduce "epistemic identities" as a concept helpful for understanding the dynamics of interdisciplinary science practice. After acknowledging the ambiguity of "identity" and examining divergent meanings, we argue that analysis of identity is necessary in order to account for social and personal dimensions of practice non-reductively, and to better understand values and implicit hierarchies in science practice, as these, in turn, influence cognitive practices. With reference to ethnographic data from two integrative systems biology laboratories, we analyze specifically three theories of identity in terms of their affordances for understanding intergroup characterizations in interdisciplinary problem spaces.

1. Introduction

Confronting any science studies or learning sciences researcher in the 21st century is the reality of interdisciplinary science. New hybrid fields[1]

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1. When transferred from the original biological context, implying a combination of species, in the context of cultural and epistemic integration indicated by "hybrid field," the emphasis shifts to an intersection of meaning systems and implicates political as well as theoretical dimensions, given that questions of resource distribution and power are at stake. See for example, Canclini, 1995.

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collaboratively build new concepts, combine models from two or more disciplines (e.g., biomedical engineering) and forge inter-reliant relationships among specialists with different skill sets to solve new problems (e.g., computational systems biology). This paper emerges from our recognition that inescapable psychological factors, including identity dynamics, must be described and analyzed in order to better understand the social and cognitive practices specific to interdisciplinary science.

In analysis of the foundations and opportunities for an interdisciplinary science of learning, Bransford and colleagues claim that "one of the major insights about cognitive performance in the last century is the extent to which the local cognitive and social ecology can constrain or support it" (Bransford et al. 2006, p. 59). More provocative is the authors' second insight: "the importance of social aspects of learning as they are manifest in how people engage with learning activities, one another, and their senses of themselves as learners and identities as doers of particular activities" (Bransford et al. 2006, p. 59). Though the reference is to social aspects of learning, one's "sense of oneself" is relevant to or might be understood in a variety of ways: as self-representation, subjectivity, or identity. Thus it is more accurate to acknowledge that sense of oneself or identity is neither a personal nor social aspect in exclusion of the other, but one that is irreducibly social *and* personal, as has been long recognized (Cooley 1902; Mead 1934). Yet the various ways one's "sense of oneself" as a scientist might impact science practice and science education remain poorly understood.

Our present purpose is to make a case for the incorporation of identity theories into the study of interdisciplinary science, and in so doing to contribute to a better understanding of nodal identity and epistemology relations. To date, the relevance of identity to science assumes three primary foci. The first might be characterized as regional identity, as when "Eastern" and "Western" perspectives on knowledge are contrasted. The second is in relation to racial, gender, or other forms of "otherness," especially in feminist or critical studies of science that draw a contrast from identification through a hegemonic or master narrative[2] co-implicated in the normative framework of scientific method. The third and most recent is the focus on disciplinary identity; in which can be found descriptive accounts of ways identity is shaped and negotiated through discipline-specific communicative practices. Our claim is that it is important to understand the epistemic and social implications of less visible forms of identification that take place around discipline but are not reducible to discipline. It is

2. The term "master narrative" may be understood in both a broad sense recognized across critical theory and in a narrow sense specific to Lacanian discourse (personal communication, Kareen Ror Malone, March 11, 2016). See also Glynos and Stravrakakis 2002.

valuable to recognize that identity is enacted around a theoretical framework, the form of data collected, the method of analysis, and research goals. Thus identities vary within discipline, even in relation to the same phenomenon of study, as evidenced by qualitative and quantitative research encampments within the social sciences. Identity also extends across disciplines, as when scholars from divergent academic backgrounds organize around a given theoretical commitment (e.g., psychoanalysis, phenomenology). What is at stake is broader or more encompassing than merely epistemological commitments, epistemic stance, or even epistemic value: hence our use of *epistemic identity*. Identity, though hopelessly vague, captures an affective dimension, a relation to self-representation, and a relational tie to other possible identities in a way that must be included in the effort to understand the intricacies of social and personal dynamics in the intergroup relations that enable interdisciplinary science.

We introduce the concept of epistemic identities as a descriptive tool for better understanding collaborative and cognitive practices in interdisciplinary spaces. We examine identity enactments in two integrative systems biology labs, and considered the applicability of a range of identity theories to capture the experience and collaborative practices of interdisciplinary researchers. We have conducted 14 years of NSF-sponsored research into the cognitive and learning practices within two main areas of contemporary bioengineering sciences, biomedical engineering, and integrative systems biology. Our study comprises four cutting-edge bioengineering sciences research labs—two in biomedical engineering (BME): a tissue engineering lab (Lab A) and a neural engineering lab (Lab D), and two in integrative systems biology (ISB); one is purely computational with external biosciences collaborators (Lab G) and one has its own wet-lab for conducting biological experiments in the service of model-building (Lab C). In our studies of bioengineering scientists, differences in identification as biologists or engineers and the differences in vantage point these identifications entail accompany differences in attitude toward what constitutes good science, a source of conflict to be managed or reconciled in interdisciplinary collaborations or in making the transition to a "hybrid" bioengineer. Although there are significant differences in the way identity is enacted and the issues encountered around epistemic identity in BME, which aims to produce researchers with hybrid bio-medical-engineering identities, and in ISB in which collaboration between bioscientists and engineers is—and will likely remain—the norm, in both areas encounters with other disciplinary perspectives in collaborations bring the researcher's epistemic identity to the fore. We focus our analysis here mainly on the issue of collaboration, drawing exemplars primarily from the ISB study of collaboration.

As noted, in some respects our project complements the empirical study of disciplinary identity, particularly when disciplinary identity is understood in terms of the practices and assumptions students must adopt for successful participation in an academic community. Regrettably, the concept of discipline is itself hazy, as Hyland, a leading figure in disciplinary identity studies, is quick to recognize, though he proposes "sites of identity" as a means of conceptualizing disciplines, pointing to the very real structures that contour academic practices: journals, conferences, professional memberships, departments, and "other paraphernalia of daily academic life" (Hyland 2012, p. 25), things around which academicians "act to persuade others" of their disciplinary identifications. Hyland's analysis targets disciplinary paraphernalia, looking for linguistic patterns in researchers' formal (e.g., academic bio) and informal (e.g., Facebook page) self-presentations, research articles, book reviews, and related corpora. Indeed, Hyland regards research articles as forms of self-representation, ways of giving information about the self as well as a body of content (Hyland 2011). Our method, however, did not make principal use of disciplinary writing as sources of data. Rather, we interviewed scientists and scientists-in-training in interdisciplinary sites, made observations of their interactional practices, and attended their group discussions. We coded the interviews line by line in a procedure we call grounded coding, because of its compatibility with the coding phase of grounded theory analysis (Corbin and Strauss 2014). Details of our method, including reliability checks employed, are provided in chapter 2 of Osbeck et al. (2011). Our open coding phase produced many codes related to identity, long before we had consciously anticipated including identity categories in our analysis of cognitive and learning practices.

For the purposes of the present discussion, we focus here not on identity categories relating to race, gender, or nationality, but specifically to identities as doers of activities, that is, identities that directly concern learning and problem solving practices in the context of interdisciplinary science.[3] We examine various ways identity related aspects of practice affect the potential for collaborative problem solving and the quality of the collaborative experience of researchers and students in interdisciplinary settings. Questions include how we might best understand the entry points and functions of identity in interdisciplinary science.[4] These questions in turn implicate

3. Questions of gender and race identity enactments in relation to laboratory culture are explored in *Science as Psychology: Sense-making and Identity in Science Practice* (Osbeck et al. 2011), especially chapters six and seven.

4. We assume, too, that disciplinary or epistemic identity enters into a complex configuration with other identity categories and thereby implicates power differentials, as expressed in the concept of intersectionality from critical theory (e.g., Crenshaw 1989; Collins 2008).

broader questions such as what we mean by identity, why we need to talk about it, how identities might be enacted in interdisciplinary collaborations, and, importantly, how identities intersect with cognitive practices in interdisciplinary practice settings. In turn, we ask what theories of identity are most relevant to interdisciplinary science, and what implications for science learning we might draw from a study of identity enactments or practices and the application of identity theories to these practices.

We first situate what we mean by identity and illustrate its place in science by means of an historical example from early psychology in section 1. This is followed by a more detailed discussion of the meaning of identity and its relation to other concepts (section 2), and then we demonstrate how questions of identity and value are implicated in the interdisciplinary research laboratories we have been investigating (section 3). In the course of demonstrating the relevance of identity analysis to interdisciplinary science we examine the affordances of three theoretical frameworks that have been useful for understanding identity in other contexts of interpersonal and intergroup relations.

2. Science, Values, and Identity

2.1. Historical Example: The Functional Attitude and "Point of View"

As we have emphasized elsewhere (Osbeck and Nersessian 2015), functional psychology represents an early effort within psychological science to bring a systems level view to the project of understanding human consciousness and intelligence (Angell 1904, 1907). Functional psychology displaces focus on the "plan of arrangement" in the mind's "mass of tangled processes," for concern with the "system of functions" that enables the mind to "do" things for us or equips us to "do" (Titchener 1899, p. 290). As a systems perspective (namely, the organism and environment system), functional psychology is associated principally with a point of view that differs from that of structural psychology. That is, functional psychologists were no less interested in robust psychological science and were no less concerned with adequate descriptions of consciousness, but considered structural psychology to be operating from the wrong scientific perspective—exploiting the wrong science for analogy: "The mind has been regarded too exclusively on the analogy of the chemical compound which is to be resolved into its elements, and too little as an expression of life to be studied in its activities" (Angell 1912, p. 12). By contrast, the functional "attitude" is one that "brings the psychologist cheek by jowl with the general biologist" (Angell 1907, p. 69).

In his depiction of the functional attitude, Angell expresses an alignment, an epistemic identification with general biologists, scientists who

study living systems, concerned with processes, interconnections, and temporal relations. Epistemic identifications overlap with or encompass attitude and point of view, as well as what has typically been thought to fall under the general heading of values. Embedded in Angell's emphasis on function in the preface to his introductory textbook on psychology is a not-so-subtle reference to the influence of perspective, point of view, or value in relation to the goals of the text:

> Psychologists have hitherto devoted the larger part of their energy to investigating the structure of the mind. Of late, however, there has been manifest a *disposition* to deal more fully with its functional and genetic phases. To determine how consciousness develops and how it operates is *felt* to be *quite as important* as the discovery of its constituent elements. (Angell 1904, p. iii)

We have claimed that the feeling of what is "quite as important" is a matter of epistemic value, related to the goal of understanding how consciousness develops and operates. As an epistemic value, it shapes decisions about what are to be counted as psychological data, how data are to be collected and analyzed, and what will be taken as implications of the analysis. Less obviously at play in the example given are non-epistemic values that also infuse the functional attitude this interest, reflecting considerations that a functional perspective would yield a more socially useful psychology.

The definition of values in terms of what is felt to be important is resonant with contemporary understandings of value and how they relate to science:

> In a scientific context, the main way values show their importance is how they enter as premises or bases for making decisions or performing actions in the context of doing science and scientific research. That is, if scientists let certain factors affect and guide their intellectual and practical endeavors, then these factors are what they take to be important (for whatever reason). The *various beliefs, techniques, and practices that scientists use to make judgments and evaluations* are the loci in which values display themselves. Whether or not scientists can justify these values is a different question…" (Machamer and Wolters 2004, p. 2)

Machamer and Wolters acknowledge that the debate on science and values has long moved past the question of whether or not science is a value free enterprise, and onto the question of what different kinds of values enter into science and how they interact with one another toward various ends, some facilitative of sound practice and some not so. There is a good deal of disagreement about the kinds of values in play, the extent to which there

are genuine differences between kinds of values, how they interact in practice, and to what end. A distinction between epistemic and non-epistemic values is one of the most entrenched, relating to the classical conception of philosophy of science as rational reconstruction (Reichenbach 1938; Carnap 1935). Rational in this context referred to what is "purely epistemic," bearing on truth or falsity only (Laudan 2004). Epistemic values concern the adequacy of evidence and inference, on explanatory and predictive powers. However, they also encompass what are to be counted as data in the first place (what count as psychological data, for example—behavior, introspective experiences, cognitive processes, neural patterns of activation, discourse, parapraxes) (Machamer and Osbeck 2004; Osbeck and Nersessian 2012). Contemporary perspectives on the relation between epistemic and non-epistemic values are extremely varied (e.g., Douglas 2009; Lacy 2005; Laudan 2004; Longino 1990), and there are questions concerning the relevance of the very distinction (Machamer and Osbeck 2004).

One suggestion is that philosophy of science can help scientists recognize and make explicit the values they hold and what kind of values they are (Machamer and Wolters 2004). Understanding the kind of values could then allow scientists to determine the extent to which they have grounds for advocating on scientific, social or political issues (Douglas 2004). However, with analysis of *in vivo* scientific practices, the task of extricating values and demarcating by kind becomes extremely difficult, even at the first level distinction of epistemic from non-epistemic values. That is, epistemic and non-epistemic values—epistemic and social values—comingle and co-implicate one another. There are differences in epistemic values evidenced in different sciences or in different approaches to the same science, as exemplified in the example of functional psychology in relation to consciousness. Socialization into a practice community as part of one's educational preparation and early career development requires mastery of a particular method or evaluative approach. Thus whether one takes a reductive or systems level view, though determined by the relevant question posed with each approach being merely a tool of evaluation, is determined in large part by the approach or point of view that is sanctioned within the community of which one becomes a part, with very few exceptions. Epistemic values, that is, just like non-epistemic values, are inflected with identity. Identity in turn has social and personal dimensions, a personal story line and a social history by virtue of the groups with which one actively and passively identifies, along with the history of these groups. In brief, we are claiming that identification as an engineer is as social a matter as identification as Catholic or Tunisian, and that identification as an engineer has epistemic implications, and that it impacts epistemic values and cognitive practices.

3. Identity and Interdisciplinary Collaboration

Much remains mysterious about the factors that facilitate or impede successful collaborations across disciplines in interdisciplinary endeavors. Moreover, interdisciplinary science creates new challenges for philosophy of science. A problem that is widely discussed in the literature on interdisciplinarity but underappreciated in philosophy of science is that in interdisciplinary science there are often multiple (sometimes conflicting) norms and values—differing ideas about what constitutes good science.

It is sometimes the case that there is no single set of norms for researchers to navigate, no single overarching, and thus ultimately authoritative set of ideas about what it means to be a good scientist or to do science right. For collaboration to be possible one side cannot be squelched; norms of any one science cannot be imposed on the other. Where normative influences are less entrenched, as in an interdisciplinary setting, they must be negotiated through various practices. There is no single means of accounting for or describing the means by which these negotiations take place; they must be studied and described in the contexts in which they are occurring, with careful attention to the features of the context and the subtleties of interaction between scientists. That is, we cannot fully understand the dynamics of interdisciplinary science without examining how "good science" is understood and enacted by actual scientists working within these new settings. This is a matter of understanding how values are enacted in ordinary contexts of science practice. However, because ideas about what constitutes good science are tied up with what it means to be a scientist (at least a good or competent one), ideas about how science is to be done implicate identities as well as values. Greater attention needs to be given to disciplinary identity and how this implicates epistemic value, and more broadly, how identity cuts across different types of value: epistemic, social, aesthetic, and even ethical. This requires, in turn, a focus on the epistemic affordances of different disciplinary positions/perspectives. Among the questions to pursue is whether there are ways to talk about "identities that are good for science" (and science education), that are analogous to discussion of "values that are good for science" (e.g., Douglas 2009).

To make the case for why a complementary focus on identity might be required, that is, why we need to theorize identity and not just values in relation to science, especially interdisciplinary science, we organize our discussion by considering 1) definitional issues and controversies surrounding identity, 2) ways in which identity is enacted in interdisciplinary science, and 3) what might be some useful frameworks for understanding such enactments.[5]

5. We note, too, that a focus on epistemic identity complements increasing attention to the meaning and importance of perspective in scientific practice, with perspective understood in terms of constraints on claims one can make about the universe. Giere

4. Definitional Issues: Identity, Identities, Identification

Problematically, "identity" is notoriously vague, overlapping with self, self-concept, subjectivity, affiliations, and group cohesiveness. Definitions and theories are many: "Organizational scholars have provided a plethora of textured and politicized theoretical treatments of identity" (Tracy and Trethewey 2005, p. 168). Rogers Brubaker and Frederick Cooper provide an excellent overview of the historical trajectory of the notion of identity in the social sciences, and with it, a scathing critique leading to identification of an "identity crisis" in social theory, "a crisis of overproduction and consequent devaluation of meaning" (Brubaker and Cooper 2000, p. 3).

Key developments Brubaker and Cooper feature in the historical trajectory of identity include:

1. Original psychoanalytic context, chiefly Freud's "identification" (as a mechanism for resolving Oedipal complex: Object choice (mother) is relinquished through identification with father.
2. Widespread interest in Erik Erikson's work, popularization of "identity crisis" in 1960's.
3. Appropriation from original psychoanalytic contexts into theory on race and ethnicity in the 1960's, largely through Gordon Allport's work on prejudice (1954).
4. Symbolic Interactionist: Social theory moved from an emphasis on self [e.g., Mead's *Mind, Self, and Society* (1934)] to emphasis on identity, largely through influence of Anselm Strauss (1959).
5. Identity as presentation, dialectical construction, and performance (Berger and Luckmann 1966; Butler 1990; Goffman 1959)

Given the definitional problems that emerge from multiple contexts of use, Brubaker and Cooper acknowledge the "emotionally laden sense of belonging to a distinctive, bounded group, involving both a felt solidarity or oneness with fellow group members and a felt difference from or even antipathy to specified outsiders…." yet they note that "[R]ather than stirring all self-understandings based on race, religion, ethnicity, and so on into the great conceptual melting pot of 'identity', we would do better to use a more differentiated analytical language" (Brubaker and Cooper 2000, p. 20). It is also the case that identity is used in conjunction with both the sense of belonging or connectedness with and the sense of differentiation from others,

emphasizes that constraints are imposed both by instrumentation, by the specific instruments used for measurement, but also by "principles defining generalized models" (Giere, 2010, p. 81). Perspective, clearly, enables epistemic claims and implicates epistemic values.

personal uniqueness. Thus claims concerning the looseness of identity as a conceptual category are well taken.

Erikson himself anticipated some of the muddle in an account of identity that is surprisingly complex and importantly social. In "The Problem of Ego Identity" (1956) Erikson depicts identity as "certain comprehensive gains" that are "derived from experience:" it is for him an acquisition through learning with wide ranging implications. It is important to Erikson that Freud used the term identity only once in relation to his link to Jewish people.[6] He interprets its significance for Freud as "less based on race or religion than on common readiness to live in opposition" (1956, p. 109). Identity is, for Freud, as Erikson sees it, a matter of felt relation and potential relation to other groups.

The inherent ambiguity of identity is revealed in Erikson's acknowledgement of two interdependent senses: the term identity "expresses a mutual relation in that it connotes both a persistent sameness within oneself and a persistent sharing of some kind of external character with others." Approached "from a variety of different angles," it will appear at one time "to refer to a conscious sense of individual identity at another to an unconscious striving for continuity of personal character; at a third, as a criterion for the silent doings of ego synthesis; and, finally, as a maintenance of an inner solidarity with a group's ideals and identity."

The ambiguity is heightened by the sociological view of identity not as acquisition, possession, or gain, but as performance—something people do in interaction. This view of identity has appeared more recently in conjunction with theories of gender as socially constituted, and prompts a shift in emphasis to identities—multiple, contingent, and tenuous. Judith Butler is exemplary:

> Identities can come into being and dissolve depending on the concrete practices that constitute them. Certain political practices institute identities on a contingent basis in order to accomplish whatever aims are in view… Gender ought not to be construed as a stable identity or locus of agency from which various acts follow; rather, gender is an identity tenuously constituted in time, instituted in an exterior space through a stylized repetition of acts. (1999, pp. 22, 179)

The idea that identity is best understood as enactment is tied to the view of the subjected self, with focus on the influences as ascriptions to which one is one is subjected by virtue of participation in a language community; that is, as the means by which identity is produced and constrained through language (Althusser 1971; Foucault 1972). One must adopt,

6. Though Freud used "identification" much more readily. See Laplanche and Pontalis 1973.

reject, manipulate or otherwise negotiate the existing possibilities for categorization (woman, Catholic, scientist), as well as the history, sometimes politicized, always culturally inflicted, that accompanies those categories. Thus the idea of identity as enactment is tied to considerations that have to do with power structures variously imposed.

The recognition of connection between identity and power hierarchies did much to mobilize identity theory, particularly in relation to issues of race and gender. It is exceedingly helpful for understanding identity as far as it goes. Recent years, however, have brought recognition that links between theories of power and the domain of the psyche must be better understood (Benwell and Stokoe 2006). As Butler put it succinctly, "We cannot presume a subject who performs an internalization if the formation of the subject is in need of explanation" (1997, p. 32).

The neglected domain of the psyche includes, at a minimum, the ability to assent to or reject categorizations that are imposed by others' agendas. One can be identified by others in ways that are not consistent with one's own identifications. One can, for example, identify as black while being identified by others as white; be identified as gay, when one identifies as bisexual; American, when one identifies as Canadian, and so on. In some cases this can be exploited, even in the service of a power reversal, as in the case of passing for white, a phenomenon blue eyed, blond haired Walter White exploited to uncover racist practices in the South as part of his service to the NAACP (White 1948). As summarized by Hall, the possibility that "one can gain control over that which has controlled one's consciousness by becoming conscious of the dynamic of control is the premise of most twentieth-century theories of politicized subjectivity" (Hall 2004, p. 55).

5. Identity Enactments in Interdisciplinary Science

What is clear about identity is that there are sundry ambiguities attending any talk of it. As Erikson himself acknowledged, [Identity] can appear in some aspects to be "colloquial and naïve;" "vaguely related to existing concepts in psychoanalysis and sociology." It is for him, nevertheless, a "*significant problem*" and "*necessary point of view*" (Erikson 1956, p. 109). As for Erikson, despite the ambiguity and possible muddle, attention to identity underscores for us an important problem and brings what we believe to be a necessary perspective on interdisciplinary science. Why might identity be a significant problem and necessary point of view for interdisciplinary science? What, as a concept, does it do?

We propose two related functions of identity concepts that are useful for characterizing some (certainly not all) aspects of interdisciplinary science practice. First, identity is an inherently integrative concept. It offers a crystallized means of talking about the dizzyingly complex relations

between the embodied agentive scientist and the normative milieu in which she operates. As noted elsewhere, accounts of science practice have tended historically to emphasize either the powers of individual cognition in scientific reasoning or the social traditions that establish the norms and sanction knowledge production (Longino 2002; Nersessian 2006). There have been few integrative accounts of practice that do justice to the complexity encountered in analyzing real world practices examples (Nersessian 2006).

Moreover, as we have argued, even blended social and cognitive accounts are easily able to account for the contribution of the particularity of the scientist, whose embodiment is more than a brain and who never enters the collective space void of goals, aspirations, fears, revulsions, and desires (Osbeck et al. 2011). The contribution of this additional dimension—this particularity—to the practices and processes that constitute science is more or less ignored in the mainstream of science studies, at least outside of biographical analyses of scientists. It is principally acknowledged as a source of error or contamination. There are notable exceptions, most famously Polanyi's *Personal Knowledge* (1958), which rejects the ideal of scientific detachment and the conflation of objectivity with the impersonal, as well as several depictions of the contribution of subjective processes and operations to the highest achievements of scientific reasoning (Mahoney 2004; Mitroff 1974; Maslow 1968; Watson 1938).

But we continue to fall short on providing a clear account of the ways the personal dimension contributes to science practice in both the discovery and justificatory phases; that is, in ways that enhance science, not merely detract from its purity and precision. Increasingly, however, we are required to account for the ways the personal dimension enters into the specific forms of interdisciplinary practice that require new roles and forms of interaction from scientists of sometimes quite varied disciplinary backgrounds. The task is to include in our accounts of science the concepts that enable us to talk about the personal dimension (emotion, meaning, agency, and disposition) without resorting to an (isolated) individualist framework.

In the situated cognition literature focus on practice in learning communities has frequently centered on the problem of identity and identity negotiation as important to understanding how learning occurs. In these contexts, the jointly personal and social aspects implicated by the concept of identity are directly acknowledged. Wenger, for example, calls identity "a pivot between the social and the individual, so that each can be talked about in terms of the other. It avoids a simplistic individual-social dichotomy without doing away with the distinction"… "It is the social, cultural, and historical with a human face" (Wenger 1998, p. 145). Wenger has also identified the formation of communities of practice as the negotiation of identities (1998).

An emphasis on identity within the literature on practice reflects a construal of identity as a form of enactment rather than as a set of fixed self-representations. That is, there is an activity focus in much of the literature on identity. Even Brubaker and Cooper, who are critical of identity for its ambiguity, suggest "identification" as a worthy substitute. In our view, one may make reference to identities or to the more active construction of "identification" without losing the important conceptual work performed by reference to identity.

The second function of identity is related to the first: Identity encompasses, but is more comprehensive than value. It is a multi-dimensional concept, incorporating disposition, cognitive style, affect, judgment, and value. It is, for want of more precise language, a more "whole person" concept than that of value in isolation. As such it can be expected to have bearing on a wider range of interactions, consistent with Erikson's view of identity as offering comprehensive gains (Erikson 1956, p. 108). The impact could be expected even outside of the specific practice setting (the laboratory, the discipline).

An interesting example of comprehensive gains attending an engineering identity appears as a comment posted in response to the online article "What's so wrong with an open marriage?" published by Vickie Larson in the Huffington Post on April 17, 2013:

> I really don't get the attraction of "casual sex" or purely physical affairs. My wife and I have a love life that is a whole lot more enjoyable than when we first became physically intimate, because we both know each other's likes, dislikes, and boundaries. It took a lot of trial and error to get to that stage, so going off with some stranger and starting that whole process again just doesn't seem enticing at all. Maybe it's my engineer's brain talking, but there doesn't seem any sense to go throw a system into chaos when it has already been optimized.

Apparent from this comment is that the author experiences himself as a kind of person (or at least, as the container for a brain) by virtue of his engineering background. The identification as an engineer spills over onto other situations outside of engineering, incorporating a perspective and accompanying values that have ostensibly little to do with engineering or epistemic considerations. The irreducibly personal and social aspects of identity are reflected in this example. Although the view of casual sex is claimed on the basis of group identification (an engineer), expressing solidarity with the profession, it is hardly a professional matter on which he is bringing the perspective to bear. The statement reflects something that

this engineer does with his identification and affiliation with engineering, not something that applies to engineers as a collective, despite the fact that his identification with the collective is used as a basis for the particular sentiment expressed.

6. Dimensions of Identity Enactment

In our study, we first engaged in a phase of open coding of interview transcripts without explicit regard for their theoretical contribution. Many text passages were coded as having to do with identity (as a scientist, as an engineer, as a biologist) without further analysis of what this meant or the dimensions being communicated. Upon further analysis, the following sub-themes were distinguished under the general heading of identity:

Belonging to a group and Differentiation within it. This category includes the problems and projects owned as one's own, one's sense of being part of a community (the lab, systems biologists, research scientists, etc.), and niche within the community—one's specific function or task (e.g., modeling, experimenting, translating between biology and computational perspectives).

Perspective taken in relation to the data of systems biology. This includes epistemic norms; epistemic stance, constraints on inquiry, world view and level of analysis (e.g., systems), one's view of one's own work/domain/level of analysis (how I see myself), one's view of others' work/domain, level of analysis, and a view of others' view of ones work/domain (how do they see me?).

Values: views about what constitutes good or desirable science. This includes ideas about how science relates to truth (epistemic values) and the wider relevance of the work (non-epistemic or social values).

Affect: Feelings are closely related to values. Relevant feelings associated with identity include aspiration, desire, esteem, frustration, and joy. In an interdisciplinary space, one must manage feelings arising from interaction and from values/perspectives that are different from one's own. So among the affective requirements is an ability to manage feelings of devaluation from others.

These dimensions are not distinct, but highly interconnected. The interconnection of these dimensions is best illustrated by example:

> Sometimes from the mathematical point of view [perspective], it would be nice [value, affect] to have some strain that doesn't have a given enzyme. But I know as a biochemist [belonging, group alignment] that I cannot grow that strain, for example. There are things that are not possible and if you are just from the modeler side [perspective], sometimes you ask things that are not biologically possible [affect, frustration].

Given these dimensions or sub-themes, identity appears to relate to adaptation to an interdisciplinary problem space, to learning achievements within that space, to modes of collaboration that impact problem solving within the space, to motivation for work and collaboration, and to resilience in the face of failure.

Major theories that focus on specific facets of identity can be mined for insights in considering the impacts of identity on cognitive practices in interdisciplinary science. In each case, however, the theories should be regarded only as frameworks that provide potentially useful ways of understanding complex social relations and personal experience and how these both relate to what have been traditionally regarded as essentially epistemic questions. Harré and Langenhove caution that concerning the second of these, positioning theory applies to each of the theories considered. That is, each "should not be regarded as a 'general theory' that calls for a deterministic application to several specific subject matters. It is not like gravitational theory. Rather, it is to be treated as a starting point for reflecting upon the many different aspects of social life" (Harré and Langenhove 1999, pp. 9–10).

7. Identity Theories

As noted, identity theories abound, and capture in various ways the reciprocity of individual and community. We have found three theories particularly useful for imagining how identity might impact learning and collaboration in our bioengineering laboratories, which constitute interdisciplinary communities of practice. From traditional social psychology we examine Social Identity Theory; from the "new social psychology" we consider Positioning Theory; and from developmental/clinical psychology we explore the implications of Dialogical Self Theory. We will discuss each briefly and clarify how they contribute to an understanding of the comprehensive category of identity/identification and what implications they have for the training and education of interdisciplinary scientists.

7.1. Social Identity Theory

Identity is a centrally important construct in theories of intergroup relations. One of the most important frameworks for understanding intergroup relations is social identity theory, origins of which date to the minimal group paradigm research findings of the 1970's (Moghaddam 1998). In this seminal research, Tajfel and colleagues demonstrated that in-group bias was exhibited when they assembled groups on the basis of arbitrary and meaningless criteria, even random assignment (Tajfel 1970; Tajfel et al. 1971). From this line of research, the concept of social identity

obtained a distinction from personal identity, with the former taken to represent aspects of self-understanding or presentation that reflect affiliation with groups of various sizes and levels of social organization (political party, religion, ethnic group, gender, fraternity, etc.) (Turner 1982). An assumption that follows from research on the minimal group paradigm is that we are motivated to maintain an adequate social identity, and that this requires a view of the groups whose affiliation we claim as our own, as both distinct from other groups and favorable to other groups. Thus, for example, even groups disparaged by other groups garner in-group solidarity and positive self-representation by means of elevating the very descriptors used by other groups to disparage or marginalize (e.g., "rednecks," "geeks," "Yankees").

Tajfel's original research is helpful in formulating predictions about specific conditions that tend to engender less favorable comparisons with other groups, relating to conditions of social mobility and security of group identity. Moreover, Tajfel (1981) outlines a series of strategies of intergroup differentiation and distinctions such as secure and insecure social identity that are important to a lengthier discussion of the relation of social identity to disciplinary specialization. Here we wish to only point to the potential for fruitfully exploiting social identity theory for the problem of understanding interdisciplinary dynamics.

Social identity theory is expanding in reach and influence, especially in relation to studies of organizational dynamics (Haslam et al. 2014; Hogg and Terry 2014). Nevertheless, social identity theory has many critics. Criticism of social identity theory centers on the presumption that personal and social identity can be meaningfully demarcated, that doing so reifies the notion of an independent self that precedes social categorizations (Billig 2002; Brown 2002). The idea that identity is agentive, too—a set of choices to be made from an array of options available to everyone—stands in contrast to theories of identity that construe identity as produced through and reflective of meanings upheld by the wider culture (Steele 2003). For example, one is identified as raced and gendered in particular ways, whether or not one's own choice is to transcend or reject those categories.

Yet, though criticized for reifying the idea of an independent and autonomous subject (Billig 2002), social identity theory can be included among those approaches that call into question the idea of stable or solid self-representation. One may and does identify with various groups at various times for various purposes. Moreover, the groups with which one identifies evolve over time; as the groups themselves change, so does identity. Through identification with various groups at various times, one identifies in multiple ways, and thereby negotiates different identities in relation to different contingencies and purposes across a complex temporal unfolding.

Personal Identity. The reference to one who identifies with multiple groups over time underscores that social identity can be distinguished at least conceptually from personal identity, which bears on the experience of one's own unique being in the world. For example, one might identify as Catholic in childhood and an atheist in adulthood, one might change political parties or family name or even gender without changing the experience of one's own being. The notion of personal identity has been centrally important theologically, philosophically, and psychologically to account for the continuity or coherence in our experience; it reflects the uniqueness of embodiment and life trajectory and is the basis of concepts ranging from Kant's synthetic unity of apperception in the *Critique of Pure Reason* to traditional and contemporary theories of consciousness (James 1890) and subjectivity (Mol 2008).

Yet reflecting on our experience as unified and belonging uniquely to us is itself an activity, an *enactment* that can be analyzed and understood through talk (discourse). That is, personal identity need not imply stable self-representations in the way that has been criticized. In our transcripts, what we might consider personal identity is expressed through self-narrative, for example in response to interview questions about telling one's story.

Although we remain cognizant of the criticisms of social identity theory, in our own coding we have found it useful to distinguish what we call for the purposes of distinction "personal identity" from identifications made more explicitly on the basis of group participation. In the following example, the researcher answers the interviewer's question "How did you get here?" first with a statement about education and disciplinary identity: "I have a (Master's) degree in biology"; then country of origin: "in [country], which is where I am from"; then her marriage: "And so I was working in [city] at a biotech company and I met my husband who is American"; then work: then I moved over here and I worked at[a different university] and then we moved down here and I worked at a biotech startup company… and then they downsized. Finally, she answers in terms of the role and function of another person:

> "[former lab manager] who had my job before me was going to leave a few months later and so she hired me and then I was here a month and a half two months, running in parallel with [her], so she taught me so that I could take over like hit the ground running and that was June of last year." (C11)

Her self-narrative implicates her sense of her abilities, but also affect, values and goals:

> "When I started at university I chose between English and Biology because I'm good at languages, but Biology was more interesting so I picked that… 'cause it's more of a challenge. I didn't want to

> become a language teacher or something and I didn't feel I was contributing a whole lot by, you know, writing a thesis on Jane Austen or such …which is what I imagine I would end up doing (laughs). So I went into biology…" (C11)

Statements of what we can call personal identity might also be extracted from summaries of learning goals, especially those in which one identifies things that need to be accomplished or learned in order to facilitate one's progress as a researcher, as stated by another researcher whose learning we followed:

> "I really thought I should learn how to deal with the data. Although it's not the kind of thing that we exactly do, it's a really powerful tool, I thought. I know like five of the methods for machine learning… I am sure that with that kind of tool I will use it somewhere in the future… I also thought that it is really important for me to distinguish the methods… to be able to tell them apart somehow" (G16)

Social Identity. Narrative claims about historical trajectory or about values and goals that implicate a kind of self-direction can be contrasted with identity statements that explicitly display alignment with one or more groups, including disciplinary groups: "When you were an engineer, and you used to work with exact stuff and formulas… It's like a very neat little problem" (G16).

This identification, a social identity, then affects personal experience of the laboratory, including emotional: "So when you get here, you're like very frustrated. Like, nothing is known to any extent! [with emphasis]. That's what you think in the beginning" (G16). Similarly, "I guess being a biologist for me, the whole thing is finding out how things work" (C11). Group identifications (social identity) are sometimes expressed by claiming a kind of mindset: "It's experimentalist mindset. It's still what I have." A frequent marker of social identity is the use of the pronoun "we" in relation to a task or way of working: "Cause we aren't, we aren't theoretical modelers. We don't just come up with ideas and then just shoot them out there and wait for people to do them" (C9). The idea of "finding one's niche" in a new research community seems to implicate both personal and social dimensions of identity.

One interesting finding relating to social identity from our laboratory studies is that group/disciplinary identities in an interdisciplinary setting do not necessarily always privilege one's own disciplinary background, especially as one gains exposure to and heightened awareness of the epistemic values and problem solving practices of the group represented by

collaborators. Thus, for example, although initially identifying strongly with her biology background, later interviews with C11 reveal a more disparaging stance toward her own field of biology, in particular the forms of mathematical analysis employed by biologists: "as a biologist they basically teach you enough that you can calculate population differences if you're out looking at birds, you know" (C11).

One possibility is that awareness of the limitations/constraints of one's own discipline accompanies acclamation to the interdisciplinary community; it is a sign of growing appreciation of the legitimacy of other methods, other problem solving goals, and importantly, new epistemic values (those of collaborators), possibly even incorporation of new values into one's view of science practice. That is, disparaging remarks about the discipline in combination with a more nuanced view of the problem space might be read as indicating transition to a problem-orientation.

Dyadic Identity. However, in addition to the distinction between personal and social identity (whatever the grounds for challenging the distinction theoretically), our coding revealed another powerful and frequent form of identification that concerned not one's own trajectory or aspirations or the perspective of a group with which one is claiming alignment, but rather reflects alignment with a particular individual, usually a powerful or influential other that inspires, motivates, and stimulates ways of working. Identity in this case is aided by powerful dyadic connection ("I – Thou"), including inspiration by and alignment with the goals, values, abilities, or style of a powerful Other. In this case it is the attributes of the individual and not any identifiable group that provide the primary impetus for identification.

This is, indeed, the sense of identification first articulated by Freud in relation to the resolution of the Oedipal complex (Freud [1933] 1965). The child identifies with the father, taking on the father's values, standards, and ideals, and in the process of identifying, thereby compensates for the primary object of loss (Mother). Thus the dyadic connection is central to the early identity theory but tends to be downplayed in more recent theories that focus on group affiliation and social categories in identity formation and performance.

In education, what we can call dyadic identity is an important aspect of the mentoring relationship, and the identity component of mentoring is vital for understanding its affective and motivational dimensions. Less well understood, however, is the means by which dyadic identification can impact reasoning style and epistemic values in a trajectory of influence that extends beyond the original educational setting. The powerful other (mentor) can become a kind of symbol for the identifying student or novice researcher, setting standards of practice that are to some extent adopted and carried forward into new practice settings. In interdisciplinary science,

these dyadic identifications then become standards for evaluating the work and contributions of collaborators.

In our study, principal investigators of both labs prompted dyadic identifications on the part of researchers new to the field of computational biology in particular:

> I think I had a better understanding of why it was necessary because I had worked with [lab C director] and she did basically mostly modeling for her, um, graduate thesis so she sort of rubbed off on me the importance of it and how you could get at certain things that you can't get at experimentally. (C9)

> The thing I really like about [lab G director] is that he knows a lot of stuff like the modeling part, the things that I'm trying to learn from him very well. He has insight on it. (G16)

7.2. Positioning Theory

We have previously argued for the usefulness of positioning theory as an analytic tool for understanding the dynamics of interdisciplinary collaborations, including cognitive practices (Osbeck and Nersessian 2010) in our study of biomedical engineering laboratories. We have found positioning theory similarly useful for understanding identity interactions in systems biology laboratories and especially for conceptualizing the relation of epistemic values to disciplinary and task identifications in these settings.

Positioning theory as an approach to identity is situated within what has been called the "New Social Psychology," focused principally on discourse and symbolic communication (e.g., Harré and Gillett 1994). Arguably the roots of positioning could be traced to a much earlier origin, for example Adler's analysis of the psychological impact of family position (Ansbacher and Ansbacher 1956). Likewise, feminist theory placed an emphasis on the development of both feminine and masculine "subjectivities" through "the product of their history of positioning in discourses" (Hollway 1984, p. 228). Through Harré and colleagues, the spatial metaphor inherent in the notion of positioning is exploited more explicitly and extended to everyday conversations; positioning is defined as "the discursive process whereby people are located in conversations" (Davies and Harré 1999). In conversation, in narrative, we continuously align with and distance ourselves from others, elevate ourselves above others or elevate others above ourselves; such alignment and distancing has social effects that can be analyzed in micro-episodes of conversational exchange. The effects of positioning are bidirectional (dynamic); we position ourselves in relation

to others and position others in relation to us through the things we say to and about them. Through Harré the concept of positioning acquired an emphasis on the "rights and duties" accompanying different positions, which are similar to the central concepts of affordance and constraints from ecological theory (Gibson 1979; Greeno 1998), but with an emphasis that is more obviously moral in a broad sense. Related to the importance of rights and duties, positioning theory is closely tied to analysis of social power relations. Power relations are always implicitly implicated in positioning, that is, to the dominance or superiority of one group over another. The micro level of discourse in conversation (e.g. between two researchers) is assumed to reflect macro level social hierarchies and normative structures; analysis aims implicitly at both levels (Benwell and Stokoe 2006).

An important point of social identity theory derived from Mead's *Mind, Self, and Society* (1934) is that human adaptation to a social environment allows reflexive recognition of the self as an object; a view of self is enabled and constrained by the network of social relations in which it is embedded. A related point stemming from the symbolic interactionist framework underlying positioning theory, and more remotely, the concept of the generalized other from Mead (1934), is that "the meanings and expectations for each position are related to the meanings and expectations for the other positions to which each is tied… what it means to be a teacher is tied to what it means to be a student; what it means to be a boy is tied to what it means to be a girl" (Burke and Stets 2009, pp. 26–7). In bioengineering laboratories, then, what it means to be an engineer is tied to what it means to be a biologist; what it means to be an experimenter is tied to what it means to be a modeler.

In interdisciplinary science, positioning of the discipline or field (e.g., biology, engineering) and its associated epistemic practices or tasks (experimenting, modeling) implicates identity by implicitly positioning representatives of those fields and practices in various ways. Characterizations of one's own or others' practices reveal implicit values and hierarchical models of knowledge production, with some practices positioned as more consistent with the aims of good science. Power implications are tied to the conception of which group is more closely aligned with the cannons and ideals of good science.

Our previous study afforded analysis of multiple forms of positioning in an interdisciplinary laboratory setting within biomedical engineering. We similarly focused in that work on effects of disciplinary alignment (as biologist or engineer) and the authoritative stance assumed in relation to forms of practiced evidenced by the collaborating scientist. Positioning was again a dominant theme of analysis in our current laboratory study. But in comparison to our analysis of positioning in biomedical engineering, the systems biology laboratories revealed even more potently disparaging positioning on the part of both biologists and engineers, and with a more varied range

of criticisms. This is likely due to the higher degree of interdependence between modelers and engineers and a more fraught history of attempts at collaboration. We will examine some of the critical ways modelers positioned biologists through their descriptions, and then consider the ways biologists positioned modelers.

Disparaging ways modelers positioned biologists include the following:

1. As "Recipe followers," which accompanied depictions of biology as "tedious," consisting of "memorizing," "recipe following," and contrasting with the modeler's view of the problem solving approach of the modeler/engineer.
   "in their daily experiments…they will follow those instructions, that's their way to do things" "it's [assay learning] not that difficult – like a recipe – when you cook."
2. Mathematically challenged. Further, modelers positioned biology as easy for a modeler to learn, but position the mathematical modeling in which they engage as more difficult to learn. The director of lab G maintained this was because math is "hierarchical" while it is easier to pick up biology because it is "horizontally organized," enabling one to get a "pretty good grasp on small area."

In addition to positioning biology as easy and modeling as difficult, biologists were often characterized as not able to learn the complex and high level math required for modeling. Statements modelers made about biologists in this respect include the following:

"if you let a medical student learn this structure or the algorithm, wow, they will fail, trust me only 1%–5% can survive"
"it's too difficult for them to learn these things… philosophy of biology and mathematics are … totally different"

3. Unengaged with or uninformed about models. Modelers made comments suggesting that experimenters lack awareness of and concern for the possibilities and uses of models, including understanding of or concern for dynamics, the focus of or reason for models:

"they treat it as a black box… they will not get deep into the model's detail because that's maybe too complicated"
"it doesn't make any sense to them"
"because if they cared, they would care about the dynamics of the thing, but they don't care."
"they don't care about time series… how this dynamically changed. They just care what is the result."

By contrast, the collaborating experimentalists (bioscientists) we interviewed position modeling and modelers in ways that may be considered disparaging in comparison with their ways of characterizing their own work. Among the characterizations are that modelers are naïve about what is biologically possible and about the demands of the experimental process.

> "sometimes they ask things that are not biologically possible"
> "the data they want is [sic] not that simple to generate"

Experimentalists positioned modelers as naïve in relation to seeking data that are not available, in relation to understanding the legitimate reasons why experimentalists take so long, or choose a limited experiment, or are reluctant to do new experiments to test model predictions.

> What modelers ask for is "time consuming and money and effort or sometimes we already passed that point"
> "they don't know how to ask the right question"

Similarly, experimentalists positioned modelers as not interested in accuracy or precision:

> "they are not really interested in actual numbers… more like getting sense rather than .. accurate"
> "we know how complicated the system is… one change in experimental condition can totally change the result"

Experimentalists expressed mistrust in the model, viewing it as relying on a great deal of estimation, or guesses. When predictive, the predictions would change significantly because "one little perturbation can make a huge difference in outcome."

A related value is expressed in positioning modelers as modeling for modeling's sake, rather than focusing on outcome or utility: There can be difficulty understanding why just getting a model to work can be a goal and achievement in itself; it is difficult for experimentalists to see value in this.

> "trying to model something published 15 years ago… well what are you going to do with that?"
> "not taking it to the step where it's useful for the biologist… more interested in making a system to describe the system"

Implicit in this positioning on the part of experimentalists is their concern with understanding the entity or event, in contrast with an emphasis on process and on the possibilities inherent in the entity that they regard as characteristic of modelers. What is expressed are essentially epistemic

values, but tied to identification as experimentalist or modeler, and thus social identity.

Yet it is important to view disparaging comments as positioning strategies rather than as descriptions of disciplinary role. Among the benefits of viewing these kinds of characterizations as positions expressed in dialogue rather than as fixed social roles, is precisely the possibility for changing positioning with increased experience in interdisciplinary settings. Unlike the concept of social role, positioning is fluid, dynamically shifting and renegotiated with further talk. Changes in positioning can be analyzed in relation to experience in interdisciplinary settings over time, indicating acclamation or adaptation to the problem space of the laboratory.

A further implication of positioning theory is the preservation of some form of agency in identification. Positions can be resisted or revised through interaction; identity is negotiated through discourse rather than imposed (Bamberg 2004; Benwell and Stokoe 2006). The effects of disparaging positioning of collaborators and the influence of powerful mentoring relationships on epistemic values and identities are both evident in our study of systems biology. Cultivation of awareness of these influences can be expected to facilitate more adaptive experience in interdisciplinary spaces and enhance collaborative potential.

The idea of positionality as flexible and identity as actively negotiated through positioning leaves room for identifying strategies for attending to and modifying identity construction through experience, in our case through experience in an interdisciplinary research setting. That is, if identity is negotiable, we can think through ways of identifying, of positioning oneself and others in ways that lead to productive and harmonious interdisciplinary collaboration and effective problem solving on the part of particular researchers. But doing so requires some normative considerations in relation to interdisciplinary identities. That is, we need some notion of what to strive for—what identity configurations are optimal for the interdisciplinary scientist. The question of identity formations that might be good for science leads to the consideration of additional identity theories, for example, dialogical self theory.

7.3. Dialogical Self Theory

We examine a third approach to identity and self theory here because it offers some helpful ways of framing the question of what might constitute an ideal identity configuration in interdisciplinary science, at least as concerns the settings we have been studying. In turn, these considerations have implications for educating scientists.

Dialogical Self Theory (DST) (Hermans and Kempen 1993; Hermans 1991, 2001) complements positioning theory in important ways but offers a clearer

model of how identity configurations might engender greater resilience and epistemic flexibility. The underlying idea is that the self is not unitary, consistent with and informed by both (1) William James' primary distinction between the "I" and the "me," indicating two distinct selfpositions (1890) and (2) Bakhtin's polyphonic metaphor and dialogic framework (1981).

For James, the position of "I" is an active stance, equated with the self-as-knower. Three features attend this position: continuity of perspective as knower (I am continuous in time), distinctness of perspective (I am unique, claim a particular point of view), and volition (I continuously and selectively attend to or reject the objects of experience (thought content) and subject. The "Me" is the self-as-known: composed of the empirical elements considered as belonging to oneself: "not only his body and his psychic powers, but his clothes and his house, his wife and children, his ancestors and friends, his reputation and works, his lands and horses, and yacht and bank-account" (James 1890, p. 291). Things are felt or experienced, as Hermans notes, as mine. For the scientist, the empirical elements that contribute to constituting the "me" and mine include one's methods, projects, artifacts, publications, indications of reputation and influence, and statements expressive of epistemic value. The self is, through theme, extended into the environment. Hermans offers the insight that this means, "not only 'my mother' belongs to the self but even 'my enemy'" (Hermans 2001, p. 244). The environmental extension of self provides a way of thinking about identity as distributed in an important way, with epistemic values entering the mix that constitutes a distributed cognitive system: "With his conception of the extended self, James has paved the way for later theoretical developments in which contrasts, oppositions and negotiations are part of a distributed, multivoiced self" (Hermans 2001, p. 245).

The polyphonic metaphor attributed to Bakhtin's literary analysis emerges from analysis of Dostoyevsky's multiple voices expressed through the actions, thoughts, and experiences of characters in a given novel. The voices are frequently juxtaposed, are in conflict, or at least in some relation that contributes to dynamic tension and exploration of a range of possibilities. Yet the competition between voices need not be negative; indeed incorporation of multiple voices into a more nuanced and complex self is associated with greater resiliency and health (Hermans 2001). Each voice occupies a distinct position, commands a particular point of view, has a unique perspective, set of values, goals, interests, and constraints. There is constant dialogue; each does different things, represents different considerations. There may be a negotiation between two opposing voices, or one can incorporate a variety of voices, of perspectives, that can be adopted or occupied at different times, for different purposes, expanding possibilities for response and adaptation.

Importantly for our purposes, the multi-vocal self or identity provides a helpful way of understanding the implications of positioning theory for subjective experience, especially changes in that experience over time: transformations through learning. The emphasis in positioning theory is on what is done, what is accomplished through discourse, and the social effects of these enactments. Although exceedingly important to interdisciplinary settings, it is equally necessary to understand subjective experience, how learning is experienced and understood by the researchers engaging in the discourse. To do so is not to fall back on a self-contained individualism or a view of identity as a possession. Hermans and colleagues recognize that the positions or voices represent societal standards, norms, expectations and ideals; these are incorporated as different voices with differing, perhaps conflicting interests, demands, and standards. "The dialogical self is 'social', not in the sense that a self-contained individual enters into social interactions with other outside people, but in the sense that other people occupy positions in a multivoiced self" (Hermans 2001, p. 250). The occasional competition between the voices or positions of parent, spouse, and employee is an example familiar to many. In our laboratories what we might call conflicting voices are reflected in the ideas about science that sometimes led to disparate views of the task, foci, or capacities of one's own or others' disciplinary affiliations.

The idea of a multivoiced self in dynamic interaction with other multivoiced selves leaves open the possibility of identifying strategies for attending to and modifying identity construction through experience, even cultivating a more flexible identity appropriate to the demands of interdisciplinary science. In both labs, we found that specific, concrete learning experiences can influence identity flexibility in transdisciplinary space, with important benefits for adaptation to the space, interactive expertise, and problem solving.

To better understand the experience of transformation in interdisciplinary research, we selected two researchers from our labs for intensive case study. That is, in addition to coding across transcripts, we also focused coding and analysis on interviews with particular researchers across time, to trace the learning trajectory and consider the development of cognitive tools and identity as enacted with experience in the laboratory. This case study analysis followed individual researchers chronologically, using careful line-by-line reading and interpretation of interview text. In these case studies we focused principally on the identity developments and their interrelation with cognitive and interactional practices.

From the case study, two events stood out as especially salient to the possibility of incorporating another voice into one's developing scientific identity, even a voice that articulates a competing set of standards to those of the original voice. As part of our NSF-funded research we assisted the

lab directors in setting up experiences aimed at enhancing the collaborative abilities of student researchers. In one case, a modeler expressed a developing identity as an experimenter through a focused "experimental summer camp" kind of experience (G16) and a biologist expressed greater appreciation for and understanding of the affordances of modeling through a one semester introductory biosystems modeling course,[7] designed to give biologists and modelers a "feel" for modeling systems (C11). In both cases, researchers described the learning as provoking a kind of transformation, experienced as internal change to incorporate the other perspective. This change is accompanied by greater cognitive flexibility and what we call epistemic awareness, which stems from reflection on one's own and the other's commitments to what constitutes doing good science. Both cases resulted also in more effective performance – even of one's own task – in the laboratory (modeling or experimenting).

G16 (modeler, engineer) described a summer experience in an experimental lab which included basic instruction in experimental technique, followed by hands on experience with conducting real experiments that were part of the lab's on-going research. The following gains were evident in G16's description of the experience: increased self-confidence, increased comfort with experiments, increased knowledge of experimental procedure, which enhances ability to communicate, anticipate needs and questions, increased appreciation for difficulties/constraints of experimentation, ability to characterize experimentalists' reasoning process, and ability to identify resources available to experimentalists.

G16 portrayed these gains in terms of an "internal change" attributable to the experience:

> "Like in a month you just like change inside. It's not about the exact things you learn cause it really does matter that you know what to learn… it's just knowing how to learn stuff."

This can be understood as expressing a transformation of sorts, an expanded identity or increased flexibility in keeping with the summer learning experience.

Similarly, a biologist (C11) references "internal change" on the basis of experience with modeling in the class. She had previously had a failed collaboration with a modeler (C7) in her lab. Throughout the course she tended to see what she was learning through the lens of that collaborative effort and also discussed her modeling and insight with him.

> "I wish I had taken this class 2 years ago. I wish he [modeler] and I had…taken it together. We would have looked at each other and said

7. For discussion of the development of the course see Voit et al. 2012).

> 'Oh, I get it – I know what you are doing now.' It would have been very helpful for me to understand what kind of data he needed; to understand what kinds of questions he should have been asking of me."
>
> "I think actually after this semester, it overlaps more cause I tend to separate those parts of my thinking into quite distinct parts. This is a computer. This is math, and this is like the real world. Now it's starting to overlap where's it's like "oh this is the actual real world application."
>
> And now it's happening inside my brain. Most of my brain is going "what? Why are you getting rid of the data points?" and the other part's going "look a smooth curve."
>
> it's giving me more insight of what we were talking about, but ways of looking at it make sense.
>
> I guess I'm mixing it up a little bit more internally now, whereas before I was taking advantage of other people, um, having different backgrounds, but now I'm actually, yeah, I'm internalizing it more.
>
> So two weeks ago I'm at my daughter's [name] school and one of the parents comes up to me and he sees me studying, and I go "yeah, it's computational modeling of biological systems." And he goes "computer models? So they're not real." That's when I realized that I was a changed woman. Cause I was disagreeing with him, I was like 'let me tell you about models, and explaining what you could do with them and why they're wonderful.' It feels like talking to myself two years ago.

Awareness of the affordances of models and the sense of math as a flexible tool are additional gains for experimentalists exposed to modeling through collaborative projects and informal conversation in shared work spaces.

> I had no intuition about what mathematical functions could be used, before. And then there are some people who have no idea about what might possibly be going on in a biological system. But you need to know both if you're going to model. You need to know both. (C11)

These findings suggest the value of targeted learning experiences, formal (C11) and informal (G16) for enhancing epistemic awareness—a meta-awareness of the implications of one's epistemic identity and of that of the collaborator, and cultivating an emergent identity that is more flexible and better-adapted to the demands of interdisciplinary problem solving by contributing to more effective collaborations, better reasoning, greater awareness of affordances of methods, and broader range of cognitive tools.

8. Summary and Conclusion

In this paper we have attempted to make a case for the incorporation of identity theories into the study of interdisciplinary science. We have introduced the concept of epistemic identities as a descriptive tool for better understanding collaborative and cognitive practices in interdisciplinary spaces. We examined identity enactment in two integrative systems biology labs and considered the applicability of a range of identity theories to capture the experience and collaborative practices of interdisciplinary researchers. Undoubtedly there are other theories useful for understanding identity enactments in interdisciplinary science, so our discussion of the three theories chosen should be taken as only an illustration of how identity theories can be usefully applied to understanding science practice.

Referring to academic disciplinary discourse, Hyland asserts that, "every act of communication is an act of identity because identity is what the writer does in a text" (2012, p. 195). Our claim is complementary: that every act of communication about one's work in the context of an interview or in interaction with colleagues is an act of identification, an act that is informative about self-representations. Importantly, however, our claim is also that these self-representations simultaneously implicate representations of one's collaborators, and thus have implications, even consequences for the cooperative practices that lead to the production of knowledge.

Consideration of identity aids in promoting recognition of the important ways in which interdisciplinary science constitutes a case of intergroup relations, and as such the problems of its dynamics are analogous to those of more visible or obvious instances of intercultural relations. It is the nature of intergroup relations to negotiate hierarchies of status and power, and the focus on epistemic identity in interdisciplinary science helps to illuminate ways in which power differentials and clashes of ideology challenge the complex tasks of collaborative problem solving and cooperative innovation. In other words, we can acknowledge that identity infiltrates science in multiple and complex ways, and that the identity complexities and their influence on normative structures is increased in interdisciplinary science. Power dynamics integral to intergroup relations are instantiated in personal experience, in this case the experience of research scientists. Thus conflicting ideologies concerning good science, the norms and standards specific to disciplinary specialties, specialized tasks, or theoretical framework can be expected to impact the practices of students and researchers at all levels. However, the direction of influence is not necessarily a negative one, because interdisciplinary experience can facilitate more complex identity formation, which we regard as conducive to flexible problem solving and innovation, and which therefore provides a way of imagining contours of identities that are good for science. There are

clear implications for science education in the suggestion that efforts deliberately directed toward the project of building flexible identities, encouraging facility with alternative vantage points (e.g., between the demands and affordances of both experimentation and modeling) might enhance problem solving potential in fledgling researchers. Similarly, principal investigators sensitized to identity enactments and their implications in interdisciplinary practice sites (problem spaces) might find it fruitful to explore strategies for cultivating complex epistemic identities, as illustrated in our examples of the modeler being embedded in an experimental research lab for a brief period and the conversion narrative of the biologist following an interdisciplinary biosystems modeling course.

Our analysis also suggests that there is a need to go beyond acknowledging differences in disciplinary identity, even in the same interdisciplinary field, such as bioengineering. As noted, we found identification by discipline (engineers and biologists) more prevalent in biomedical engineering labs but identification by function (modeler or experimentalist) in the systems physiology labs we studied. Each organizational system is unique, and requires careful attention to the identification strategies and configurations within it. Our methods underscore the fact that interdisciplinary collaborations themselves take many forms, and can only be properly understood through intricate study of their complex practices, preferably in the contexts in which they take place. The finding that identification occurs around epistemic task means that epistemic identity seeps across disciplinary borders, affecting collaborative practices in ways that are difficult to anticipate and require analysis informed by the actual practices of the particular laboratory under investigation.[8]

A summary of our assertions is that the cultivation of awareness of epistemic identities and development of flexible epistemic identities may facilitate more adaptive experience in interdisciplinary and transdisciplinary spaces, enhance collaborative potential and expand range of problem solving possibilities and perspectives.

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8. We are grateful to a reviewer for pointing out that dis-identification is an important aspect of identification, and thus it is important to future analysis to consider the possibility that rejection of epistemic identities might contribute to the interactive patterns observed.

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